The BRT Planning Guide

Welcome to the BRT Planning Guide, 4th Edition.

This is the first major update of the guide since the 3rd edition in 2006. It has been reorganized and expanded with much more information and depth on certain topics, including:

- more detailed and enhanced chapters on service planning, demand analysis, and speed and capacity
- consolidated and expanded information on communications,
- new chapters on institutional issues, contracting, and financial modelling,
- more information on physical design – expanded to seven chapters, and
- more complete chapters of different types of integration, from walking and cycling to multimodal integration.

This is still a work in progress and is in the process of being finalized. If you see something wrong, please let us know. That said, we are excited to have this version online. This will allow for more dynamic updating and more involvement from the community. We are also developing a PDF version for download and use offline.

If you have found a problem, would like to make a suggestion or are interested in contributing to the guide, please email us at `brtguide@itdp.org`.

You can browse the repository where all the content is stored and managed; it's also possible to report an issue or propose a change there. To simplify collaboration, the project is hosted on GitHub:

https://github.com/ITDP/the-online-brt-planning-guide

To navigate through the guide...

Whether you are browsing the guide online or viewing the PDF, you can find the Table of Contents essentially on the left - in the left-side menu. Click on a volume title and it will expand with the chapters beneath it, while taking you to the landing page for that volume. To go to a particular chapter, click on the chapter name in the left-side menu. And to get to the different subsections, you click on those as well.

Additionally, you can also use the "breadcrumbs" at the top – but only available online – to see at a glance the path you have taken within the guide.

And finally, a brief introduction...

Cities are faced with the tremendous challenge of providing residents access to jobs, education, and public services, all while not exhausting the finite environmental, social, and economic resources available to them. At the same time, just over half of all people currently live in cities, and that proportion is projected to grow to two thirds of the global population by 2050. Further, the challenges of providing access and mobility to a growing population are only compounded more by the ramifications of climate change, which are not distributed equitably, as well as growing disparity and inequity globally. Fortunately, leaders at international, national, and city levels have turned a corner, as seen with the Paris Climate Agreement and Habitat III, to not just strive towards sustainable and equitable transport, but actively set goals, take action, and hold themselves accountable.

Although much progress is still needed, climate action is gaining momentum, and the movement must address inclusivity, air pollution and urban development in order to reach its goals. An over-dependence and prioritization of single-occupant vehicles has exacerbated air and noise pollution, traffic congestion, sprawling development, and traffic fatalities. Cities need to invest in a more complete set of sustainable mobility options that shift people away from driving cars, while simultaneously reforming their planning policies to develop around dense corridors with public transport and accessible amenities. At the heart of this strategy is providing high-quality public transport for all people.

Bus Rapid Transit (BRT) has risen to the task of providing high-quality transport, particularly during the past decade (2004 – 2014) in which BRT has grown by 383 percent in cities around the globe. With roots in South America, BRT began in Curitiba, Brazil in 1972, and it is a cost-effective, bus-based rapid transit system, which can achieve high capacity, speed and service quality. The system accomplishes this through a combination of features: segregated bus lanes that are typically median aligned, off-board fare collection, level boarding, bus priority at intersections, and other quality-of-service elements (examples include information technology and effective branding).

Because BRT is cheaper to plan and implement and can be done in relatively short timeframes for infrastructure projects, BRT can be an effective and efficient tool for achieving the goal of provising high-quality public transport for all people. By requiring less time and money for implementation, BRT empowers cities to become resilient and adaptable to urban growth and climate change. Coupling this implementation with on-the-ground community engagement in underserved areas, cities can ensure equitable access and mobility for those residents who need high-quality public transport the most.

The BRT Planning Guide details the steps of the planning process for a BRT system. Lloyd Wright developed the first two versions of the guide, which were published through the Sustainable Urban Transport Project (SUTP) of the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). Walter Hook and the Institute for Transportation and Development Policy (ITDP) collaborated with Lloyd Wright on the 3rd Edition, upon which this Guide was developed. Both Lloyd Wright and Walter Hook were the visionaries for the update to this Guide and were instrumental in the development of this 4th Edition.

The chapters of the guide are grouped in the following volumes: Volume I: Project Preparation, Volume II: Operations, Volume III: Communications and Engagement, Volume IV: Business Plan, Volume V: Technology, Volume VI: Infrastructure, Volume VII: Integration. Within these volumes are 33 chapters that touch on a variety of topics essential to the planning of a BRT system, including: project initiation, demand analysis, service planning, communications, public participation, costing, marketing, evaluation, contracting, operational planning, vehicles and stations, roadway design, control centers, modal integration, operating technology, transportation demand management, and transit-oriented development. Content has been expanded based on recent projects, which have deepened the base of knowledge for this guide, and in particular more content has been developed for the chapters on service planning, communications, the business plan, and multi-modal integration.

Fortunately for cities, the technology for providing high-quality public transport have been developed, tested, and documented in cities around the world. It is instead the political will and planning processes that need to be developed to push past auto-centric development in which cities have become gridlocked. Using these building blocks of BRT, this guide hopes to provide parties delivering public transport services to urban areas a process with step-by-step documentation. This audience includes municipal planning professionals, planning consultants, as well as non-governmental organizations and civic organizations involved in transport, environment, and community development. Other potential stakeholders include business groups, regional and national government agencies, and international development organizations. With proper planning and investment, high-quality BRT can help mitigate the effects of climate change and catalyze the movement towards a more livable and sustainable scale of development for all people.

VOLUME I

Project Preparation

Volume 1 lays the groundwork for initiating a Bus Rapid Transit (BRT) system from the initiation of a project to sparking real momentum that will bring the project into reality.

BRT systems have become increasingly popular as a cost effective way for cities around the world to provide high quality transit. However, it is crucial to the success of a project's development that a driven and committed group of people advocate for BRT (Chapter 1), explain how the system works and the reasons why it is needed (Chapter 2), and capture the necessary political commitment and leadership to catalyze a fully comprehensive setup and planning process (Chapter 3).

Project teams will need to look at a number of factors that are described in detail in Volume I, as these will determine the BRT system potential for success. These include: capital and operating costs, performance, flexibility, scalability, implementation speed, and the impact the system will have socially and environmentally on the immediate surroundings of the system as well as the metropolitan region as a whole.

The first three chapters of the BRT Planning Guide delve into these factors among others while providing examples of how advocates, governments, and citizens alike have provided the vision, leadership, and action to see the project through and launch a successful BRT system.

1. Project Initiation

"Never doubt that a small group of thoughtful, committed citizens can change the world. Indeed it is the only thing that ever has."

— Margaret Mead, anthropologist, 1901–1978

A decade ago, despite the existence of a few exceptional examples in the world today, the transformation of public transport conditions was a relatively rare event. Over the past decade, the number of kilometers of BRT worldwide has increased by more than 300 percent. Kilometers of light rail transit (LRT) and metro, while also increasing, did not grow at such a rate. BRT has proved itself a viable means for providing mass transit, with easy scalability, low costs, and operational and implementation advantages.

As BRT systems have spread around the world, some have had problems in planning, implementation, or operation, mainly due to the lack of one or more key elements in their development. Cultivating public and political will toward changing existing public transport conditions is perhaps the most important activity discussed in this planning guide. Strong political will, coupled with public investment and desire in an improved public transport system (and effective participation of civil society), make for a successful project. Without either of these factors, it is unlikely that a project will survive the myriad challenges posed by special-interest groups opposed to the endeavor. With both political will and public support and participation, success is much more likely.

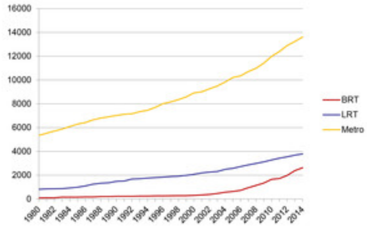

Figure 1.1. Growth in kilometers of mass transit options around the world. *ITDP.*

This chapter outlines a few mechanisms to help groups interested in initiating a project to improve a city's urban transport system. This chapter also cites examples of how some cities have achieved political commitment for a project and how that support has been translated into a wider vision for a transformation of public transport operations.

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1.1 Project Catalyst

"To accomplish great things, we must not only act but also dream. Not only plan but also believe."

— Anatole France, writer, 1844–1924

Before a customer boards a new system, before a new line is constructed, and before a plan is developed, a person or a group of people must decide that action is required to improve a city's public transport system. The inspiration may come from a private-sector operator, a civil servant, a political official, a civic organization, or even just a concerned citizen. Nevertheless, without someone acting as a catalyst, a city's public transport potential will likely go unrealized.

The inspiration for a new public transport vision may stem from reading about alternatives, seeing a photo, visiting other cities, or a person's simply asking "what if?" In many cases, the catalyst may unfortunately originate from the dire conditions of public transport in much of the world today. When poor customer service, extreme levels of discomfort and insecurity, and official neglect characterize public transport conditions, the issue can become a principal topic of public discourse. In too many cases, corrective actions are only undertaken once conditions become truly unbearable.

Because most top officials do not generally utilize public transport, improving the poor conditions of many systems is often not part of the political agenda. Instead, the impetus may fall on public transport customers and citizen groups who are closer to the day-to-day realities. In some instances, public transport customers have formed their own organizations to demand improved conditions. In Los Angeles, the Bus Riders Union has successfully launched several campaigns to convince decision makers to expand bus-priority lanes, as well as to modernize the vehicle fleet (Figure 1.2). In Bogotá, Colombia, "user leagues" of various types have been created by citizens in recent years to constructively criticize their BRT and its operations, and in many cases this has resulted in improvements to the system.

Figure 1.2. The Los Angeles Bus Riders Union has proved that people power can catalyze more progressive policies. *Bus Riders Union.*

In other instances, environmental organizations have led the charge due to the unsustainable nature of existing conditions, especially when private-vehicle usage begins to overwhelm a city's streets and greatly harm the area's air quality. Often an engaged civic vanguard can advocate for innovative ideas, provide examples of new solutions, and build a constituency for risky change, as is discussed in the study *The People's* History of Recent Urban Transportation from TransitCenter, a foundation that sparks innovations and supports policies that improve public transportation for riders, businesses, and communities. The report argues that a strong civil sector is critical in directing public support for new projects and innovative ideas and that helps build support from the political leadership—helping mitigate the risks from change.

In a similar manner, groups concerned with deteriorating urban conditions, such as physicians, air-quality professionals, tourism specialists, and police, may also play a role in propagating the need for change. Additionally, university researchers and staff can provide the technical evidence of the costs of existing conditions, as well as be sources of new ideas. In Delhi, India, staff from the Indian Institute of Technology were instrumental in the implementation of the city's new BRT system. CEPT University in Ahmedabad, India, was a main player in planning the Janmarg system.

Likewise, poor conditions for drivers, conductors, and transport owners may stimulate a search for a better model. In many instances in lower-income countries, the private-sector interests delivering public transport services in cities struggle to make a living. Through awareness of successful models in cities such as Bogotá, Colombia and Curitiba, Brazil, private operators can see that forming an integrated network and providing a higher level of service can indeed lead to greater profit. Thus, the private sector may well provide the inspiration for change. Luckily, this same phenomenon has started to happen with many other transport operators in cities where BRT systems have been implemented, creating a greater consolidation of a professionalized transport operation in these cities.

The news media may also play a prominent role in raising awareness of existing conditions. Articles, images, and films of poor-performing public transport services can help coalesce public opinion around the need for change. Further, articles and video on successes in other cities may stimulate many to ask why the same could not be done in their own city. The recent surge of BRT systems has also helped in providing the media with examples to make the case for BRT in cities where public transport conditions are poor.

Finally, international organizations can play a vital role in facilitating information sharing between projects, as well as providing direct financial and technical assistance to cities. Such organizations can help share experiences, raise awareness among local groups, and build the local capacity for a new project to take hold. International nongovernmental organizations such as the Institute for Transportation and Development Policy (ITDP), the WRI Ross Center for Sustainable Cities—the EMBARQ transportation program, GiZ, and the Energy Foundation have been instrumental in providing cities with both the inspiration for change and the tools to achieve it.

Figure 1.3. GiZ delivers training courses with hands-on examples with local policy makers. *Carlosfelipe Pardo.*

The international private sector is also now playing an increased role in raising awareness of public transport options. For example, Volvo partners with municipalities in places such as India to build the capacity for options such as BRT, and Mercedes-Benz has created a full initiative of BRT information and promotion. While private firms clearly have their own commercial incentives for favoring one technology over another, these firms can help put forward ideas within the context of a competitive marketplace.

Bilateral and multilateral agencies such as the Asian Development Bank, the World Bank, the Inter-American Development Bank, the Swedish International Development Agency (SIDA), and the United States Agency for International Development (USAID) have all helped facilitate public transport initiatives.

International funding organizations, such as the Global Environment Facility (GEF) and the Hewlett Foundation, are likewise key catalysts in this process. Further, international financing organizations, such as the World Bank and regional development banks, not only help financially support projects, but also often work to raise awareness and provide supportive guidance.

Additionally, international organizations, such as the Clean Air Initiative (CAI), the United Nations Centre for Regional Development (UNCRD), the United Nations Human Settlements Programme (UN-Habitat), the United Nations Development Programme (UNDP), and the United Nations Environment Programme (UNEP), have also provided assistance to cities on sustainable transport issues. Municipalities thus have a plethora of international resources at their disposal to undertake a public transport improvement initiative. In many cases, it is merely a matter of contacting the right individuals to make such cooperation available.

Finally, climate-related initiatives, such as the German International Climate Initiative and others, have created specific funds to improve the likelihood of successful projects. Climate funding in general has become a suitable means to provide support to bus rapid transit implementation.

From the concerned individual to a local civic organization, to universities, the news media, and international groups, a range of parties can spark change toward improved urban transport. Any city can take advantage of these linkages to catalyze change. However, to date, most cities have not taken such a transformative step. While the gulf between problem recognition and construction of a modern public transport system seems quite daunting, this chasm can be overcome with the array of resources now available to cities. Very often, just one individual can provide the initial spark.

1.2 Political Commitment

> *"I have never learned to tune a lute or play upon a harp, but I can take a small and obscure city and raise it to greatness."*
>
> — Themistocles, Athenian statesman, 525 BC–460 BC

Ultimately, though, a project concept must enter the political mainstream in order to move toward official development. A leading political official must make a strong commitment to overhauling the city's public transport system. Political will and commitment are probably the most critical and fundamental components in making a new system a reality. Outside groups can certainly help create the right conditions for project consideration, but as a public good, public transport requires political support to become a reality.

While almost all political officials will claim to hold strong political will and commitment to public transport, the reality is often quite different. Is an official willing to give priority road space to public transport over private vehicles? Will the official risk upsetting powerful lobbying groups, such as existing transit operators and private motorists? Will the officials seek out the best technical help they can find, and the best financial resources to make a project happen? Convincing officials to say yes to each of these questions is the basis of establishing project commitment. "Political will" are just words until backed up by tangible evidence of a serious intent to fully implement a project.

There are some risks associated with having one particular individual or party largely responsible for developing a bus rapid transit project. In Bogotá and Guadalajara, Mexico, for example, the fact that one politician or political party promoted and implemented the BRT system has made it more difficult to expand after that individual left office. Thus, political will is important to the success of the project, but the initiative itself should be neutral—associated more with the city itself and not an individual.

1.2.1 Political Officials

The creation of a political environment suitable to introducing a new public transport system can depend on many factors. There is no set amount of time required or set series of events. In the case of cities such as Bogotá and Curitiba, the election of dynamic mayors who entered office with a new vision was the determining factor. Both former Mayor Enrique Peñalosa of Bogotá and former Mayor Jaime Lerner of Curitiba came to office with a strong intent to improve public space and transport (Figures 1.4 and 1.5). They also possessed a base knowledge of these topics and brought with them highly trained professionals as their core staff. In such instances, the progress toward system planning happens almost immediately.

Figure 1.4. Enrique Peñalosa, former mayor of Bogotá, transformed the city with BRT. *Por el Pais que Queremos (PPQ).*

Figure 1.5. Jaime Lerner of Curitiba is among former mayors whom transformed their cities with BRT. *Jaime Lerner Foundation.*

In other instances, a long period of persuasion and information gathering will precede the commitment. Naturally, the more senior the political figure leading the cause, the more likely the official's influence can lead to action. Thus, mayors and governors are the logical targets for gaining political support. In many cases, as in Jakarta, Indonesia, key local politicians often quickly realize that BRT can help them politically because it can show results within the length of their administration. In some developing cities, support from national ministry officials may also be necessary for project approval. The role of national officials may be particularly important in capital cities.

In many instances, a mayor or governor will lack the necessary background on transport or urban planning issues. It requires confidence to grapple with a widespread transformation of the public transport system. In such cases, building the trust of the decision makers and giving them the necessary confidence to implement such a seemingly far-reaching proposal will be key. Political officials will be averse to risk with key constituencies, such as car owners and transit operators, unless the issue is a core part of their platform.

Further, mayors and governors are busy individuals juggling an array of issues and interests. The amount of time these officials can devote to a studied consideration of a public transport transformation is limited. For this reason, it may be more effective to target the top advisers of a mayor or governor. Such individuals may be able to give the idea greater attention, and then subsequently be in a position to make a trusted recommendation to the official.

However, even in the absence of support at the highest levels, a strategy to begin influencing officials at lower levels may still merit effort. Fortunately, there are many other starting points within the city's political and institutional environment. Deputy mayors, deputy governors, and councillors are also relevant positions from which a project can be launched. Among such officials, it may be more likely to find a specialist with a background in transportation, environmental issues, urban planning, or other related fields. In such cases, the learning curve will likely be less. In Johannesburg, South Africa, the effort was led by a councillor who was the adviser to the mayor on transportation.

Another useful starting point can be unelected officials holding key positions within municipal institutions. Directors and staff within departments of planning, public works, environment, health, and transportation will all likely play a role in any eventual project. Without the support of such officials and staff, institutional inertia can delay and weaken implementation. Further, these officials often have a direct relationship with top elected officials. During their daily or weekly briefings, technical staff can prompt a discussion of public transport options. A concept being supported by both citizens' groups and departmental directors will stand a better chance of approval by a mayor than a project being pursued by just one outside group.

The best strategy is to approach all relevant officials, both elected and appointed, who may be influential on public transport. Even if an official is unlikely to become an overt supporter of a public transport initiative, eliminating the threat of overt opposition is equally important. Thus, an initial preemptive session with the potential opposition can be vital to reducing any strongly negative reactions. Much care must be given to the manner in which the issue is presented to any given audience. In fact, the key points to be stressed will likely vary from one official to another, given their different starting points and initial understanding of mass transit options.

One common and rather unfortunate complication is the existence of opposing political parties in key positions overseeing the project. For example, if the local government control is held by one political party while the regional or national government is held by another party, then cooperation to make the project a reality may be lacking. The lack of cooperation between national and local officials scuttled the Bangkok BRT project until it was finally launched in May 2010 after various delays. While local government will typically have direct implementation responsibility, approval from the national government could be required for either budgetary or legal reasons. In Colombia, the success of TransMilenio in Bogotá generated a strong commitment to implement eight more BRT systems throughout the country, with a contribution of up to 70 percent from the national government. Something similar happened in India, where the Jawaharlal Nehru National Urban Renewal Mission (JNNURM) was developed as a financing mechanism to implement suitable public transport solutions for its cities, some of which have been designated as BRT systems.

The duration of the political administration's time in office (and the possibility for reelection) is also another key factor to consider. If a mayor or governor has only a short time remaining prior to an election, then such officials may be reluctant to embark upon bold initiatives. The risk of alienating potential voting groups can override any political boost that a project announcement could garner. Further, once an incumbent takes a strongly favorable position on a public transport option, this position may imply an equal and opposite reaction from the opposition candidates.

For these reasons, catching political officials at the earliest stages of their time in office provides the best chance for achieving commitment to implementation. Often, a major selling point for mayors and governors of an option such as BRT is that it can be built easily within a single term of office, helping establish the politician's career. It may also be effective to introduce public transport options even prior to officials taking office. Providing information to staff within the major political parties can be a worthwhile investment of time and effort. Identifying potential future leaders and establishing a mentoring relationship with them can be equally useful.

1.2.2 Awareness-Raising Mechanisms

There are several different mechanisms available to help alert political officials to the potential of various public transport improvement options. These mechanisms include:

- Site visits to successful public transport systems;
- Tours of own city's existing public transport services;
- Visits from successful mayors and other successful implementers, such as the directors and commissioners of transport departments;
- Basic information provision on options;
- Videos on public transport improvement examples;

- Simulation videos of potential systems in the particular city;
- Physical models of public transport options;
- Pre-feasibility study.

These various mechanisms are not mutually exclusive, as several different information techniques can be combined to build a case on the need for change. Frequently, all it takes to generate political interest is to provide fairly basic information to mayors and other decision makers.

Figure 1.6. International visitors gain many insights by speaking with Macrobus technical staff in Guadalajara, Mexico. *Carlosfelipe Pardo.*

In most cases, however, firm political resolve only comes after chief decision makers visit a successful system like Mexico City or Guangzhou, China, to see it and understand it for themselves. "Seeing is believing" is completely true in the case of BRT. Usually, the decision makers are also accompanied by senior technical staff who will be responsible for implementing the project. Members of the city's media, as well as existing transport operators, may also participate in the visit. By speaking directly with technical staff and political officials in cities with existing systems, prospective system developers can understand the possibilities in their own cities (Figure 1.6). Experiencing a high-quality system in a relatively low-income city, such as Quito, Ecuador, also shows city officials that a system is possible regardless of local economic conditions. In many instances, the process of developing a new public transport system can seem quite overwhelming at the outset. Seeing systems in practice and walking through the development process can do much to dispel uncertainties and fears. At the same time, care should be exercised to avoid giving the impression that project implementation is always easy, fast, and problem free.

Figure 1.7. The only perspective many decision makers have on transport is based on a chauffeur-driven ride to work each day. *Lloyd Wright.*

Surprisingly, political officials and even municipal technical staff can be relatively unfamiliar with public transport in their own city. Given the background and income levels of such persons, many will utilize their own private vehicles for transport. In the case of top elected officials, their only view of daily transport issues may be from the back of a chauffeur-driven luxury vehicle (Figure 1.7). Thus, public transport systems are frequently conceptualized and designed by individuals with little actual familiarity with the daily realities of public transport.

Figure 1.8. Leading political officials, such as former Mayor Enrique Peñalosa of Bogotá experiences public transport for himself. *PPQ.*

Organizing a tour of the public transport conditions in an official's own city can be an eye-opening experience for the official. In cities such as Bogotá, Delhi, Johannesburg, and São Paulo, officials have either made a point to regularly utilize public transport and/or have required staff to use public transport for certain periods of time (Figures 1.8 and 1.9).

Figure 1.9. South African Minister of Transport Jeff Radebei rides the bus. *South African Ministry of Transport.*

Testimonials from one political official to another may sometimes be appropriate. Visits to cities by prominent former mayors such as Enrique Peñalosa and Jaime Lerner have been sponsored by international organizations to help catalyze local actions. Showing how mayors and governors who delivered high-quality systems have tended to win subsequent elections can also be quite motivating to local officials.

Advances in information and communications technologies (ICT) have put the power of sophisticated visual and software tools in the hands of most municipalities. Visual renderings of stations, vehicles, and runways can do much to excite political officials over the possibilities (Figure 1.10). Videos of high-quality public transport systems in cities such as Bogotá, Colombia; Brisbane, Australia; and Curitiba, Brazil provide an accurate visual display of the options to decision makers. Likewise, digital video technology is now available to simulate how a new system would actually operate in a city of interest. Being able to "virtually ride" the new system at an early stage in the planning process cannot only work to stimulate political commitment but it can also help planning staff with design considerations. In a similar manner, small models of vehicles, stations, and runways all help give political officials a hands-on feel with the possibilities (Figure 1.11).

Figure 1.10. A rendering of the proposed BRT system in Dar es Salaam, Tanzania, using a combination of digital photography and graphic design software. *Luc Nadal and ITDP.*

A pre-feasibility study is also an effective mechanism to build initial interest in public transport improvement. The pre-feasibility work can include the identification of major corridors for public transport development, early estimates of potential benefits (economic, environmental, social, etc.), and approximations of expected costs. This work will be fairly superficial, but will at least give decision makers a degree of confidence in a possible project direction. The faster and more compelling this early vision of the new system, the easier it will be for decision makers to build the necessary political commitment to move forward. This early vision will be needed to persuade the public and interested parties to support the project, and to guide the information-gathering process.

Figure 1.11. Small-scale models, as shown here with a proposed terminal facility in Quito help give decision makers a three-dimensional understanding of the physical infrastructure. *Lloyd Wright.*

The techniques for achieving project commitment are varied, and can depend greatly on the local context, but the principal aim is to get the chief decision maker to make a public commitment to implementing a major transformation of the public transport system, and to create a sense of expectation among members of the public.

1.3 Statement of Vision

> *"If you want to build a ship don't drum up the men to fetch the wood, allocate the jobs and divide the work, but teach them the yearning for the wide open sea."*
>
> — Antoine de Saint-Exupéry, writer and aviator, 1900–1944

An initial vision statement from the political leadership marks an important first step in making the case for improved public transport. This political announcement provides a broad-based perspective on the general goals of the proposed system. This statement gives a direction and mandate for the planning teams and will also be used to stimulate interest and acceptance of the concept with the general public.

The vision statement should not be overly detailed, but rather describe the form, ambitions, and quality of the intended project. Thus, the statement will set the agenda for the ensuing planning activity. Examples of the type of phrases that can form part of the vision statement include:

- "Provide a high-quality, cost-effective public transit system that will ease congestion, reduce contamination, and ensure public confidence in the city's transit service";
- "Establish a fast, comfortable, economic, and car-competitive public transport system that will serve the mobility needs of all segments of the city's population, even current owners of private vehicles";
- "By developing a modern public transport system for the twenty-first century, the city will become increasingly competitive, attract more investment and tourism, and ultimately stimulate the economy and job creation";
- "Place more than 80 percent of the city's population within five hundred meters of a public-transport corridor";
- "Provide a one-ticket service that will allow a person to travel to any point in the city in less than thirty minutes with no delays from congestion."

While this initial vision statement will be quite broad in scope, the message can become more detailed and specific as the project progresses. The important issue in developing this vision is that it includes the opinions of various stakeholders, proposed solutions and needs, and that it truly addresses the main issues that public transport must improve in the medium term. Subsequent pronouncements can detail costs, travel times, and amenities of the new service more precisely.

The announcement should be placed within an overall press and media strategy for the project. The press and media organizations should be thoroughly briefed about the vision being put forward. These organizations should also be given a basic overview of the various public transport options and their potential for the city. In some cases, press visits to cities with existing systems can help reinforce the positive attributes of the project.

1.4 Barriers to Project Development

> *"The great tragedy of science—the slaying of a beautiful hypothesis by an ugly fact."*
>
> — Thomas Huxley, biologist and writer, 1825–1895

The case for improving public transport quality would seem to be quite strong. The economic, environmental, and social benefits are well documented. However, major public transport improvement initiatives are actually quite rare. The barriers to transport improvement often overwhelm the call to action. Understanding the obstacles likely to be faced allows project developers to devise strategies for countering this opposition.

Some of the most significant barriers include:

- Lack of political will;
- Lack of inclusion of civil society;
- Governance;
- Opposition from key stakeholders (existing public transport operators, motorists, etc.);
- Political and institutional inertia;
- Institutional biases;
- Lack of information;
- Poor institutional capacity;
- Inadequate technical capacity;
- Insufficient funding and financing;
- Geographic/physical limitations.

Political will is one of the most important ingredients in making a public transport initiative happen. Overcoming resistance from special-interest groups and the general inertia against change is often an insurmountable obstacle for mayors and other officials. However, for those public officials that have made the commitment, the political rewards can be great. The political leaders behind BRT systems in cities like Curitiba and Bogotá have left a lasting legacy to their cities, and in the process, these officials have become enormously popular and successful. To achieve this success, a great deal of political capital was expended to convince project detractors, the mass media, and the general public.

Many political officials may be reluctant to undertake a BRT project due to the perceived risks, especially in relation to upsetting powerful special-interest groups. Motorists and existing public transport operators will tend to resist such change. Thus, political officials may end up playing it safe by avoiding any type of major public transport initiative that will risk alienating specific stakeholders. However, when officials take the perceived low-risk path of inaction, the ensuing political rewards will certainly be diminished.

The trajectory of former Mayor Enrique Peñalosa makes for an interesting example. Mayor Peñalosa implemented transport and public space changes in Bogotá that shocked many people. Under Mayor Peñalosa, laws preventing motorists from parking on footpaths were enforced for the first time. Outraged motorists led a campaign to impeach him. At that point in his term, Mayor Peñalosa suffered through one of the lowest popularity rankings recorded by a Bogotá mayor. However, subsequently, something rather miraculous occurred. As Peñalosa's vision and projects came to fruition, the public responded in quite a positive manner. With new bike lanes, improvements in public space, and the creation of the TransMilenio BRT system, citizens could see the transformation of their city. By the time Mayor Peñalosa finished his three-year term, he left office with the highest popularity ratings ever recorded by a Bogotá mayor.

It is quite likely that a political official with less drive and passion for public space and sustainable transport would have reversed course at the first sign of upset motorists. Instead, the risk taken by Mayor Peñalosa to transform Bogotá and the public transport system resulted in significant political rewards and international renown.

Citizens as a whole must also be involved from the early stages of the development of a new public transport system. Their point of view is extremely relevant, as they will use the system, and a favorable opinion of the BRT will be greatly enhanced if civil society is included as part of the planning process. This will also reduce the likelihood of opposition to the system once implementation (i.e., building the infrastructure) has begun.

While automobiles may represent less than 15 percent of a developing city's transport mode share, the owners of such vehicles represent the most influential sociopolitical group. The idea of prioritizing road space to public transport may appear to be counter to the interests of private vehicle owners. However, in reality, separating public transit vehicles from other traffic often improves conditions for private vehicles. But motorists may only understand this benefit once the system is in operation. Prior to the project, car owners may only see BRT as an intruder that is stealing road space.

Existing public transport operators will likely also view BRT as a threat to their interests and livelihood. In cities such as Quito, the existing operators took to violent street demonstrations to counter the development of the BRT system. The government ultimately called in the military to disperse the protests after the operators shut down public transport in the city for four days. Likewise, in other cities private transit operators have pressured political officials through recall efforts and intense lobbying.

It should be noted that the threat to existing operators might be more perceived than real. In most cases, an effective outreach effort with the operators can help dispel unfounded fears. In reality, existing operators can gain substantially from BRT through improved profitability and better work conditions. The existing operators can effectively compete to win operational concessions within the proposed BRT system. In Bogotá, the existing operators launched seven different strikes to protest the development of TransMilenio. Today, many of these same operators are shareholders of concessionaire companies in TransMilenio, and these operators have seen a significant increase in profits. Few, if any, would want to revert back to the previous system.

The professional staff within municipal agencies may also represent a barrier to public transport improvement. Such staff often does not utilize public transport as their primary means of travel. Instead, municipal officials are part of a middle-class elite who have the purchasing power to acquire private vehicles. Thus, the professionals who are responsible for planning and designing public transport systems frequently do not use public transportation. This lack of familiarity with public transport customers' needs and realities can result in less than optimum public transport design. Such staff may also unwittingly give funding and design preference to individual motorized travel since this mode is the one with which they are most familiar.

Despite the rise of global information networks, a lack of knowledge of options like BRT remains a very real barrier. The long period of time between the development of the system in Curitiba and the realization of BRT by other cities is evidence of this information shortfall. Through the assistance of international agencies and nongovernmental organizations, awareness of BRT has risen sharply in recent years. Visits to Bogotá by city officials from Africa and Asia have helped catalyze new BRT projects. Nevertheless, many developing cities still do not have the basic information required to develop a public transport improvement initiative.

The lack of information at the municipal level often occurs in direct correlation with the lack of human-resource capacity. The transport departments of many major developing cities must cope with a wide array of issues with only a handful of staff. The lack of institutional and technical capacity at the local level inhibits the ability of agencies to consider projects even when general awareness of the opportunity is present.

Financing can also be an issue with public transport projects, although it tends to be less of an issue with lower-cost options such as BRT. Access to capital and the cost of capital can be real constraints, especially for costlier forms of public transport infrastructure. Additionally, the lack of resources to sustain any sort of operational subsidy means that systems must be largely designed to be financially self-sustainable.

Various local conditions, such as urban, geographic, and topographic factors, can also present barriers to implementation. For instance, extremely narrow roadways and steep hills can pose design challenges. However, in general, there are technical solutions to each one of these issues. Local conditions require local solutions, which ultimately make each project unique in its own way.

All of the barriers and challenges noted in this section can be overcome. Nevertheless, for many municipalities, these issues greatly dampen the ability to initiate a project. Project champions will need to provide answers to each of these barriers that represent a threat to project acceptance.

1.5 Understanding and Presenting the Benefits

> *"Nothing is ever done until everyone is convinced that it ought to be done, and has been convinced for so long that it is now time to do something else."*
> — F. M. Cornford, author and poet, 1874–1943

Perhaps the best answer to critics of public transport initiatives is the overall benefit that such initiatives bring to a city and the quality of life of its inhabitants. In many cases, these benefits can be directly quantified to produce results in monetary terms. In other cases, the qualitative benefits can also be assessed within a logical framework.

Table 1.1 outlines some of the direct benefits that public transport improvements have provided to cities. Beyond these benefits, though, there exist others that can further increase the system's value to a municipality. For example, public transport projects can lead to reduced costs on the public associated with vehicle emissions and accidents. Such impacts include costs borne by the health care system, the police force, and the judicial system. By reducing these costs, municipal resources can be directed toward other areas such as preventive health care, education, and nutrition.

Table 1.1. The benefits of public transport initiatives

Factor	Impacts/Indicators
Time-savings benefit to transit users	• Labor productivity • Quality of life
Time-savings benefit to mixed-traffic vehicles	• Labor productivity • Delivery efficiency for goods and services
Fuel savings from transit operations	• Reduced fuel expenditures for public transport operators • Reduced fuel expenditures for vehicles in mixed traffic • Reduced dependency on imported fuel or reduced usage of domestic supply
Air-quality improvements (reduced emissions of CO, NOx, PM, and SOx)	• Human health • Preservation of built environment • Preservation of natural environment • Labor productivity
Greenhouse-gas emission reductions	• Global environment

Noise and vibration reductions	• Human health • Labor and educational productivity • Built environment
Other environmental improvements	• Reduced solid and liquid wastes • Reduced impacts on flora and fauna
Public transport system employment	• Construction employment • Operational employment
Amenity benefits to public transport customers	• Comfort of customers • Prestige of system
City image	• Civic pride • Tourism
Urban form	• More sustainable urban form, including densification of major corridors • Reduced cost of delivering services such as electricity, sanitation, and water
Political	• Delivery of public transport system within one political term • Delivery of high-quality resource that will produce positive results for virtually all voting groups

The purpose of any public transport project is to provide substantial benefits, not just to its users but also to the community at large. For major projects, the structure of benefits, costs, and impacts can be complex. There may be a variety of benefits, not all of which can be expressed in monetary terms. The capital and operating costs of the project may be borne by different combinations of users, government organizations, or corporations. Some project impacts may take monetary form, but more typically relate to physical or environmental changes. For any major new project that has been proposed, it is likely that from its proponents' point of view, specific benefits have been shown to substantially outweigh the costs so far identified. Otherwise, the project-development effort would not have been initiated.

The following subsections describe the main benefits from a public transport project, and Chapter 2: Mode Selection: Why BRT? features a more detailed discussion on these benefits as related to a BRT system.

1.5.1 Listing of Benefits Commonly Sought with Major Public Transport Projects

Mobility deficiency, like congestion, that needs to be alleviated

Perhaps the most obvious reason for a project is to significantly improve mobility within some district of the city/region or some corridor within the city/region. Mere increases in the number of buses, jitneys, or such, or increases in service duration during the day, either will not provide enough additional capacity, its quality will not be high enough, or due to congestion it will not have much effect.

Current pollution needs to be alleviated and future pollution increases curtailed

The current mix of vehicles within a district or city/region results in pollution that is judged to be detrimental to health, visibility, buildings and plants, or some combination of all of them. Or it has become evident that the current trend in the mix of vehicles will soon result in the aforementioned problems. Note that this benefit can also be interpreted as a reduction in cost. This is a distinction that sometimes causes confusion or ambiguity during the evaluation process.

Safety problems need to be alleviated

It has been widely reported that traffic collisions count as one of the greatest causes of death in countries both rich and poor. In developing countries, there is often an additional element of injustice, in that the majority of the deaths are pedestrians, who bear danger but do not receive the benefits of motorization. The problem tends to be further compounded in its severity and frequency when there are many high user-vulnerability vehicles like motorcycles and bicycles in mixed traffic. Improved public transport can simultaneously reduce the number of user-vulnerable vehicles by attracting former users as well as tame street conditions.

Health problems need to be alleviated

Many metropolitan areas have now reached the point where peoples' lives are being shortened, and their ability to participate in daily life hampered, due to poor environmental quality. While transport can also contribute to water quality, solid waste, and other such environmental-quality problems, the single most urgent problem is usually air-quality reduction caused by vehicle exhaust as well as tire, brake, and dust particulates. Reductions in total vehicle pollution can result from major public transport projects that reduce the number and use of smaller, less efficient, obsolete, and/or poorly maintained vehicles.

Energy conservation by current population and future energy-efficiency improvements

Energy production is related to a host of potentially serious problems, depending on the fuel sources. There is greenhouse gas generation, costs of investments in fuel exploration and power plant construction, environmental impacts from exploration, extraction, and refining, and so on. Even non-fossil-fuel sources like hydropower are not without damage. Furthermore, there are investment costs, including for non-fossil-fuel infrastructure, balance of payment issues associated with importing fuels, and other financial impacts. Even if current impacts and costs are manageable, future impacts may be worse. Furthermore, energy consumption is closely related to other problems, such as pollution and health issues. Energy reduction will usually result in reductions to these as well.

Redirection or elimination of excessive or ineffective subsidies

Attempts to improve the mobility of the masses and the need for affordable mobility options for lower-income populations make the case for the provision of subsidies to public transport operators. On the other hand, this money may have little impact relative to the level of support provided. In some cases it is a matter of corruption; in others, it may just be that traffic conditions are such that vehicles operate too slowly to ever be efficient or to attract customers willing to pay higher fares. In either case, a more formal public transport system, with right-of-way upgrades, and more centralized control could use the same level of subsidies to much better effect.

Economic development improvements as a result of the previous five items

There are always opportunity costs associated with public expenditures. Decreased public spending on health problems, on harm caused by accidents, on policing, on imported fuels, and so on, liberate this money for other productive uses such as education, agriculture, etc. Furthermore, private expenditure reductions on the same things and reductions in private mobility solutions can result in improvements in the material quality of life, as well as productive commercial investments.

When public transport investments succeed in reducing congestion, the decreases in time spent travelling result in less productivity loss to both individuals and to commerce that depends on the timely movement of goods and key staff across the region.

Transport-sector employees need more secure employment and better wages

Ad hoc transport systems that are not the result of coherent projects are often characterized by high employee turnover, due to low pay and perhaps abusive or highly stressful working conditions. This is not only detrimental to the workers themselves, but can also translate into very poor service, such as being forced to wait until a jitney is absolutely full before departure. It can also translate into very poor safety, with low wages and operating margins resulting in poorly maintained brakes, tires, exhaust systems, and overloaded vehicles combined with aggressive driving where operators compete for customers.

Population growth within a region needs to be absorbed more efficiently

Fast-growing populations often expand into lower-density perimeters. On the other hand, the existing built-up areas may not have the transport capacity to absorb more people, even if the zoning laws would permit higher-density development. Space-efficient public transport systems can be central to managing spatial change and growth.

Tourism in decline or unlikely to increase under the status quo

A location with a reputation for very unpleasant or unsafe traffic conditions, poor environmental quality, and a lack of suitable mobility options for visitors will conspire to reduce the desirability of the place as a tourist destination. Many places depend on tourists for their economic livelihood, and many have the potential to attract tourists if transport conditions improve.

1.5.2 Preparing the Way for a Project

Generally speaking, government agencies tasked with planning public transport projects will have limited time and financial and human resources for the development of projects. It is therefore important to distinguish a promising project worthy of support from the often numerous proposals that are submitted by concerned political activists, citizens, businesses, and technological boosters, which may be well intentioned but lack sufficient justification.

Listing of potential benefits and potential obstacles

The best way to justify a project for further study, and to convince decision makers of the same, is to provide a short summary that includes the nature and scope of the project and the higher-level goals it seeks to achieve. This should be followed by a quick recognition of any potential obstacles or impediments and a realistic assessment of whether any could prove insurmountable. The idea is to provide confidence that the time and effort expended is likely to result in the formal creation of a real project, whose benefits vastly outweigh the costs, and that has a strong chance at success.

What follows is a description of what a typical short summary should contain. Some fieldwork might be necessary, in addition to doing "meta-research" into all relevant research and survey work done to date.

Concise description of project scope and goals

There is always a set of questions that needs to be answered immediately in order to hold the interest of people who need to know why they should spend their time on this particular project proposal. They are the same questions that reporters and journalists are taught to answer: who, what, when, where, and why?

What, when, and where are a description of the scope of the project.

"What" refers to what would be built and purchased. How large is the project and what types of infrastructure, vehicles, and land takings might be involved? "Where" describes the parts of the region that would be involved and impacted. "When" describes how quickly this project would be implemented—is this long term, or will this have a quick impact? Together these allow a visual impression to be formed. However, if the particular mode and right-of-way standards (street level, elevated, in tunnel) are elements to be selected during the project, then several different alternative visions might need to be painted.

"Who" describes the parties responsible for developing the project and which particular elements within society are being targeted (if any). The reader should be left with an impression of who is going to manage the process and which communities are likely to have people expressing personal interests in it.

The "Why?" is the single most important question. This question should be answered as carefully and completely as the early stages of a project exploration will permit (and it is strongly related to the "vision" discussion earlier in this chapter). The politicians, agencies, and municipalities that will be asked to assist in or cooperate with, the communities that will be affected, and the general public that might help to pay for the system, all have a right to know. The principal goals of the project should be clear, should be linked to specific benefits, and if possible, prioritized. This will make it much easier to evaluate project alternatives. There may also be project benefits that are not directly linked to the formal goals, but can be used to build support. Project benefits can be divided into three broad groups:

1. Direct benefits that can be monetized, that is, estimated in quantitative terms in units of currency. Direct benefits are those for which the connection between project completion and improvements is clear. Monetizable benefits may already take the form of local currency, or can be assigned a unit of monetary value with reference to the marketplace. For example, fuel-purchase savings may occur to users, and operating-cost reductions may be achieved by transport operators. Users may experience reduced travel times, and the entire region experience a reduction in greenhouse gas emissions; for both of these, a monetary value can be imputed;
2. Direct benefits that can be estimated quantitatively, but for which it is difficult to assign a monetary value. These would include improvements in accessibility (i.e., the number of employment opportunities that can be reached within a reasonable travel time), or safety;
3. Indirect benefits are more contentious because the link between the project and the benefit is not always straightforward, and estimation techniques can be complex or controversial. Nevertheless, they can be compelling reasons for a project. For example, reduced congestion can contribute to an improvement in the efficiency of commerce through the lowering of transport times and costs. Poverty might be reduced through improved mobility to employment or education for some subpopulations. Land in the perimeter might be preserved through densification enabled by higher capacity transport. Reduction in petroleum imports is yet another.

Recognize potential conflicts between analysts and between community stakeholders

There is likely to be some skepticism about a project's worthiness, or how realistic it is, even from well-intentioned people. While some opposition is to be expected from those with stakes in the status quo, any major project could also founder on irreconcilable conflicts that cause gridlock. Risks of technical inability to execute, or of cost escalation, may be perceived as too high, and conflicts too serious to be overcome. There is also the chance that aggrieved parties will take redress in the courts. In the interest of minimizing the chances of such eventualities, here are some questions to attempt to answer early on:

- **Are there important goals that conflict?**

  This is not uncommon for public transport projects, and points to the need to prioritize goals. Project goals can often express the tension between reducing operating-support requirements (subsidy) and increasing ridership or delivering other user benefits such as improved comfort. Claims that one can optimize two conflicting goals at once cast doubt on whether the importance of goals has been decided. This leaves other analysts with the opportunity to criticize and oppose based on their own judgments;

- **Are there conflicts between the short-term and longer-term needs and goals?**

  An example: Reducing car use is an example of a longer-term goal, but the achievement of the shorter-term goal of congestion reduction may actually promote it. This may imply that measures to restrain auto use might be needed if the longer-term goal is a serious one;

- **Are there conflicts of interests for project decision makers?**

  While this can happen anywhere, it is of particular relevance where only small numbers of people own autos. They are likely to also be the ones who would have to approve the taking of lanes from autos when this is essential to a project;

- **Are there conflicts of interests for governing institutions and authorities?**

  A typical example is a multimodal planning agency that is trying to improve conditions for both private motorists and public transport customers. It might not be able to advocate fairly or evenhandedly for both parties;

- **Can one identify inequitable incidences of costs versus benefits?**

  It is axiomatic that the good of the majority outweighs the good of the few. If it were not, very few transport projects could ever advance, as almost all projects impose some costs disproportionately—better to identify them up front to ascertain the degree of inequity and to see if it is excessive or something that might derail a project.

- **Can one include mitigations of inequities in project design?**

  In some cases, mitigations could be easily affordable relative to the size of the project budget. In others, there may be no mitigation possible, leaving only unsatisfactory solutions or drastic measures. An example of an unsatisfactory solution would be overpasses or underpasses to connect severed neighborhoods. An example of a drastic measure would be the relocation of people against their will due to condemnations.

Develop a more limited set of benefits that can still justify a project if some benefits are a source of contention

If it is apparent that some of the indirect (sometimes even direct) benefits are going to be disputed, a reduced list can be developed. This can be done by eliminating some types of benefits entirely, or using lower values when ranges are assigned to benefit estimates. These ranges of uncertainty tend to widen as forecasts go further into the future. Similarly, one can look at particular cost estimates and assume higher ranges for them, now and in the future. If the project still looks feasible, perhaps still even very strong, this is compelling evidence of a project worthy of further advancement.

One should also point out features of the project that retain flexibility to adapt to changing circumstances if assumed developments do not come to pass, if higher or lower demand than forecasted develops, if new technologies supplant old ones, etc. For example, stations that are limited by city block size will constrain vehicle size. As another example, projects that use proprietary technologies cannot adopt new bus and rail features that quickly become standardized.

Projects are called “robust” if they do not depend on only one particular type of benefit or on achieving a very high level of a particular benefit in order to be judged successful, and can adapt to circumstances well. This is a very positive attribute for projects with long life spans.

Recognize the opportunity costs

The "opportunity cost" is defined as the alternative use for the same resources. If the opportunity is to be funded by the same mechanisms, having the same criteria, and staffed by the same resources as the project under consideration, the answer to the question of the best use is, of course, resolved by properly and impartially using these internal evaluation and performance criteria. But if the opportunities being discussed are outside, what are realistic opportunity costs for the same resources? This is a more difficult question to answer. Who is to say what type of project is more worthy? The answer in practice comes from elected officials who allocate budgets to departments and agencies and make transfer payments to other levels of governments for certain purposes. These should, in principle, reflect the democratically set priorities of the public.

Often a project will receive criticism, not on its transportation merits per se, but on the grounds that the money would better go elsewhere to other priorities. Perhaps schools, health care, and agricultural water supplies are also in need of funding. Thus, an argument can be made that the transport project is "gold plated." On the other hand, what would happen to both the transport project and the money if the money were indeed withdrawn? For concrete purposes, removing an elevated or tunnel section of right-of-way may lower costs, but it might also lower the speed and reliability performance of the investment such that middle- or upper-middle-class auto owners would no longer patronize it. This might then withdraw political support of the entire project. Meanwhile, would the savings really go to schools or health care? It might well go instead to building a motorway that benefits the auto-owning class. Indeed, the entire project funds could go to this alternative project instead. If so, this would be an example of a "straw man" argument against investment. The opportunity cost is not realistic and indeed a project reduced in scope could be put in jeopardy of no further consideration.

Thus, the final step in documenting a project in order to prepare the way for a project to get permission to proceed and to receive funding is to develop a comprehensive and fair description of realistic opportunity costs. Including these early in the process will preclude further delays due to the inevitable and understandable questions about how well opportunity costs were studied. It may also serve to clarify some of the essential characteristics of the project to retain political or popular support.

1.5.3 Assembling the Project Justification

Once the planning agency and municipal/regional governments have agreed that the project is worthy of formal project status, the next step is usually to get permission from higher levels of government and elected officials to proceed with more detailed development. This step might include requirements to show proof of intent to comply with higher-level laws, directives, and procedures (such as environmental protection statements, historic preservation, etc.). It may also require the assembling and presentation of the project justification materials in a particular format and process, because the materials will be compared in direct competition with other proposals. In some nations, a formal environmental impact study or assessment must be conducted at this time; in others it may be presented at a later date. Box 1.1 lists the typical set of elements that should be submitted, even if not strictly required, in order to minimize the chances of requests for further information.

In return, the planning agency may receive not only permission to proceed, but also a commitment for funding contributions, or at least a commitment to do a further evaluation of its worthiness for a matching contribution. Without such contributions, a project often needs to be aborted due to financial infeasibility. High-cost projects often need assistance from nonlocal sources, and are, in fact, very often predicated from the beginning of the feasibility study on obtaining such assistance.

Box 1.1. Essential Elements for Project Justification

- Context for the project;
- Comprehensive set of direct and indirect benefits;
- Comprehensive set of identified costs and negative impacts;
- Benefits and costs to be refined after environmental reviews are completed;
- List of potential mitigation measures for negative impacts;
- Reduced set of non-contentious benefits still sufficient to justify the project;
- Discussion of opportunity costs.

2. Why BRT?

> *"For a successful technology, reality must take precedence over public relations, for nature cannot be fooled."*
>
> — Richard P. Feynman, physicist, 1918–1988

The choice of rapid transit technology will affect travel times, personal transport expenditures, and commuter comfort. The choice will also dramatically affect government finances and a city's economic efficiency. Ultimately, the selection will shape a city's urban form and the lifestyles of its inhabitants. But the choice should be guided first and foremost by what type of service is needed. Technology then becomes the tool to provide that service.

Choosing the appropriate rapid transit technology for a city requires balancing what citizens want and where they want it with more technical considerations such as costs and potential benefits. This chapter summarizes the technical differences among three main mass transit options: Bus Rapid Transit (BRT), Light-Rail Transit (LRT), and Heavy Rail Transit (HRT).

When deciding on the type of rapid transit most appropriate for a city, cost, performance, implementation speed, scalability, and local preferences all need to be taken into consideration. For most cities, the costs of different rapid transit alternatives, both capital and operating expenditures, should be preeminent decision-making factors. Even wealthier cities will benefit from cost-effective investments, offering greater benefits per dollar of investment. As the economic and social benefits of funds invested in rapid transit need to be weighed against other economic and social investments, an effort should be made to get the greatest social benefit per dollar of investment possible. The quality of the service, including the capacity, the speed, and the comfort of the service are also very important. People will willingly pay more for a higher speed and more comfortable service, and some corridors have more potential riders and require a higher capacity service.

The flexibility and scalability of the system also matters. Perhaps normal existing transit speeds are very fast in a city everywhere except in one area such as downtown. A high-speed congestion-free service may be needed in the congested area but not elsewhere. For different transit modes, there are different minimum operable lengths, which are the shortest segments that make sense to build and still bring benefits. The costs of the stations, vehicles, rights-of-way, and other factors will change this length for various modes. Some modes are easy to build in small segments, while other modes make financial sense in larger segments. There is also a benefit to expanding existing modes, as services and infrastructure can be connected more seamlessly.

As all public investments are ultimately political, they require some sort of mandate from the political leadership and the general public. Because politics and public opinion change rapidly, implementation speed is also very important. If a project can be implemented during a single term of political office, it stands a greater chance of being implemented, and its benefits can be realized more quickly.

Economic development impacts also matter. If one type of rapid transit is known to have a greater economic development impact, this would also affect investment decisions. Many cities are looking to rapid transit investments to help stimulate economic development in particular locations to guide urban growth to strategic locations. This chapter reviews how BRT, LRT, and HRT options vary with respect to each of these issues.

2.1 Defining Rapid Transit Modes

> *"The technologies which have had the most profound effects on human life are usually simple."*
>
> — Freeman Dyson, physicist, 1923–

Public transportation includes all publically accessible transportation services that convey people in common vehicles from one place to another. These services generally run on fixed routes at regularly scheduled intervals. Rapid transit is a form of public transportation on a fixed route that includes features that dramatically improve the speed, capacity, reliability, and quality of the service.

2.1.1 Defining BRT

BRT is:

> *"... a bus-based rapid transit system that can achieve high capacity and speed at relatively low cost by combining segregated bus lanes that are typically median aligned, off-board fare collection, level boarding, bus priority at intersections, and other quality-of-service elements (such as information technology and strong branding)."*
>
> — *BRT Standard*, 2015

Five essential elements put the "rapid" in bus rapid transit:

- Physically separated bus lanes allow buses to avoid congestion;
- Stations and bus lanes aligned to the center of the street to avoid being delayed by turning vehicles and vehicles dropping off passengers or goods;
- Fares collected off the bus, to avoid delays caused by passengers paying on board;
- Boarding from a platform level with the bus floor to make boarding faster, and so that people in wheelchairs or with strollers can roll directly onto the vehicle;
- Turn restrictions and bus priority at intersections to reduce delay at intersections from red signals.

BRT corridors consist of dedicated, physically demarcated bus lanes that are aligned to the center of a street or a functionally equivalent configuration for the majority of the corridor. They also include one or more of the other three essential elements described above. A more detailed discussion of what constitutes a BRT corridor can be found in the *BRT Standard* (http://brtstandard.org).

2.1.2 Defining Other Rapid Transit Modes

Light-Rail Transit (LRT): a rail-based rapid transit system that uses predominantly exclusive, but not grade-separated, rights-of-way. Like BRT systems, LRTs can have a wide range of passenger capacities and performance characteristics. These capacities and performance characteristics are for the most part driven by the same essential elements that are critical to BRT system performance. These essential elements are defined in the *BRT Standard* (http://brtstandard.org) and will be discussed in this guide at length. If a rail system were to operate (as some do) in mixed traffic, on the curb lane, with turning movements allowed across it, where passengers have to pay the driver, and passengers need to step up into the vehicle rather than boarding at level, the operating characteristics of the system would be similar to those of a normal bus service, as opposed to an LRT. Conversely, an LRT that operates with prepaid boarding, has a dedicated right-of-way, operates in the central median of the right-of-way, and has all of the other elements of Gold Standard BRT, is likely to provide better service and operate more as a rapid transit system. As such, the BRT Standard technical committee has approved the limited use of the BRT standard to also rate LRT systems, with certain specific caveats (*BRT Standard*, p. 55).

Heavy Rail Transit (HRT): an electric rail-based public transport system, often referred to as "Metro," with high-passenger-capacity rail cars that generally preclude sharp turning movements and require a high platform to board. As such, they cannot generally be operated in normal street conditions, and hence require grade-separated rights-of-way. HRT systems have off-board fare collection, operate within a single built-up urban area with regular station spacing, and provide all-day bidirectional service with regular frequencies. For the purposes of the BRT Planning Guide, HRT will include systems described as commuter rail and metros that align with the above definition. As the vehicles cannot operate on normal streets, many elements recognized as critical to BRT systems do not apply to HRT systems. Though most HRT systems would probably rank "Gold" under the BRT Standard, the BRT Standard Technical Committee has not authorized the use of the BRT Standard for rating HRT systems.

For the purposes of this Planning Guide, what distinguishes LRT from HRT is that it operates for at least part of the transit corridor on normal streets and uses shorter train sets with lower capacities. As such, LRT tends to have flexible bodies capable of tighter turning radii than HRT systems and tends to have floors closer to street level than HRT vehicles. This guide includes in the definition of LRT both systems that are generally referred to as "LRTs" as well as some streetcars and trams.

Monorail: a rail-based public transport system composed of a single rail, usually elevated and thus grade separated. What differentiates the monorail from LRT of HRT is that monorail trains are wider than the guideways that support and guide them. Monorails are only mentioned in passing in this guide, as they are very expensive to build given their carrying capacity. Monorail is not a viable mass transit solution. Note that the definitions above were adapted from the Transportation Research Board and the American Public Transportation Association.

2.2 Costs

> *"While real trolleys in Newark, Philadelphia, Pittsburgh, and Boston languish for lack of patronage and government support, millions of people flock to Disneyland to ride fake trains that don't go anywhere."*
>
> — Kenneth T. Jackson, historian, 1939–

2.2.1 Capital Costs

On the same corridor, with the same type of right-of-way (elevated, underground, or on the street in a dedicated lane), many of the costs of BRT, LRT, and HRT will be similar. HRT systems by definition cannot operate on normal streets but require a grade-separated right-of-way. This generally requires expensive tunneling or the construction of elevated rights-of-way and stations. Full grade separation brings significant time savings benefits (as all traffic congestion and intersection delays are eliminated), but also significantly increases construction costs and maintenance costs, regardless of whether the vehicles operating on elevated or underground structures are buses, heavy rail vehicles, or light-rail vehicles.

In the past, many HRT systems were built using less expensive "cut and cover" construction methods. Such construction methods were highly disruptive of the surface environment, leading most cities to depend on deep boring techniques that allow the surface to remain intact but are much more expensive. Another reason that HRT systems tend to be much more expensive than street-level LRT or BRT options is because the elevated or underground stations and their access and egress, as well as the wider turning radii required by the vehicles and the large area generally required for the rail depot, make more land acquisition necessary than BRT or LRT alternatives. The costs of tunneling and elevating the HRT system are not only related to tunneling or elevating the right-of-way. Even costlier is elevating or excavating for each station, which is likely to cost around US$100 million per station. Most elevated or underground heavy rapid transit systems minimize the number of stations to increase speeds and keep the costs down, but this frequently limits accessibility to the system. It is fairly typical for modern HRT systems to have stations 1 kilometer apart, whereas it is generally recommended (see Chapter 6: Service Planning) that high-capacity public transport stations be placed around .450 to 500 meters apart to minimize walking access times. Were stations located in optimal locations, the cost of HRT alternatives would be significantly increased. LRT and BRT both have significantly lower capital costs in relation to HRT primarily because they can be located on normal city streets.

In general, the most significant capital cost differences between an LRT and a BRT are due to the following:

- LRT requires rails and switches, and the roadbed to support them;
- LRT requires electric catenary to conduct electricity to the vehicle safely;
- LRT requires rail vehicles;
- LRT requires a special depot connected to the system by rail tracks.

From a sample of five LRT projects in the United States, the average cost per kilometer of the light-rail track was US$38.6 million a kilometer, though the range was wide, from US$17.0 million to US$66.9 million.

A reasonable estimate of the cost of an LRT vehicle is US$3.6 million in the United States (http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_165ch-08.pdf, p. 8-1), though the range is from US$1.9 million to US$4.5 million (http://www.apta.com/resources/aboutpt/Documents/table22_vehvosttransitlength.pdf).

The number of vehicles needed will vary greatly with the passenger demand. Normally, an LRT vehicle will have a capacity of around 150 people, similar to that of an articulated bus. An articulated LRT vehicle can have a capacity of about 240 people, similar to a biarticulated bus (http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_webdoc_6-c.pdf, pp. 3–60). A decent quality 12-meter bus today can be purchased for as little as US$70,000 in India, but more typically costs about US$250,000 in most of the world and about US$400,000 in the United States. An articulated bus today can be purchased from China for under US$300,000, with US$450,000 being more typical in Latin America, and closer to US$800,000 in the United States. The cost of a biarticulated BRT bus in Latin America today is around US$800,000, and would probably be roughly double this in the United States, but there are few in operation in the United States (http://www.apta.com/resources/aboutpt/Documents/table22_vehvosttransitlength.pdf).

In addition, the LRT vehicles need to have a depot where they can be safely stored and repaired in a location that is connected to the tracks. Both BRT and LRT need depots. The primary capital cost advantage for a BRT depot is that it does not necessarily need to be adjacent to the BRT corridor, but can be anywhere in proximity to the corridor. In addition, a BRT in a higher-income country can probably use an existing bus depot. In most BRT systems in the United States, existing bus depots were used when standard diesel buses utilized the BRT corridor, while for new LRT systems a new yard or depot is generally necessary. For the two LRT systems for which disaggregated data was available, the cost of the LRT depot ranged from US$10.4 million to US$65.7 million.

Table 2.1. Average Cost per Kilometer by Mode(BRT, LRT, HRT), Developed Versus Developing Country

Type	Lower Income Countries (2013 $/Km)	Higher Income Countries (2013 $/Km)
BRT Average	$11,504,575	$10,054,824
BRT Gold	$16,312,504	n.a.
BRT Silver	$9,528,467	$9,729,605

BRT Bronze	$9,612,943	$10,380,042
LRT	$25,373,992	$37,496,032
HRT	$87,429,209	$433,660,969

Out of a database of forty-two BRT projects, nineteen LRT projects, and twenty-six HRT projects, the average cost per kilometer in constant 2013 dollars was derived and shown in Table 2.1. The number of data points is limited, and the clarity of this cost data is also limited, so these figures should be taken as very rough indications. The database has taken out LRT and BRT systems that involved elevation or tunneling to make the costs more comparable. For example, the Crenshaw/LAX LRT in Los Angeles, which is partially elevated and partially underground, is projected to cost upward of US$125 million per kilometer. The Boston Waterfront Silver Line busway, which was not long enough to qualify as a "BRT" corridor, cost US$625 million for 1.6 kilometers of exclusive tunnel, or about US$391 per kilometer, of which US$237 million (US$148 million per kilometer) was because of the tunnel under Boston Harbor and the underground stations. The system also used extremely expensive specialized buses (with both diesel and electric trolley propulsion systems) that cost roughly US$1.7 million each (http://www.fta.dot.gov/documents/FINALBOSTONBRTREPORT062507.pdf).

Based on this data, in lower income countries, with all other things being equal, it is reasonable to expect an LRT system (surface only) to cost 1.5 to 2.6 times that of a comparable BRT system. An HRT system could be expected to cost 5 to 9 times as much as a BRT and 3.4 times as much as an LRT. In higher income countries, it is reasonable to expect that a surface LRT alternative is likely to cost 3.6 to 3.9 times that of a BRT alternative. An HRT alternative is likely to cost up to 40 times as much as a BRT alternative, and up to 12 times as much as an LRT alternative.

Curiously, the difference in cost between BRT projects in higher and lower income countries was minimal. To some extent this reflects a higher quality of BRT projects in lower income countries. On average, a Gold Standard BRT in lower income countries costs double that of a Silver Standard or Bronze Standard BRT system. There was no significant difference between the cost of a Bronze Standard and a Silver Standard BRT in either higher or lower income countries, indicating that it is tough political decisions rather than a willingness to spend money that largely distinguished Silver Standard projects from Bronze Standard projects.

The cost of an LRT in higher income countries was 50 percent more than an LRT in lower income countries, and the cost of an HRT project in higher income countries costs five times as much as an HRT project in lower income countries, probably due to the higher cost of labor in construction.

Table 2.2. BRT Project Capital Costs by Country and Quality

Country	City	Project	Length (km)	Cost/Km (2013 USD/km)	Quality (BRT Classification)
BRT Lower Income Economies					
Brazil	Belo Horizonte	Cristiano Machado	7	$4,040,571	Gold
Brazil	Curitiba	BRT "Linha Verde"	33.8	$7,146,213	Gold
Brazil	Rio de Janeiro	TransCarioca	39	$14,716,462	Gold
China	Guangzhou	Guangzhou BRT	22.9	$7,672,668	Gold
China	Yichang	Yichang BRT	22.9	$6,812,169	Gold
Colombia	Bogotá	TransMilenio Phase 1	41	$18,574,652	Gold
Colombia	Bogotá	TransMilenio Phase 2	42	$33,036,852	Gold

Colombia	Bogotá	TransMilenio Phase 3	37	$24,582,229	Gold
Colombia	Medellín	Metroplus	13	$30,230,724	Gold
				$16,312,504	*Gold Average*
Brazil	Belo Horizonte	Antônio Carlos-Pedro 1	15	$24,124,667	Silver
Brazil	Rio de Janeiro	TransOeste	55	$15,268,816	Silver
China	Lanzhou	Lanzhou BRT	9	$7,805,467	Silver
Colombia	Barranquilla	Transmetro	14	$19,295,428	Silver
Colombia	Cali	Mio	49	$17,046,807	Silver
Colombia	Pereira	Megabús	27	$5,326,363	Silver
India	Ahmedabad	Janmarg BRT Phase 1 + 2	88	$3,003,560	Silver/Bronze
Mexico	Chihuahua	Vivebús	20	$3,856,908	[likely Silver]
Mexico	León	Optibús Etapa 1	25	$2,678,309	[likey Silver]
Mexico	Estado de Mexico	Mexíbus Línea 1 - Cd Azteca - Tecamac	16	$7,861,951	Silver
Mexico	Estado de Mexico	Mexíbus Línea 3 Chimalhuacán - Pantitlán	15	$8,934,935	Silver
Meixco	Mexico City	Metrobús Líneas 1-4	93	$6,216,923	Silver
Mexico	Mexico City	Metrobús Línea 5	10	$6,352,388	Silver
Mexico	Monterrey	Ecovía Line 1	30	$4,274,341	Silver
South Africa	Johannesburg	Rea Vaya 1a	30	$10,387,801	Silver
				$9,495,644	*Silver Average*
China	Beijing	BRT Line 1	79	$1,064,030	Bronze
India	Indore	Indore iBus BRT	11	$4,920,486	[likely Bronze]
India	Pimpri Chinchwad	Primpri Chinchwad BRTS	45	$5,482,658	Bronze
India	Surat	Surat BRTS	11	$12,461,951	Bronze
Mexico	Puebla	RUTA, Line 1	19	$6,526,254	Bronze
South Africa	Cape Town	MyCiTi Phase IA as of 2010	17	$23,794,946	Bronze
South Afria	Johannesburg	Rea Vaya Phase 1b	18	$13,040,278	Bronze
				$9,612,943	*Bronze Average*
India	Delhi	Delhi High Capacity Bus System (HCBS) Pilot	6	$3,909,769	Basic BRT
Indonesia	Jakarta	Transjakarta - Line 2 & 3	14	$5,812,720	Basic BRT
Indonesia	Jakarta	Transjakarta - Line 11	11	$3,366,204	Basic BRT
Indonesia	Jakarta	Transjakarta - Line 12	24	$1,429,598	Basic BRT
Brazil	Fortaleza	Avenida Alberto Craveiro	3	$5,041,467	Rating pending
Colombia	Cartagena	Transcaribe	13	$42,452,618	Silver pending
Colombia	Bucaramanga	Metrolínea	50	$6,917,539	Rating pending
Mexico	Puebla	RUTA, Line 2	20	$12,433,272	Rating pending
South Africa	Tshwane	A Re Yeng Phase IA	7	$13,834,400	Rating pending
				$10,577,510	*Other Average*

BRT Higher Income Economies					
France	Paris	TVM Rungis - Croix de Berny RER	22	$4,898,500	Silver
France	Rouen	TEOR (Phase 1)	38	$5,410,316	Silver
USA	Cleveland, OH	HealthLine	11	$18,880,000	Silver
				$9,729,605	*Silver Average*
USA	Eugene, OR	Franklin Corridor (Green Line)	6	$4,427,910	Bronze
USA	Los Angeles, CA	Orange Line (Original)	23	$16,332,174	Bronze
				$10,380,042	*Bronze Average*

Note: Systems referred to as “likely” Gold, Silver, or Bronze means that they have been evaluated but their rating is pending final approval from the technical committee.

Table 2.2 shows the full list of BRT projects and their costs, and their quality as measured by the *BRT Standard*. Some of the highest scoring elements of the *Standard*, which account for many of the differences between Silver and Bronze systems, such as turning restrictions across the busways or physical separation of the rights-of-way, are relatively low cost, yet require political will to implement. Most of the costs in Gold Standard BRT systems are related to creating a high-quality station environment.

The range of costs ran from US$1 million per kilometer for a Bronze Standard BRT in China (which had no depots and was low-quality construction) to US$42.4 million in Cartagena (Silver Standard), which experienced significant construction delays that added to the project cost. A major reason for the divergence in cost among BRT projects is the amount of land and property acquisition required to implement the project.

While the construction costs of the first phase of the Bogotá BRT system (which included the complete reconstruction of the roadbed building wall to building wall) totaled approximately US$18.6 million per kilometer, the second phase increased to as much as US$33 million per kilometer for the costliest segment. This increase was in large part due to land and property purchases. The city decided to widen some roadways during Phase II in order to maintain the number of mixed traffic lanes along the BRT corridor. For Phase III, costs came down again to around US$24.6 million per kilometer (“Applicability of Bogotá’s TransMilenio BRT System to the United States.” USDOT: FTA. May 2006 http://www.fta.dot.gov/documents/Bogota_Report_Final_Report_May_2006.pdf).

Table 2.3. Table 2.3 LRT Project Capital Costs

Country	City	Project	Length (km)	Cost/Km (2013 USD/km)
LRT Lower Income Economies				
Algeria	Constantine	Constantine Tram	8	$50,000,000
Algeria	Oran	Oran Tramway	19	$22,664,211
Brazil	Rio de Janeiro	PPP|Port Maravilha Light Rail	28	$16,071,429
China	Shenyang	Shenyang Tram	60	$12,900,000
Mexico	Guadalajara	Tren Ligero Linea 3	16	$31,890,625
Morocco	Casablanca	Casablanca Tramway	31	$19,354,839
Morocco	Rabat-Salé	Rabat-Salé Tramway	19	$24,736,842
Average				*$25,373,992*

LRT Higher Income Economies				
France	Paris		14	$60,714,286
France	Rouen		15	$45,333,333
France	Besançon	Line 1 Tramway	15	$19,278,333
France	Dijon	Line 1+2 Tramway	19	$26,634,737
France	Le Havre	Line 1+2 Tramway	13	$41,653,077
France	Reims	Line 1 Tramway	11	$44,188,182
France	Lyon	Line 4 Tramway	16	$19,397,500
USA	Charlotte	LYNX Blue Line	16	$31,445,625
USA	Charlotte	LYNX Blue Line Extension	16	$66,856,250
USA	Minneapolis	METRO Blue Line	20	$45,145,730
USA	Sacramento	RT Blue Line extension	7	$32,321,429
USA	Houston	Purple Line/SW Corridor	10	$16,983,900
Average				*$37,496,032*

The costs of at-grade LRT systems in countries with both developed and emerging economies, shown in Table 2.3, range from US$19.3 million per kilometer for tramways in France to US$66.9 million for the Charlotte (North Carolina) LRT extension. A few of the LRT systems in the United States were rated using the *BRT Standard*, and they ranged from Silver to Bronze. There was no clear correlation between the cost of an LRT system and its rating using the *BRT Standard*.

Table 2.4 contains the range of costs for HRT projects divided into countries with developed and emerging economies. The lowest cost systems are in India, at a minimum of US$51 million per kilometer. Labor costs for construction are very low in India, and these are primarily elevated structures with a limited number of station stops.

Land acquisition costs also tend to be lower in lower income countries than in higher income countries, though this is not always the case. One of the world's costliest public transport projects to date has been the Jubilee Line extension to the London metro system. The 16-kilometer extension came to a total of US$500 million per kilometer. Much of this high figure was due to the procurement of private land and property in areas such as the Canary Wharf business district.

Another factor is the amount of and depth of other competing infrastructure. The highest cost public transport project ever to be built was the New York Second Avenue Subway, costing an estimated US$982.658 million a kilometer. This project bored under the bedrock on the east side of Manhattan, at a significant depth (98 feet) to avoid an unprecedented density of existing infrastructure. Each station is being done with traditional cut and cover methods, requiring land acquisition in a very high cost land market. A high water table is another factor when estimating construction costs, as construction below the water table adds additional expense.

Table 2.4. Table 2.4 HRT Project Capital Costs, Emerging and Developed Economies

Country	City	Project	Length (km)	Cost/Km (2013 USD/km)
HRT Lower Income Economies				
Brazil	Rio de Janeiro	Line 4 metro	16	$233,750,000
Brazil	São Paulo	Line IV metro	14	$101,992,857
China	Lanzhou	Lanzhou Metro Line 1	34	$93,176,471

China	Guangzhou	Guangzhou Metro Line 1	18.5	$87,729,730
China	Shenzhen	Shenzhen Metro Line3	33	$56,224,491
China	Guangzhou	Guangzhou Metro Line 2	18	$79,259,480
China	Guangzhou	Guangzhou Metro Line 3	36	$68,288,974
China	Shanghai	Metro Line 2	19	$81,104,400
China	Beijing	Metro Line 4	29	$88,750,707
Colombia	Medellín	Tranvía de ayacucho	4	$81,149,750
Colombia	Bogotá	Metro de Bogotá	35	$98,571,429
India	Delhi	Delhi Metro Phase 1 + 2	167	$43,699,867
India	Mumbai	Mumbai Metro Line 1	11	$71,149,762
India	Hyderabad	Hyderabad Metro Phase I	72	$54,166,667
India	Bangalore	Bangalore Namma Metro Phase 1	42	$104,659,325
India	Kochi	Kochi Metro Phase 1	25	$36,491,914
Indonesia	Jakarta	MRT	14	$109,929,275
Mexico	Mexico City	Metro Línea 12 Extension	4	$158,769,459
Mexico	Mexico City	Línea 12 Metro Ciudad de México	25	$86,715,346
Mexico	Zona Metropolitana/ Valle de Mexico	Suburban Rail Line 1	27	$78,131,686
Mexico	Monterrey	Línea 3 Tren subterráneo de Monterrey	7.5	$58,473,896
South Africa	Johannesburg	Gautrain	80	$51,257,110
Average				$87,429,209
HRT Higher Income Economies				
United Kingdom	London	Jubilee Extension	16	$501,264,813
USA	DC Metro Area	Silver Line Phase 1	19	$165,393,158
USA	Washington DC	0	19	$152,930,789
USA	New York City	0	17	$982,658,960
Average				$433,660,969

These ranges, divided between developed and emerging economy contexts, should provide a reasonable set of benchmarks when performing back of the envelope alternative cost appraisals.

2.2.2 Operating Costs

To date there have been no systematic comparisons of operating costs and the farebox cost recovery ratios between BRT, LRT, and HRT due to the numerous methodological problems involved. In many higher income countries, BRT systems are operated by agencies that do not keep separate accounts for their BRT operations and their normal bus operations, and there are few operational LRT systems in lower income countries. It was not possible as part of this guide to compile tables of comparative statistics on operating costs and cost recovery ratios. Nevertheless, the following operating costs can significantly diverge among BRT, LRT, and HRT:

- Vehicle cost depreciation and maintenance;
- Catenary depreciation and maintenance;
- Labor;

- Fuel;
- Cost of capital (interest on loans).

Vehicle Cost Depreciation and Spare Parts

A system operator needs to replace rolling stock over time. The cost of the rolling stock should be depreciated over its expected commercial life. For BRT systems, most buses are depreciated over ten years depending on the type of bus and its expected useful life. In Indian and Chinese BRT systems, where the expected commercial life of the bus is lower, the depreciation should be adjusted to reflect this. Typically, the commercial life of rail vehicles is longer, frequently twenty years, so the initial investment should be depreciated over twenty years. These depreciation costs should be calculated using one of the accepted methods for calculating depreciation and reflected as operating costs.

Despite the fact that rail vehicles tend to be depreciated over a longer time frame, their much higher initial cost tends to make the depreciation costs associated with rail systems higher than the depreciation costs associated with BRT systems. One of the reasons that bus costs are far lower than the cost of railcars is the number of manufacturers. With China, India, and Brazil joining Europe and the Middle East as suppliers of buses, the cost of buses is coming down in real terms. An even larger number of countries are able to assemble buses domestically so that only the engines and chassis need to be imported. BRT infrastructure can generally accommodate buses from a wide variety of manufacturers.

A rail system, by contrast, tends to be locked into a permanent dependence on one or two suppliers of rolling stock. While buses tend to use truck engines where the spare parts have over time come to be produced by alternative low cost producers on a massive scale, the manufacturers of rail technology tend to remain monopoly suppliers of their spare parts, as the market for them is far more limited. These monopolistic conditions tend to drive up the operating cost of rail rolling stock. There are only a few major rail manufacturers in the world today (i.e., Alstom, Bombardier, Hitachi, Kawasaki, and Siemens). The scale required to set up local rail manufacturing is unlikely to be achieved in most lower income nations. Instead, manufacturing (and the associated employment) will be based in higher income countries, such as France, Canada, Japan, or Germany. When a city such as Bangkok purchases its rail metro vehicles, the carriages arrive almost fully fabricated (Figure 2.1). This tends to make the vehicles far more expensive.

Figure 2.1. A metro rail car arrives in Bangkok from Germany. *Bangkok MRTA Company.*

The long-term cost of keeping the rolling stock operational is even more sensitive to the cost of spare parts. Over the life of a bus or a railcar, far more money is spent overall on spare parts than on the initial cost of the vehicle's procurement. The same monopolistic conditions that tend to drive up the procurement cost of rail vehicles relative to buses also affect the supply of spare parts. While some bus operators are also partially locked into expensive spare parts contracts with the bus suppliers, a growing number of bus operators are successfully switching to generic spare parts suppliers that considerably reduce their overall costs. With rail vehicles, it is far more difficult to avoid a dependence on the original manufacturer for spare parts, driving up costs.

Catenary Depreciation and Maintenance

One of the primary operational cost differences between BRT systems and LRT and HRT systems is the cost of depreciating and maintaining the electric catenary. These costs have escalated in recent years (Cervero, http://www.uctc.net/papers/UCTC-FR-2010-32.pdf , p. 9). The overhead wires of an LRT system or an electric trolleybus BRT system need to be maintained well, since a failure results in system shutdown. A system shutdown imposes massive operating costs on the operator. These overhead wires are generally quite expensive to maintain and need to be replaced periodically. These costs are absent from BRT systems using diesel technology.

It should be noted that recent advances in electric battery technology have made battery-powered electric vehicles a more affordable option for transit vehicles, as seen by new fleets of battery-powered electric buses and trams in operation or on order in Thailand, China, and the United States (as of 2016). Given the new technology, it is not clear how these vehicles will compare in terms of operating and maintenance costs, as compared to gasoline-powered buses or electric trolley buses or trams, but they should be monitored as a potential option.

Labor

The labor involved in BRT, LRT, and HRT systems is similar: vehicle operators, head office (administrative) personnel, vehicle maintenance personnel, control center personnel, fare collection services personnel, other station services personnel. A system with a similar number of stations, a similar number of vehicles, and a similar type of fare collection system should have similar labor costs. The cost of labor for rail vehicle maintenance personnel and rail vehicle operators is likely to be higher than the cost for bus operators and bus maintenance personnel as these professions are more highly specialized and require a greater degree of technical training. Typically, these staff are provided by the vehicle manufacturer for several years as part of the initial procurement arrangement. LRT vehicle operators also tend to be somewhat better paid as it is a more specialized profession.

LRT and HRT systems may gain savings in labor cost from reductions in fleet size and hence the number of vehicle operators needed. LRT and HRT vehicles come in sizes larger than the largest BRT vehicles (biarticulated buses) and can therefore carry more passengers with a single operator, reducing labor costs.

However, as explained in Chapter 6: Service Planning, this guide recommends optimizing the vehicle size following a formula that finds the optimal trade-off between minimizing passenger waiting times (with high frequency) and minimizing labor costs (with larger vehicles). While the formulas for calculating optimal vehicle size included in Chapter 6 were developed for BRT systems, they can equally be applied to LRT systems.

For any given demand profile on a transit corridor, the number of vehicles needed to satisfy peak hour demand should be set based on a vehicle size that provides the optimal trade-off between passenger waiting costs and vehicle operator labor costs.

Because in higher income countries, the value of waiting time is worth more than in lower income countries, but vehicle operators also get paid more, this trade-off works out to be roughly the same vehicle size in both higher and lower income countries.

Labor can represent between 35 to 75 percent of operating costs in Europe and North America, while the labor component of lower income country systems is generally closer to 20 percent, so in higher income countries, people value their waiting time more but vehicle operators also cost more.

Unsurprisingly, this cost-benefit analysis shows that smaller vehicles are more optimal for lower demand systems and larger vehicles are more optimal for higher demand systems. In high demand systems, there are diminishing returns to higher frequencies, so larger vehicles tend to be more attractive. In low demand systems, very low frequencies will make waiting times a very significant cost for passengers and can have a significant adverse impact on ridership.

In most typical operating conditions, the optimal vehicle size for an LRT or a BRT is lower than the largest BRT vehicle. As such, any operating benefits of using larger LRT vehicles are offset by even higher costs faced by waiting passengers, so the operational cost savings are being purchased at the expense of passengers.

Fuel Costs

Fuel price volatility can represent a significant financial risk to a transit system operator. A sudden increase in fuel prices can drive a reasonably profitable transport system suddenly into debt. Quito's electric trolleybus BRT, for instance, was initially profitable until Ecuador privatized its electricity and electric prices rose sharply, creating large operating losses for the City of Quito's electric trolleybus BRT operation. Fuel price volatility can affect any fuel, whether it is electricity, diesel, CNG, LPG, or some other form.

Electric-powered modes, such as LRT, HRT, and electric-trolleybus-powered BRT, can be cheaper to power in countries with a plentiful, stable, and low cost electricity supply (such as those with ample hydroelectric power) than in countries with high cost, unstable electricity supplies. Electricity prices per kilowatt hour vary from as low as US$0.02 or US$0.03 in some countries to greater than US$0.40 in island nations, with prices across Europe varying from about US$0.12 in Central and Eastern Europe to between US$0.20 to US$0.30 in most of Western Europe.

One advantage of BRT systems is that there are generally more fuel alternatives available. Whereas electricity prices are low and stable, it may be that the higher costs of procuring electric trolleybuses and maintaining their catenary can be justified by fuel cost savings, as was the case with the first BRT corridor in Quito. When electricity prices rose in Ecuador, Quito was able to select a diesel alternative for the next BRT corridor. Where CNG is inexpensive and the prices are stable, CNG buses can offset the higher vehicle and spare parts costs with lower fuel costs. CNG prices have fallen in many countries recently due to new methods of extraction. Diesel prices tend to be more stable internationally, though the tax treatment of diesel fuel varies widely. GIZ publishes annual average fuel prices across the world as a quick reference for relative fuel prices (http://www.giz.de/expertise/downloads/giz2014-en-international-fuel-prices-2013.pdf).

BRT systems can also introduce new buses that use hybrid-electric technology, CNG, LPG, ethanol blends, hydrogen fuel cells, or other alternative fuels. This has also proved to be important for resilience in the case of major power outages.

The market for HRT and LRT vehicles is dominated by those powered by electricity, limiting options where other fuels make more economic sense. That said, diesel multiple units do provide a diesel option for rail vehicles, but they serve a small portion of the rail vehicle market. Hybrid diesel-electric rail vehicles also provide more resilient options combining fuel technologies. In addition, there are efforts to bring CNG-powered rail transit vehicles to market, but these are not yet widely available.

Cost of Capital

If a transit operator has to borrow money to pay for either the infrastructure or the rolling stock, or both, the cost of paying this debt becomes an operating cost. If a national or state government is willing to pay for an urban transit capital investment, there will be no new debt service, and the cost of capital will be zero. On the other hand, if a transit operator has to borrow money to pay for a capital improvement, debt service will have a big impact on operating costs.

In the most indebted transit systems, debt financing costs can account for upward of 30 percent of operating deficits (http://council.nyc.gov/downloads/pdf/budget/2014/mta.pdf).).

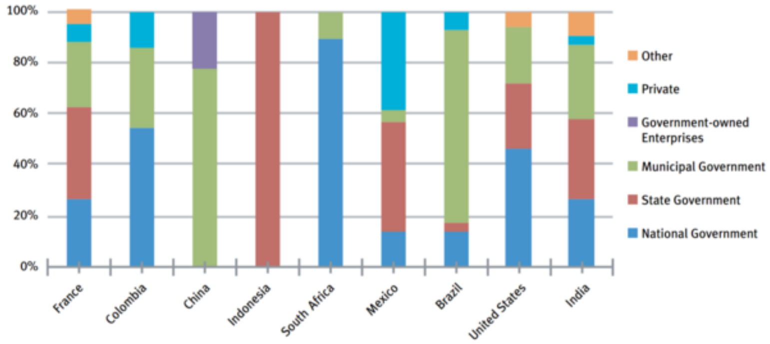

Figure 2.2. BRT capital funding by level of government. *ITDP.*

A national or state government bias in terms of which mode they are willing to support with capital investments can therefore have a profound impact on operating costs. A recent study (https://www.itdp.org/publication/best-practice-in-national-support-for-urban-transportation-part-2/, ITDP, 2015) indicates that while many national and state governments are neutral in terms of their willingness to fund LRTs, BRTs, or HRTs, in a few countries (India, Indonesia, and Brazil), state and national governments have played a much larger role in underwriting the cost of rail projects than BRT projects. The United States in recent years has had a policy of promoting streetcars, a variety of LRT, which made them more likely to receive federal government capital grants.

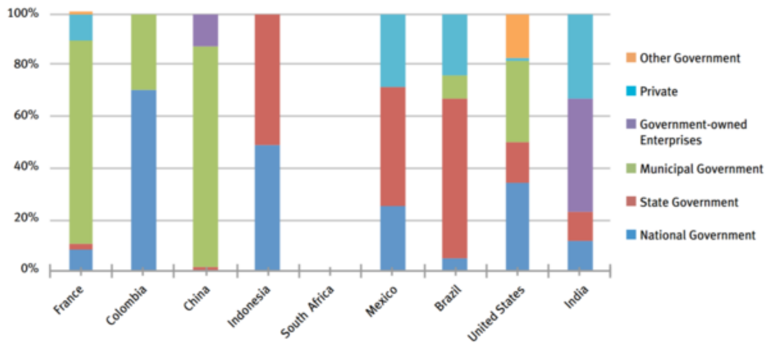

Figure 2.3. Rail transit capital funding by level of government. *ITDP.*

Rapid transit systems are classic examples of public investments that make sense for public debt financing. Because the benefits of a well-designed transit system will be enjoyed for decades to come, it is reasonable to pass some of the construction costs on to future taxpayers. According to the aforementioned study, countries that debt finance their transit infrastructure tend to produce more kilometers of transit per capita than countries that rely purely on current account funds. The manner in which these costs are financed, however, can have a profound impact on system operating costs. This study that looked at urban transit financing in nine countries \ indicated the following five typical sources of transit financing:

- Bonds;
- Bilateral loans or loans from Export Credit Agencies;
- Multilateral Development Bank (MDB) loans;
- Commercial loans;
- National Government and National Development Bank loans.

These different sources of financing sometimes are not equally available to all transit modes.

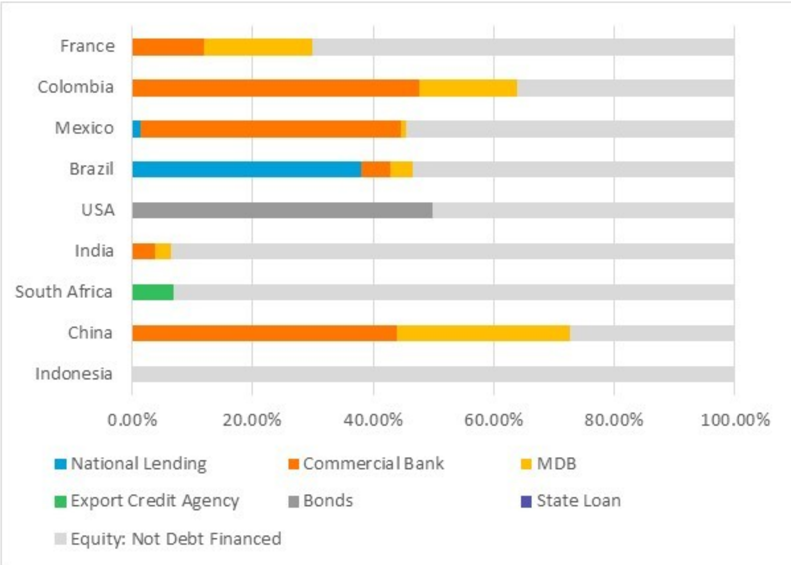

Figure 2.4. BRT debt finance by country and source. *ITDP.*

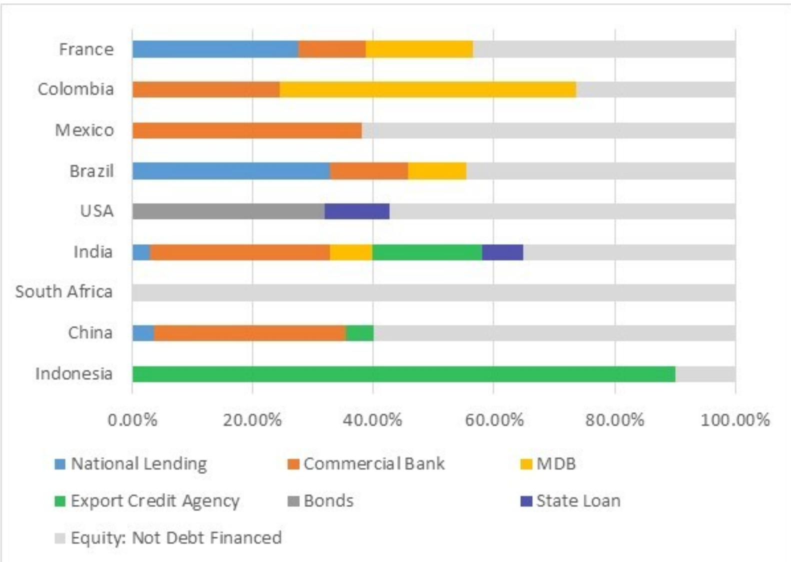

Figure 2.5. Fig 2.5 Rail transit debt finance by country and source. *ITDP.*

Projects financed by commercial loans, the multilateral development banks, or the sale of municipal bonds tend to be mode neutral. Of these, commercial loans are the most expensive, municipal bonds are lower in cost, and loans from the multilateral development banks tend to be the lowest cost of capital. BRT, LRT, and HRT projects have all been financed by commercial loans, MDBs, and municipal bonds, with no clear pattern of mode-specific bias observable.

The export credit agencies, by contrast, tend to provide credit only for modes tied to commercial interests from their country, but they offer very low interest rates that can fundamentally change comparative project costs. The Jakarta Metro, for instance, is being financed by a loan from JICA (Japanese International Cooperation Agency) at 0.2 percent interest, which is a negative capital cost (below the cost of capital). This helps support the Japanese rail manufacturing industry. The export credit agencies of the Nordic countries where Volvo and Scania, major bus manufacturers, are housed have also played a role in lowering the cost of bus procurement in BRT projects in Latin America and South Africa. In addition, the Spanish export credit agency financed the purchase of Spanish electric trolleybuses for the first BRT line in Quito. While export credit agencies subsidize both bus and rail projects, there is greater foreign government interest in selling rail technology, and larger sums involved, which frequently results in lower cost financing from export credit agencies available for rail projects than is generally available for BRT projects.

National development banks can also play key roles in determining the cost of different projects. In Brazil, credit from BNDES is considerably lower in cost than commercial credit, giving BNDES enormous influence over modal selection in Brazilian municipalities. BNDES has funded both rail and BRT projects, but a lot more funding has been directed to rail projects overall.

Ideally, state and national government grant programs for urban rapid transit should be based on mode-neutral selection criteria, as should the funding and financing criteria of the development banks and export credit agencies.

2.3 Planning and Development

> *"Plan for what is difficult while it is easy, do what is great while it is small. The difficult things in this world must be done while they are easy, the greatest things in the world must be done while they are still small. For this reason sages never do what is great, and this is why they achieve greatness."*
>
> — Sun Tzu, Military strategist, 544–496 BC

The window of opportunity for implementing new public transport is sometimes quite limited. The terms in office of key political champions are generally only three to five years. If implementation is not initiated during that period, the following administration may well decide not to continue the project. In some instances the project may be cancelled just because the new administration does not want to implement someone else's idea, regardless of the merits of the particular project. A longer planning and development period also means that a host of other special interest groups will have more opportunity to delay or obstruct the process. Ideally, a public transport project can be planned and implemented within a single political term. This short time span may provide an additional incentive to a potential project champion, as it provides the opportunity to finish the project in time to reap the political rewards; BRT's recent popularity in part is this condensed project timetable.

2.3.1 Implementation Speed

A BRT can be designed and implemented within an extremely short time frame. A few very good projects around the world, like the Guangzhou BRT and Bogotá's TransMilenio, went from a firm political commitment to implementation within eighteen months. A more reasonable time horizon is three to four years, as was the case for the Pittsburgh South Busway BRT and the Los Angeles Orange Line BRT. In many cities around the world, a major selling point for BRT is that mayors or governors are able to get the projects built and operational within a single term of office, as happened in Bogotá during the 1998–2001 term of Mayor Enrique Peñalosa.

LRT projects tend to have much longer time horizons. This means that one politician might make a promise to build LRT, only to have it realized by yet another politician years into the future. It also means that the public transport and land use benefits can be felt much more quickly with BRT than with rail-based modes. Planning a more-complex rail project can typically consume three to five years of time (Figure 2.7), and construction can also take an additional three to five years to compete, as the examples of the Bangkok SkyTrain and the Delhi Metro show.

Figure 2.6. An initial BRT corridor may take 12 to 24 months to construct (photo shows Yichang BRT corridor construction. *ITDP*

Figure 2.7. A typical underground or elevated rail system will require from three to ten years (photo shows the construction of the Luz train station in São Paulo). *Karl Fjellstrom, ITDP.*

Obtaining the project financing can be another significant time delay. Most rail projects have much higher capital costs, and thus require additional time to identify funding sources and negotiate the terms with other levels of government and financial institutions. BRT projects, due to their lower capital costs, can more often be financed largely by the municipality, with less need to involve other levels of government or protracted negotiations with financial institutions.

2.3.2 Scalability

Transit projects have to be built in minimum operational segments. BRT provides much greater flexibility in terms of phasing construction to accommodate the project budget size. A city can build high-quality BRT along just a segment of an existing bus route where the BRT infrastructure is most needed, then extend this BRT infrastructure farther along the corridor as money becomes available and the need for these measures increases. In other words, a BRT can run bus services in mixed traffic, and only use BRT infrastructure for the short segment where the bus route faces the worst traffic congestion or the greatest boarding and alighting delays, usually in a downtown area.

Figure 2.8. The proposed US$7.5 billion Metro line 1 in Bogotá, which would be completed by 2021, or over the course of twenty years. *ITDP using Mapbox.*

With LRT or HRT, operating a very short segment first rarely makes economic sense. A very short LRT or HRT can only operate where there are tracks and stations. Hence, short operational links in an LRT or HRT will force most passengers to make transfers both to reach the LRT/HRT and to continue from the end of the new LRT/HRT line to their destination.

Public transport systems with higher construction and operating costs need high passenger numbers to financially sustain them. For the same reasons, such systems may necessitate a larger network in order to operate effectively. Therefore, the faster you can build a larger network, the sooner the system will be able to recover a reasonable share of its operating costs. With its shorter implementation time and lower capital costs, BRT can be built into a network more quickly.

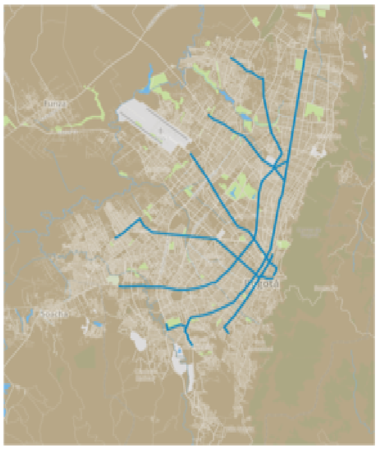

Figure 2.9. Fig 2.9 The US$3.1 billion TransMilenio system currently carries nearly two million passengers per day. The majority of passengers use Phase I of TransMilenio, which was implemented by the Peñalosa administration in less than three years. *ITDP using Mapbox.*

There are also economies of scale in production of transit infrastructure. A city that has a large rail transit network can generally better afford the sophisticated equipment needed to build and maintain such systems than a city with only one LRT or HRT line. For BRT, however, since construction techniques for BRT are not so different from normal roadway construction, the required economies of scale are far less acute than those for other types of systems. BRT has been developed in cities with populations of 200,000 to megacities with more than 10 million inhabitants. Even relatively small system additions can be economically accommodated by BRT. Thus, BRT allows cities to have a public transport system that grows and evolves in close concert with the demographic and urban form changes that occur naturally in a city.

2.3.3 System Flexibility

Modern modelling and planning practices have greatly aided the objective of matching public transport design to passenger needs. Unfortunately, even the best-crafted plans cannot account for all eventualities. Customer preferences can be difficult to know with absolute certainty. The nature of a city's urban form and demographics can change as social and economic conditions change. Thus, it is always preferable to have a public transport system that can grow and change with a city.

During the start-up phase of a new system, passenger reactions and preferences are usually different to some degree than the original predictions indicated from modelling exercises. Demand in one area may exceed or fall short of expectations and require service adjustments. Alternatively, customer demand for express or limited-stop services may be quite different from early projections, or emerge much later in the life of the system. New routes may be added to account for development in a satellite area.

The relative flexibility of BRT means that such changes can often be accommodated at a modest investment in terms of time and money. Changes to the Bogotá TransMilenio system were handled smoothly within the first weeks of opening. By contrast, routing and service changes to rail-based systems are much more complicated and expensive, as new tracks, crossovers, and signals must be installed. Thus, rail-based systems require a good deal more certainty in terms of the required demand and service preferences.

In addition to being adaptable to route and demand changes, BRT offers the added flexibility of being able to provide more direct door-to-door service. A BRT vehicle can operate in mixed traffic on normal streets and then enter dedicated BRT infrastructure without forcing passengers to transfer to another vehicle. LRT, by contrast, can only operate where there are rail tracks, and passengers coming from locations not served by the tracks must make longer walks or bicycle rides, transfer to and from buses, or utilize space-consuming park-and-ride lots in order to use the system. A transfer can pose significant delays and inconvenience to passengers and is sometimes enough to turn people away from mass transit.

It is also easier to introduce express and limited-stop services into BRT systems, since an express bus simply needs a passing lane at stations or the ability to pass in a regular traffic lane at stations, whereas rail-based transit systems essentially require double-tracking throughout for express services. At an average cost of US$41 million per mile, double-tracking rail is generally prohibitively expensive. Often, a conventional bus route ends up serving a limited- or express-stop service parallel to light-rail but without the benefits of the LRT infrastructure. Express services are one of the most important ways to increase bus speeds. It was the introduction of a large number of express services to Bogotá's TransMilenio that resulted in that system's high average speeds and capacities.

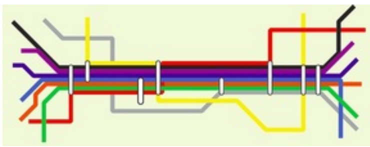

Figure 2.10. This diagram of direct services shows how multiple routes that operate along a single corridor can go to different destinations, reducing door-to-door travel times. *ITDP.*

2.3.4 Phasing

Because buses can operate both in and out of the BRT corridor, it is much easier to implement and expand BRT systems in phases, with less disruption to existing transit routes. Implementation of LRT, on the other hand, requires extensive service changes along a corridor. Existing bus routes must either stop at the LRT corridor, requiring an additional transfer, or operate parallel to the LRT without benefiting from the new infrastructure. Each expansion of the LRT infrastructure requires similar service changes. As a result, LRT systems are typically only implemented in large contiguous segments, in order to avoid multiple disruptive service changes. This reduced ability to phase system construction limits the flexibility of implementation.

2.4 Performance

> *"It is not the strongest of the species that survive, not the most intelligent, but the one most responsive to change."*
>
> — Charles Darwin, scientist, 1809–1882

A system's performance characteristics will play a large role in determining customer-usage levels. The ability of a system to attract ridership is thus a prime decision-making determinant in selecting a public transport technology.

2.4.1 System Capacity

The ability to move large numbers of passengers is a basic requirement for rapid transit systems. This characteristic is particularly important in cities in lower income nations where mode shares for public transit can exceed 70 percent of all trips. Passenger capacity is usually defined in terms of the maximum number of passengers in the peak hour that can use a particular rapid transit corridor on the most congested section (or "link") in the peak direction, or *pphpd*.

"Design" capacity assumes both a comfortable level of crowding inside the transit vehicle and a reasonable speed, which is usually defined as free flow traffic running speeds on the corridor.

The design capacity of a transit corridor is generally set based on the amount of passengers per hour per direction that either the most congested station can handle, or the most heavily used intersection, depending on where the bottleneck lies.

In BRT systems, capacity is, except in irregular circumstances, limited by the station. The typical limit on capacity is that too many buses with too many boarding and alighting passengers try to use a single station. If the next bus comes before the first bus has finished the boarding and alighting process, the next bus has to wait to enter the station, and a bus queue quickly develops. Intersections rarely represent the capacity constraint on a BRT system because many buses can queue at a traffic light like any other form of traffic, and there are only very rare instances where the bus volumes are so high they cannot clear a traffic light in a single signal phase. As such, in Chapter 7: System Speed and Capacity, the BRT capacity calculations are made based only on the capacity of the bottleneck station. Chapter 7 provides the calculations necessary to calculate the design capacity at a reasonable speed for BRT systems. Chapter 7 of this guide differs in some minor respects from the Bus chapter of the *Transit Capacity and Quality of Service Manual*, in ways that will be explained in the following text.

In rail systems it is more likely that capacity is set by some other bottleneck in the system, such as the intersection signal phase, the station platform length, insufficient number of vehicles, the signaling system, and so on. Therefore, the capacity calculation methodology in Chapter 7 does not work well for estimating the capacity of an LRT or HRT system, where there is a greater likelihood that the capacity constraint will lie elsewhere. The *TCQSM* considers not only the station capacity, it also considers other issues such as the traffic signal green time at the intersection with the longest signal phase, and operational control issues that can limit headway reductions. Therefore, for LRT and HRT system capacity estimation, we recommend following the guidance of the *TCQSM* (http://www.trb.org/Main/Blurbs/169437.aspx).

Many measures that are important to speed are not important to capacity. Exclusivity of the right-of-way, for instance, will affect system speeds but will not necessarily affect system capacity. Similarly, the number of station stops will significantly affect the speed of a transit system but not the capacity, as capacity is determined by the number of passengers that can pass through the bottleneck station at the peak hour. Restricting turning movements across the transitway is also critical to speed, but less critical to capacity.

For all transit systems, the same basic issues, discussed below, affect system capacity. Different system elements affect LRT, BRT, and HRT systems somewhat differently. It is these differences that determine the capacity differences between the three modes.

Vehicle Size and the Number of Doors

A transit station saturates and becomes the system bottleneck when the transit vehicles occupy the station more than 40 percent of the time. It is above 40 percent when queuing of transit vehicles occurs at the station. The faster passengers can board and alight, the more vehicles that can use a single station. The longer the vehicle, and the more doors that the vehicle has which passengers can board and alight through simultaneously, the more capacity that bottleneck station will have. A very long vehicle with only one or two doors will have no higher capacity than a much smaller vehicle because passengers tend to cluster around the doors. In TransJakarta, for instance, standard 12-meter buses were used that should have had a capacity of 90 passengers per bus, but because there was only one door, the buses operated at only about half capacity (45 passengers per bus). If passengers are only allowed to enter through the front door, because they need to pay the driver or for some other reason, then the capacity of the vehicle will be that of a much smaller vehicle with only one door. If the width of the door is less than one meter, the capacity is also compromised. As a result, all transit systems can carry more passengers if they have larger vehicles with multiple doors of 1 meter width or greater.

In general, the possibility exists of using larger vehicles with more doors in LRT systems and HRT systems than in BRT systems, though in most operational conditions this distinction does not matter for reasons that will be explained.

Table 2.5. Table 2.5 Standard Vehicle Types and Capacities

Vehicle Types	Vehicle Length	Doors	Vehicle Capacities
Heavy Rail Large 8 car train	176	24	1408
Heavy Rail Small 6 car train	90	18	720
Heavy Rail Car Large	22	3	176
Heavy Rail Car Small	15	3	120
LRT Siemens Avino 8 module	79	10	632
LRT Alstom Citadis Large	49	8	392
LRT Siemens S70 Large	36	4	288
LRT Alstom Citadis Small	29	4	232
LRT Siemens small	28	4	224
BRT Largest Bi-articulated	25	5	220
BRT Volvo Bi-Articulated	22	5	190
BRT Articulated	18	4	150
BRT Standard	12	2	90

The typical long HRT vehicle will have three doors per car and eight cars, so twenty-four doors, though eighteen doors or even fewer is also common. The longest LRT vehicles will have as many as ten doors, though most commonly LRT vehicles have four functional doors. The longest BRT biarticulated vehicles have five doors, but most BRTs use articulated buses with four doors, though some only have three, and 12-meter buses with two doors are also common.

The highest capacity transit vehicles have a door greater than 1 meter wide for every 5 meters of vehicle length.

For estimating the capacity of LRT vehicles, the *TCSQM* recommends:

> *"When the specific vehicle type has not yet been selected (e.g., when planning a new rail system), vehicle length can be used as a proxy for the passenger capacity of a rail car. Passenger loadings for typical North American light rail cars range from 1.5 to 2.4 passengers per foot of car length (5.0 to 8.0 p/m length). The lower level of 1.5 passengers per foot length (5.0 p/m length)-with a standing space per passenger of 4.3 ft^2 (0.4 m^2)-corresponds to a standing load without body contact, while the upper level provides 3.2 ft2 (0.3 m^2), corresponding to a standing load with some body contact."*
>
> — TCSQM, p. 8-66

> *"For heavy rail, the 75-ft (23-m) cars used in more than twelve U.S. and Canadian cities range from 2.1 to 3.5 passengers per foot of car length (7.0 to 11.5 p/m of car length). The higher end of this range approaches crush-loaded conditions."*
>
> *— continued*

> *"A reduction by 0.3 p/ft length (1.0 p/m length) should be used for smaller, narrower cars (1)."*
>
> *— continued*

Table 2.5 uses eight passengers per meter of length to estimate the passenger capacity of a rail car.

The metro systems with the longest trains have eight-car trains, with six being more typical (for BRT systems, then, this guide uses $(L-3)*10$, or 10 passengers per meter, within the range of the TCSQM recommendation discounted by the 3 meters needed for the driver). These vehicles can all carry more passengers but they would be at crush loads and above the design capacity.

Where there are no cross streets to contend with, there is no definite limit on the length of the vehicle other than the platform length. Theoretically HRT systems can be built with ever-longer station platforms but there is rarely the demand to justify it.

For LRT systems, the definite limit on the length of an LRT vehicle is the commercial availability of vehicles, the distance between perpendicular streets (as the LRT vehicle cannot obstruct an intersection when stopped), and the required turning radius. Some more popular LRT vehicles are the Alstom Citadis, which range from 29 to 49 meters in length, the Siemens S70, which varies in length from 28 to 36 meters, and the 8 module Siemens Avino, which is 79 meters in length. All of them are between 2.4 and 2.6 meters in width. Many cities, such as New York City and Portland, Oregon, have block lengths of 61 meters (200 feet) or shorter in most of downtown, and with approaches to the station a maximum vehicle length would be less than 49 meters.

For BRT systems, the length of the vehicle is limited to the current technical capacity of a bus: the biarticulated bus that accommodates 220 passengers is a reasonable upward limit on BRT vehicle size.

Therefore, the capacity of LRT and HRT vehicles is larger than for BRT vehicles. As will be shown, however, this does not mean that LRT and HRT systems necessarily have higher capacity.

The Number of Bus Lanes or Rail Tracks

Most HRT, BRT, or LRT systems have only one bus lane or one set of rail tracks in each direction. A few LRT systems have one track shared in both directions for limited segments. This single lane puts significant constraints on the capacity of any system. When these systems get overcrowded, it is sometimes necessary to add a second lane. Double tracking or adding another lane in each direction makes possible more than doubling of capacity because it also makes possible the introduction of higher speed express services that do not stop at all stops.

Because it is generally cumbersome and slow to have trains switch tracks, the introduction of express services in HRT or LRT systems usually requires double tracking for the entire express portion of the service. All of the highest capacity HRT systems are quadruple tracked (two tracks in each direction). Quadruple tracking is little used in LRT systems except in short sections.

BRT systems have the advantage over HRT and LRT systems in that they do not need two full traffic lanes across the entire length of their corridor: they only need double lanes per direction at station stops. Two lanes at station stops allow express bus services to use the busways without getting caught behind local bus services at station stops. In addition, this allows one bus to pull around another bus in front of it that faces a delay due to boarding and alighting passengers. Because there are no tracks involved, no switches are required for one bus to pass another bus. As such, the right-of-way needed for two lanes is only required at station stops and not throughout the entire corridor. If stations are placed mid-block rather than at intersections, the passing lane of the busway can give way to additional mixed traffic turning lanes at the intersection.

Boarding and Alighting Time

Most of the elements that BRT borrowed from HRT and LRT systems, such as off-board fare collection, platform-level boarding, and simultaneous boarding through multiple wide doors, all reduce the amount of boarding and alighting delay at stations. In most systems, the bottleneck is a single station where high volumes of passengers consume a lot of time boarding and alighting, saturating the station. Hence, reducing the time it takes each passenger to board and alight at the bottleneck station is the most important thing to consider when trying to increase a system's capacity.

This boarding and alighting time is sometimes called *variable dwell time*, as it will vary a lot in a corridor from one station to the next depending on the number of boarding and alighting passengers per station. Regardless of whether the system is an HRT, LRT, or BRT, for systems with the same design features, a system with very even distribution of boarding and alighting along it will achieve a much higher capacity than a system where boarding and alighting is heavily concentrated at a few stations.

The lower the boarding and alighting delay at stations, the less likely the bottleneck station will saturate, so the greater the capacity of the system.

There is no inherent advantage between BRT, LRT, or HRT for these measures: they can equally be applied to any of these modes.

Table 2.6. Variable Dwell Times

Mode	Seconds per passenger per door
HRT & LRT Alighting at level	1.39 - 2.0
HRT & LRT Alighting with Steps	3.36 - 3.97
HRT & LRT Boarding at level	1.11 - 2.61
HRT & LRT Boarding with Steps	2.91 - 4.21
BRT Boarding TransMilenio	1.2
Standard at - level BRT boarding	1.6

Source: *TCQSM*, 3rd Edition, pp. 8–25, BRT Planning Guide

BRT systems, LRT systems, and HRT systems have very similar boarding and alighting times per passenger per door when they have a similar interface between the station and the vehicle. Therefore, in addition to the critical importance of having vehicles with more doors, as was discussed in the previous section, it is critical that payment takes place off-board so that boarding and alighting can take place through all doors simultaneously, and measures such as at-level boarding be implemented to reduce the amount of boarding and alighting time per passenger per door.

The Number of Substations and Docking Bays

In any rapid transit system, there may be one or more docking bays and one or more substations. If a station can accommodate two vehicles at the same time that do not need to pass each other, these are considered two *docking bays* (they are referred to as "*loading areas"* in the *TCQSM*). Having more than one docking bay in a single-track rapid transit station can help increase capacity somewhat as passengers can get on and off more than one vehicle at once, but there is a diminishing return after two docking bays, as a delay in boarding and alighting at the second docking bay will obstruct access to the first docking bay.

Sub-stops are specific to BRT systems. Sub-stops are docking bays in BRT stations with passing lanes where the docking bays are far enough apart that one bus can pull around the bus at a docking bay in front of it. Because buses, unlike trains, can easily pass one another, so long as there is a passing lane and the docking bays are far enough apart, a single station might have more than one substation. The largest stations in the largest BRT systems currently have three sub-stops and two docking bays at each sub-stop.

There are two main reasons that the *TCQSM* underestimates the potential capacity of a BRT system. The first is that it does not distinguish between sub-stops and docking bays (see *TCQSM*, Step 6a, Determining the number of effective loading areas, pp. 6–77). As such, it underestimates the possible number of *effective* loading areas. Though the *TCQSM* considers the possibility of five loading areas at a single stop, and estimates that on average about 190 buses can be accommodated before stations saturate if dwell times are 30 seconds or less (http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_165ch-06.pdf, p. 6.21), it rightly points out that at most three of them are effective because at some point a delay in boarding and alighting in the rearmost docking bay will block access to all of the remaining docking bays in front of it. This guide includes the possibility that, with passing lanes, six docking bays can be made effective. Chapter 7 of this guide thus provides capacity calculation and station saturation formulas that accept the possibility of up to six effective loading areas, if there are at least three sub-stops with two docking bays each, based on empirical observation of stations in Latin America.

Figure 2.11. Rea Vaya in Johannesburg has two sub-stops, each with two docking bays, or the equivalent of four fully effective "loading bays," able to board and alight passengers from sixteen doors simultaneously, something not considered in the TCQSM. *ITDP.*

By having three sub-stops, each with two docking bays, or six effective loading areas, the number of doors per station stop that passengers will be able to board and alight from simultaneously increases. If a system were designed with six docking bays, and each docking bay were designed to accommodate biarticulated five-door buses, each station could theoretically board and alight passengers from thirty doors simultaneously—more than the largest metro trains. This possibility, not considered in the *TCQSM*, is why state-of-the-art BRT systems with passing lanes are reaching design capacities equivalent to those observed in multicar rail systems.

Because LRT and HRT systems cannot pass one another quickly on the same track, sub-stops are not used in LRT or HRT systems. Because sub-stops are not relevant to rail systems, the capacity of a rail system is limited to the capacity of the vehicle, the number of functional doors, and the achievable headway, unless fully double-tracked.

Services with Limited-Stop Options

If rapid transit infrastructure has been designed with two sets of tracks per direction (in the case of HRT or LRT) or with passing lanes and sub-stops at stations (in the case of BRT systems), then additional services that skip stops can be added. They can be added, however, at any time so long as the infrastructure to accommodate them has been built.

These limited-stop services increase the system's capacity mainly because the demand on the corridor can be divided into multiple services, some of which bypass all together the bottleneck station. Because the capacity of a BRT system is limited by the critical bottleneck station, having all the buses stop at that station is not always a good idea. Often, some portion of the demand can be well served by services that bypass the bottleneck station. Detailed service planning calculations, as provided in Chapter 6, would need to be made in order to determine the optimal service patterns. The greater the number of limited-stop services that are able to bypass the bottleneck station, the greater the capacity of that station, because the additional dwell time for the share of the demand bypassing the station is zero. The enormous flexibility in providing limited-stop services for BRT systems with passing lanes and sub-stops is the other factor not measured in the *TCQSM*, and another reason why it underestimates the potential capacity of Gold Standard BRT systems.

Intersections

While HRT does not have to contend with intersections, both BRT and LRT systems have to accommodate perpendicular travel across them. Both BRT and LRT require similar measures to minimize the risk that intersections become a capacity constraint and source of delay.

There are two primary capacity constraints that intersections pose: station/signal interference, and signal phase limitations on headways. The first, station/signal interference, applies to both BRT and LRT systems. The second, signal phase limitations on headways, only affects LRT systems.

Station/signal interference is when a transit vehicle at a station is unable to clear the station because it is blocked by a red traffic signal, or when a transit vehicle cannot enter an unoccupied station because of a red traffic signal. This problem can occur regardless of whether the station is placed before or after the traffic signal.

Boarding and alighting times are irregular, whereas signal phases are constant. If a boarding and alighting process takes longer than normal, and the station is immediately adjacent to the traffic signal, by the time the boarding and alighting process is completed, the signal may have changed to red, and the transit vehicle will be unable to clear the intersection. This then obstructs access to the transit station for the vehicles behind it. This problem is best avoided in the case of both BRT and LRT systems by separating the bus stop from the intersection by several vehicle lengths (*The BRT Standard*, http://brtstandard.org , p. 34). The greater the frequency, the more vehicle lengths that will be necessary. In the case of close downtown streets, it may be necessary to eliminate intersections all together, as was done on Caracas Avenue in downtown Bogotá.

As demand grows to ranges where capacity is being reached, the risk, for both BRT and LRT, of there being interference between the signal phase and the boarding and alighting process grows. The longer an LRT vehicle, the more doors in which to minimize dwell times from boarding and alighting, but at the same time, there is less space to separate the transit stop from the intersection so that two vehicles can clear an intersection in a signal phase if necessary. Similarly, in BRT systems, the greater the frequency of buses, the longer the distance needed between the intersection and the station.

Station/intersection interference can significantly reduce the capacity of either a BRT or LRT system. So long as this issue is addressed in the design, large numbers of buses can easily pass through a single green signal phase of any standard length at any intersection. As such, the capacity calculations for BRT systems in Chapter 7 do not consider intersections as the critical bottleneck.

For LRT systems, however, the length of the full signal phase at an intersection is also a capacity constraint. This is because train sets require much longer minimum headways between them. The rule of thumb for minimum sustainable headways in LRT systems is one train per traffic signal cycle if the right-of-way is fully protected from encroachment from turning vehicles of mixed traffic, and there is no interference between the boarding and alighting process and the signal phase. However, these conditions are rarely fully achieved in most LRT systems. For this reason, *TCQSM* states the following:

> *"Therefore, a common rule of thumb is that the minimum sustainable headway is double the longest traffic signal cycle on the on-street portions of the line."*
>
> — TCQSM pp. 8–57

As this problem does not manifest itself in BRT systems, they are not considered in Chapter 7. For this reason, the *TCQSM* is a better manual for calculating the likely capacity of an LRT system. It should be emphasized, however, that the potential capacity of LRT systems in the *TCQSM* may still be exaggerated as there are no street-level LRT systems with capacities of over 6,000 upon which to base formulas for calculating the capacity of an LRT.

Both BRT and LRT generally benefit from shorter signal phases, but for LRT systems shorter signal phases are critical to achieving higher capacity, as the signal phase is likely to be the bottleneck. It is fairly typical in lower income countries for signal phases to extend upward of four minutes, and traffic police are notoriously resistant to shortening signal phases. If an LRT is introduced into a corridor with a four-minute signal phase, the minimum achievable headway in most typical operational conditions will be eight minutes. In higher income countries, it is more typical that signal phases on a rapid transit corridor are kept to a maximum of two minutes. This means that for LRT, a reasonable estimate of the minimum headway is likely to be four minutes, or fifteen train sets per hour.

Comparative Capacities

There are two ways of comparing the capacity of HRT, LRT, and BRT:

1. Theoretical capacity, based on reasonable expectations given corridor conditions at reasonable minimum speeds (free flow speeds in mixed traffic lanes as an upward limit), with reasonable occupancy levels (no crush loads);
2. Observed capacities.

Both have their advantages and disadvantages. Theoretical values can, of course, make false assumptions. Observed values often fail to take into consideration that a system may be operating at below optimal speeds or with passenger overcrowding or with demand below capacity. Thus, observed capacities may be greater than design capacity, or below design capacity as is often the case in the United States, or they could face constraints unanticipated by theoretical design capacity calculations, like a demand profile with heavy boarding and alighting concentrated at a few critical stops.

Table 2.7. Table 2.7 Theoretical Capacities of Different Rapid Transit Alternatives

	Vehicle capacity	Load Factor	Frequency	Capacity
HRT 8 car single track, best signaling system	1408	0.85	30	35904
HRT 8 car double track	1408	0.85	60	71808
LRT 8 module, no turning restrictions, 2-minute signal	632	0.85	15	8058
LRT 8 module, no turns allowed, 90 second signal*	632	0.85	20	10744
LRT 8 module double track	632	0.85	40	21488
BRT largest bi-articulated	220	0.85	60	11220
BRT with passing lanes	220	0.85	193	36000
BRT with passing lanes & limited stops bypassing bottleneck station	220	0.85	241	45000

*TCQSM 3rd Edition p 8-87 provides 20 as the number of trains that can be processed at grade with a 90 second signal. They reach a capacity of 12,000 pphpd by assuming trains with larger capacity than is commercially available or operable in most on-street contexts.

The theoretical values used above are illustrative only, and local circumstances will cause significant deviations from these values.

In Table 2.7, the vehicle capacities are based on existing commercial vehicles operated in fairly typical conditions without crush loads. The longest HRT trains are 176 meters with 8-car trains. At 8 passengers per meter of length, this is 1,408 passengers per train. The longest LRT vehicles are 8 modules and 79 meters long, and have a capacity of about 632 passengers per train. This is longer than is possible to operate in many cities like New York and Portland, which have block lengths of 61 meters. The longest biarticulated BRT vehicles in North America are 25 meters and have a capacity of about 220 passengers per bus without overcrowding.

The frequency of HRT systems was set based on the *TCQSM* recommendation that no more than thirty trains per hour are possible even in fully grade-separated systems with state-of-the-art signaling systems due to extended dwell times at high-demand stations. It reads:

> *"It is apparent from the observed operating experience in New York and Washington that higher dwell times at critical stations prevent the achieving of capacities significantly greater than 30 trains per hour"*
>
> — TCQSM, pp. 8–83

The frequency of LRT systems is similarly set by *TCQSM* guidelines for on-street systems, which recommends that twenty train sets per hour is the maximum achievable frequency for systems with a signal phase maximum of ninety seconds.

The achievable frequency of BRT systems is set based on observations in high-demand systems in Latin America. As four or more buses can easily pass through a single signal phase, the intersection is rarely the constraint. Until the introduction of off-board fare collection, at-level boarding, simultaneous multiple door boarding, and biarticulated buses into Curitiba's busway, it was thought that busways could only operate in a range up to about 5,000 pphpd at speeds around 20 kilometers per hour. It was only with the simultaneous introduction of all these measures in Curitiba that capacities approaching 12,000 pphpd were reached with busways, and BRT was born. Even with these measures, however, as demand rises upward of 8,000 pphpd, there are usually a few critical stations that will bottleneck in most real-world conditions. Using bus platooning, where three articulated buses were timed to approach and depart from station stops nearly simultaneously, mimicking a longer vehicle, capacities of around 16,000 pphpd were briefly achieved, but this proved hard to sustain as it required sophisticated operational controls and driver training.

It was only with the introduction of passing lanes on the Santa Amaro Corridor in São Paulo, and later with TransMilenio's passing lanes and sub-stops in Bogotá, combined with the use of multiple limited-stop services in the corridor, that transit engineers were able to reach capacities that compete with HRT systems and significantly surpass LRT systems. Bogotá's BRT system, with a specific mix of multiple limited-stop services, passing lanes at stations, and multiple sub-stops, was designed to accommodate 36,000 pphpd, the current record. It is believed that once the TransBrasil BRT system in Rio de Janeiro opens (projected for 2018), that design capacities of over 45,000 will be achieved, due to limited intersections and a unique demand profile, which allows for an unprecedented majority of services to run very limited stops.

Table 2.8. Passengers per Hour per Peak Direction Observed: BRT

Corridor	Type	Daily Weekday Ridership	PPHPD	Level	Tracks/ Lanes	Source
BRT						
Bogotá	BRT	1200000	37,700	Surface	2	#
Guangzhou	BRT	850000	27,400	Surface	2	#
Brisbane	BRT		19,900	Surface	2	@
Istanbul	BRT	600000	18,900	Highway	1	#
Porto Alegre	BRT		15,800	Surface	2	@

Guayaquil, EC	BRT		15,000	Surface	2	@
Rio de Janeiro TransOeste	BRT		14,000	surface	2	@
Lima	BRT	350000	13,950	Highway	2	#
Guatemala City, Eje Sur	BRT		13,500	Surface	2	@
Curitiba- Eixo Sul	BRT		12,500	Surface	1	@
Quito	BRT		11,700	Surface	2	@
Cali	BRT		11,100	Surface	2	#
Ottawa West Transitway	BRT		10,000	Surface	1	@
Merida	BRT		9,000	Surface	2	@
Guadalajara	BRT		9,000	Surface	1	@
Xiamen	BRT		8,360	Elevated	1	#
Brisbane	BRT		7,700	Surface	2	#
Mexico City	BRT		7,550	Surface	1	#
Zhengzhou	BRT		7,230	Surface	1	#
Urumqi	BRT		6,230	Surface	1	#
Chengdu	BRT		6,650	Elevated	1	#
Lanzhou	BRT	290000	6,550	Surface	2	#
Dalian	BRT		6,430	Surface	1	#
Hangzhou	BRT		6,300	Surface	1	#
São Paulo - Espresso Tiradentes	BRT		6,100	Elevated	1	@
Quito	BRT		6,000	Surface	1.5	#
Baranquilla	BRT		5,900	Surface	2	@
Delhi	BRT		5,500	Surface	2	@
Johannesburg	BRT		4,510	Surface	2	#
Bucaramanga, Co	BRT		4,525	Surface	1	@
TransSantiago	BRT		4,400	Surface	1	@
Pereira, Co	BRT		4,073	Surace	1	@
Hefei	BRT		3,600	Surface	1	#
Yinchuan	BRT		3,600	Surface	1	#
Buenos Aires Juan B. Justo	BRT		3,450	Surface	1	@
Jakarta	BRT		3,400	Surface	1	#
Paris Val de Marn	BRT		3,000	Surface	1	@
Beijing	BRT		2,750	Surface	1	#
Changzhou	BRT		2,650	Surface	1	#
Medellin, CO	BRT		2,450	Surface	1	@
Los Angeles Orange Line	BRT	33,000	2,357	Surface	2	*
Jinan	BRT		2,050	Surface	1	#

Nantes, France	BRT		2,000	Surface	1	@
Leon, MX	BRT		1,950	Surface	1	#
Ahmedabad	BRT		1,780	Surface	1	@
Pittsburgh Martin Luther King, Jr. East Busway	BRT	24,000	1,714	Surface	2	*
Lianyungang	BRT		1,650	Surface	1	#
Zaozhuang	BRT		1,400	Surface	1	#
Yancheng	BRT		1,300	Surface	1	#
Bangkok	BRT		1,200	Surface	1	#
Nantes	BRT		1,200	Surface	1	#
Las Vegas Strip & Downtown Express (SDX) BRT	BRT	16,789	1,199	Surface	1	*
Cleveland HealthLine BRT	BRT	15,800	1,129	Surface	1	*
Eugene Emerald Express Green Line (EmX) BRT	BRT	10,000	714	Surface	1	*
Pittsburgh South Busway BRT	BRT	9,262	662	Surface	1	*
Pittsburgh West Busway BRT	BRT	8,419	601	Surface	1	*
Las Vegas Metropolitan Area Express (MAX)	BRT	7,400	529	Surface	1	*

Sources:

- + Taken from TCQSM 2nd Ed, Annex. http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp100/part%205.pdf, p. 5 - 123
- * Extrapolated from daily demand collected by ITDP for https://www.itdp.org/more-development-for-your-transit-dollar-an-analysis-of-21-north-american-transit-corridors/ using a ratio of 1/14 derived from TCQSM 2nd Ed data
- # Counted by ITDP China staff, from: http://www.chinabrt.org/en/cities/param-quan.aspx?param=2
- & Taken from TCQSM 2nd Ed. Part 2: Transit in North America, p. 2-13
- @ http://brtdata.org/indicators/corridors/peak_load_corridor_passengers_per_hour_per_direction
- ? BRT Planning Guide, 2007

The other way to compare the relative capacities of BRT, LRT, and HRT systems is to look at observed actual ridership per hour per direction on the highest demand link. The tables above and below are compilations of the most reliable data that the authors could collect.

The observed pphpd on two BRT systems now exceeds 20,000 (Bogotá, Guangzhou).

Table 2.9. Passengers per Hour per Peak Direction Observed: LRT and HRT

Corridor	Type	Daily Weekday Ridership	PPHPD	Level	Tracks/Lanes	Source
LRT						
Tunis- LRT	LRT		13,400	Underground Junctions	1	?
Calgary	LRT	60200	5,900	Surface	1	+
Portland MAX Blue Line LRT	LRT	66,370	4,741	Surface	1	*
Denver Central Corridor LRT	LRT	62,782	4,484	Surface	1	*
Edmonton	LRT	38000	3,800	Surface	1	+
Phoenix Metro LRT	LRT	41,784	2,985	Surface	1	*

Pittsburgh "The T" LRT	LRT	28,232	2,017	Surface	1	*
Toronto Spadina	LRT	40200	2,000	Surface	1	+
Newark	LRT	16900	1,800	Surface	1	+
Sacramento	LRT	29000	1,500	Surface	1	+
Charlotte Lynx LRT	LRT	14,000	1,000	Surface	1	*
Denver Southwest Corridor LRT	LRT	17,746	1,268	Surface	1	*
Seattle South Lake Union (SLU) Street-car	LRT	3,000	214	Surface	1	*
Portland Streetcar	LRT	11,400	814	Surface	1	*
HRT						
Hong Kong- Subway	HRT		84,000	Underground	2	?
São Paulo - Line 1	HRT		60,000	Underground	2	?
NYC Green Lines Combined	HRT		56,100	Underground	2	+
Santiago- La Moneda	HRT		36,000	Underground	1	?
NYC 4,5, express trains	HRT		30,200	Underground	1	+
Toronto Spadina	HRT	614000	26,200	Underground	1	+
Manila- MRT-3	HRT		26,000	Elevated	1	?
NYC 6 train	HRT		25,900	Underground	1	+
London- Victoria Line	HRT		25,000	Underground	1	?
Montreal	HRT	407700	24,400	Underground	1	+
Bangkok- SkyTrain	HRT		22,000	Elevated	1	?
Buenos Aires- Line D	HRT		20,000	Underground	1	?
Newark Path	HRT	126800	17,800	Underground	1	+
Washington DC Red	HRT		12,700	Underground	1	+
Chicago Red	HRT	200200	11,900	Elevated	1	+
San Fran BART	HRT	124300	6,200	Underground	1	+
Atlanta	HRT	117,000	5,100	Underground	1	+

Sources:

- + Taken from TCQSM 2nd Ed, Annex. http://onlinepubs.trb.org/onlinepubs/tcrp/tcrp100/part%205.pdf, p. 5 - 123
- * Extrapolated from daily demand collected by ITDP for https://www.itdp.org/more-development-for-your-transit-dollar-an-analysis-of-21-north-american-transit-corridors/ using a ratio of 1/14 derived from TCQSM 2nd Ed data
- # Counted by ITDP China staff, from: http://www.chinabrt.org/en/cities/param-quan.aspx?param=2
- & Taken from TCQSM 2nd Ed. Part 2: Transit in North America, p. 2-13
- @ http://brtdata.org/indicators/corridors/peak_load_corridor_passengers_per_hour_per_direction
- ? BRT Planning Guide, 2007

In fact, the highest observed capacity on TransMilenio exceeds all but the highest capacity HRT systems, and it far exceeds the highest LRT system. The highest observed capacity BRT systems all have passing lanes at virtually every station. The highest single-lane BRTs and LRTs (Istanbul and Tunis, respectively) both operate on dedicated roads or rights-of-way that overpass or underpass intersections and distances between stations longer than generally recommended for urban areas. The highest capacity single-lane BRT systems (Curitiba, Mexico City) both operate in very congested conditions. Virtually all of the BRT systems with passing lanes have a design capacity much higher than observed capacity.

A number of new BRT systems are now under construction, such as Rio de Janeiro's TransBrasil line, which may break TransMilenio's observed capacity record, mainly because the demand profile calls for a higher percentage of limited-stop services than was appropriate in Bogotá. The Hong Kong and São Paulo metro systems also operate under crush load conditions, so the observed capacity is higher than the theoretical design capacity.

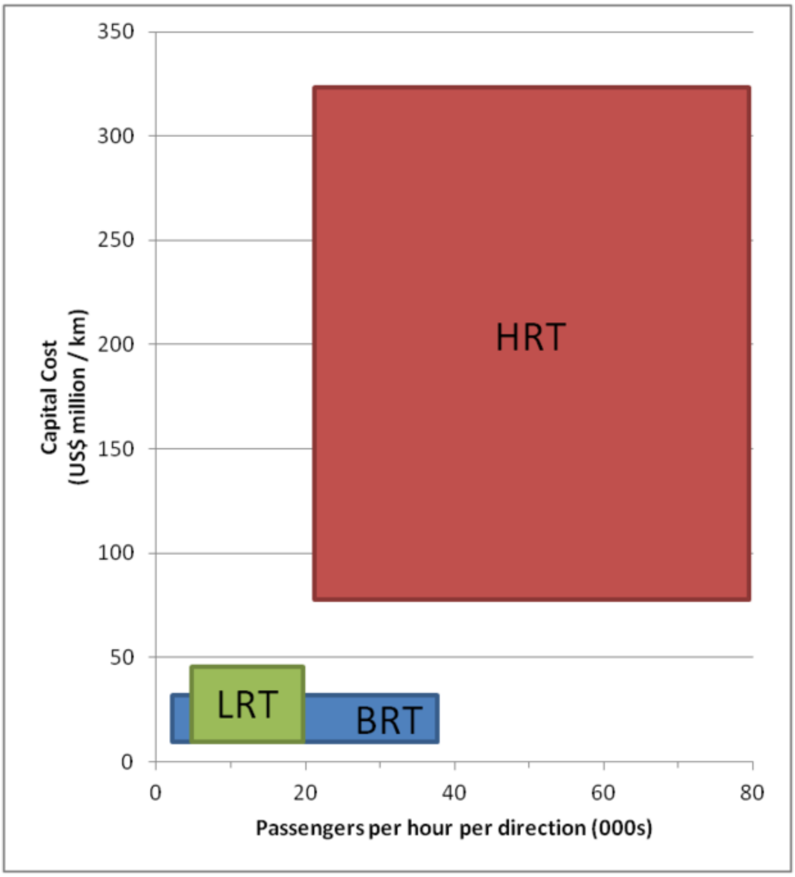

Figure 2.12. Passenger throughputs and capital cost for mass transit options. This figure compares the range of passenger throughputs for each technology measured against the range of capital costs. The ranges presented in Figure 2.12 are based on observed, not theoretical, data (Tables 2.8 and 2.9). *ITDP.*

The different sized areas of the rectangles in Figure 2.12 are also revealing with regard to the relative risk and overall flexibility of each transit technology option. Ideally, a technology will have a small band of possible capital cost levels (y-axis) and a wide band of profitable capacity operations (x-axis). In other words, a system that minimizes costs and maximizes the spectrum of profitable operating conditions provides the most cost-effective and flexible solution. The range of capital costs (y-axis) can also be interpreted as an indication of the potential risk and uncertainty involved in implementing the particular project.

Figure 2.13. The provision of multiple stopping bays and passing lanes at stations permits the Bogotá TransMilenio system to achieve very high passenger capacities. *Carlos Pardo.*

The fact that Bogotá's TransMilenio and Guangzhou's BRT both function well in cities with more than eight million inhabitants, and with population densities of greater than 260 inhabitants per hectare, says much about BRT's potential in other megacities. To achieve these capacities, road space sufficient for passing lanes at stations needs to be provided. This is generally not as difficult politically as it would seem, because if current transit demand on a corridor is high enough to require a BRT with passing lanes to avoid saturating, the existing buses or minibuses are already consuming much of the road reserve and causing traffic congestion, particularly at bus stops. A standard 12-meter (40 foot) bus is generally considered at capacity at around 90 passengers, and if a corridor has 36,000 passengers per direction in the peak hour, that means that 400 buses an hour are already passing one way down that corridor. That 400 buses an hour already consumes more than 2 full lanes of road space, and frequently more at transit stations, so putting these buses onto a BRT system will often help decongest the remaining traffic lanes. This was the case in both Bogotá and Guangzhou.

Systems in cities such as Curitiba, Mexico City, and Quito that utilize just one lane in each direction can reach capacities of approximately 8,000 to 10,000 pphpd before they face crush loads. In general, then, it is reasonable to assume that a BRT or LRT operating on a dedicated single lane will achieve approximately equal capacity levels. For most corridors in most cities, these capacity levels are sufficient to meet the projected demand. Unlike LRT, however, BRT is still a viable option for cities with demand of up to nearly 38,000 pphpd, but only if Bogotá-type passing lanes, sub-stops, and express services are introduced.

Figure 2.14. A typical scene at a Guangzhou bus stop before the implementation of BRT. *Karl Fjellstrom, ITDP.*

Figure 2.15. Capacity limitations are not the reason why cities such as Montpellier (France), prefer LRT over BRT options. The aesthetics are the key. It is therefore important to also focus on the aesthetics of BRT vehicles and stations to be competitive. *UITP.*

2.4.2 System Speeds and Operations

The factors that determine the speed of a BRT, LRT, and HRT system are:

- The distance between station stops;
- The level of encroachment onto the transit-way;
- Boarding and alighting times per passenger;
- Passenger volumes (the more, the slower);
- Transit-way saturation (usually results from design flaws or service planning problems);
- The level of priority at traffic signals;
- The number of limited-stop services.

HRT systems have an inherent advantage in terms of minimizing encroachment onto the transit-way and traffic signal delay, as they are fully grade separated, whether elevated or underground. Elevated or underground BRT systems, or those on highways, enjoy similar advantages.

The other mode-specific way of increasing speeds is through increasing the number of limited-stop services. BRT systems with passing lanes and sub-stops can add limited-stop services of a great variety at any time, while they are largely unknown in LRT systems and need to be built into quadruple track metro systems from inception. While it only occasionally makes sense to add limited-stop services to low-demand corridors, in high-demand corridors limited-stop services are a key competitive advantage of BRT in terms of speed. Some LRT and some single-track BRT systems (Curitiba, for instance) operate express bus services parallel to the BRT in mixed traffic, and at speeds higher than the BRT. One reason that TransMilenio's average speed is 29 kilometers per hour and Curitiba's is 20 kilometers per hour is because TransMilenio services include extensive limited-stop service options, although some speed increases are due to a limited number of intersections with crossing traffic. Pittsburgh's BRT also enjoys high speeds due in part to express services, but the system also benefits from grade separation and large distances between stations.

Other than these two factors, all the other determinants of speed are either pre-determined by the demand characteristics of the corridor, or addressed by the same measures. The number of station stops, the boarding and alighting volumes at each stop, the number of intersections, and the level of priority at these intersections should generally be determined in the same way regardless of whether the rapid transit technology is LRT or BRT. Central median alignment, at-level boarding, off-board fare collection, turning restrictions across the busway, and separation of the station from the intersection will all tend to increase speeds in a similar manner, whether a BRT or an LRT.

In most rapid transit systems, a vehicle's speed alone (maximum speed, rate of acceleration and deceleration) does not matter much, as transit vehicles can usually accelerate and decelerate faster than is comfortable for passengers, and they are normally able to move faster than traffic rules on normal streets would allow.

Table 2.4.2 shows the average speeds of various BRT, LRT, and HRT systems around the world. It is clear from the table that BRT and LRT operate at very similar speeds, and the variance is almost entirely explained by corridor characteristics, with the existence of express services and grade separation in Ottawa, Pittsburgh, and Bogotá giving BRT a slight advantage in a like-to-like comparison.

Table 2.10. Comparative Observed Speeds, BRT, LRT, and HRT

Corridor	Type	Speed (km/hr)	Source
BRT			
Pittsburgh West Busway Pennsylvania,	BRT	54	[ii]
Pittsburgh Martin Luther King, Jr. East Busway	BRT	54	[x]
Pittsburgh South Busway, Pennsylvania,	BRT	54	[iii]
Ottawa Transitway, Canada	BRT	52	[i]
Orange Line, Los Angeles	BRT	32	[v]
Bogotá, Colombia, TransMilenio	BRT	27	[x]
Curitiba, Brazil, Linha Verde	BRT	25	[x]
Beijing (Lines 1, 2, 3, 4)	BRT	24	[iv]
Ahmedabad, India, Janmarg	BRT	24	[x]

Guangzhou, China, GBRT	BRT	23	[x]
Las Vegas Metropolitan Area Express (MAX)	BRT	22	[x]
Curitiba, Brazil, RIT corridors	BRT	18	[x]
Los Angeles OrangeLine	BRT	18	[x]
Cleveland HealthLine	BRT	18	[x]
Mexico City, Mexico, Insurgentes	BRT	17	[x]
Eugene Emerald Express Green Line (EmX)	BRT	17	[x]
LRT			
Sound Transit Central Link, Seattle, Washington, USA	LRT	40	[vi]
Ottawa O-Train	LRT	40	[x]
LYNX Blue Line, Charlotte, North Carolina, USA	LRT	37	[vi]
Portland MAX Blue Line LRT	LRT	30	[x]
Denver Central Corridor LRT	LRT	23	[x]
Denver Southwest Corridor LRT	LRT	23	[x]
Phoenix Metro LRT	LRT	19	[x]
Budapest, Hungary, Grand Boulevard LRT	LRT	18	[x]
Portland Streetcar	LRT	16	[x]
Seattle South Lake Union (SLU) Streetcar	LRT	8	[x]
HRT			
Manila MRT 3 (Metrostar Express), Philippines	HRT	48	[viii]
Expo/Millennium Lines, Vancouver, Canada	HRT	43.5	[vii]
Tren Urbano, San Juan, Puerto Rico	HRT	33.2	[ix]

Sources:

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ii US Department of Transportation. Evaluation of Port Authority of Allegheny County's West Busway Bus Rapid Transit Project. Washington DC, 2003. Report No. FTA-PA-26-7010-03.1 http://www.fta.dot.gov/documents/Pittsburgh_West_Busway_BRT_Evaluation-April_2003.pdf

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iv National BRT Institute. "Perspectives on Bus Rapid Transit (BRT) Developments in China." Presentation. National BRT Institute. May 1, 2006. http://www.nbrti.org/docs/pdf/Darido_ChinaBRT_051106_presentation.pdf

v Flynn, Jennifer, Cheryl Thole, Victoria Perk, Joseph Samus, Caleb Van Nostrand, National Bus Rapid Transit Institute, and Center for Urban Transportation Research. Metro Orange Line BRT Project Evaluation. Vol. 0004. Washington DC: Federal Transit Administration, 2011. http://www.fta.dot.gov/documents/FTA_Research_Report_0004_FINAL_2.pdf

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viii Antiporda, Jefferson. ”DOTC Promises Better MRT Service next Year.” Manila Times, August 15, 2014.http://www.manilatimes.net/dotc-promises-better-mrt-service-next-year/119302/.

ix ”Subways of Puerto Rico.” My Transit Guide. http://mapa-metro.com/en/PuertoRico/SanJuan/SanJuan-Tren-Urbano-map.htm.

x ”More Development for your transit dollar”, 2013 ITDP. https://www.itdp.org/more-development-for-your-transit-dollar-an-analysis-of-21-north-american-transit-corridors/, derived from interviews with transit authority staff.

2.4.3 Reliability

Reliability refers to the level of confidence one has in the public transport system's ability to perform. An unreliable service can create a high degree of personal stress—for instance, if a customer does not know when or if a vehicle is going to arrive at a station. Unreliable services ultimately lead to non-captive users seeking more reliable and predictable travel options, such as private vehicles.

Each type of public transport system has different characteristics with regard to reliability. On-time performance, the frequency of service breakdowns, the rate at which disabled vehicles can be replaced, and the operational responsiveness to changes in demand all affect overall reliability. Metros, LRTs, and BRTs all have excellent records of reliability, particularly when compared to more conventional public transport services. Segregated rights-of-way help better control service frequencies and headways between vehicles, as vehicles are less likely to be stuck in traffic. Systems with complete grade separation, such as underground metros, have a particular advantage in terms of avoiding unforeseen incidents at intersections and general traffic congestion.

The relative flexibility of BRT vehicles to operate inside and outside of the segregated infrastructure allows immediate adjustments to breakdowns. Service can continue while repairs or removals are taking place. The breakdown of a metro or LRT vehicle, however, can require significant additional time for remedial actions. Until the disabled vehicle is cleared from the system, there can be disruption to service and thus to reliability.

2.4.4 Comfort

The level of comfort within a system depends on many design characteristics that are independent of mass transit mode, including station seating and protection from the elements. Underground stations have the advantage of a better natural barrier from outside weather conditions, but many people prefer to stay on the surface and see the city. The interior design of the vehicles is also dependent on design specifications and can be of equal quality for either rail or BRT services.

Ride comfort is one potential area of significant difference between BRT vehicles and rail vehicles. Rail is typically credited with a smoother ride performance both during starts and stops as well as during full operation. A smoother ride better permits value-added activities, such as reading (Figure 2.16). However, not all rail systems provide the same ride quality. The Kuala Lumpur monorail technology actually delivers a somewhat "bumpy" travel experience. Additionally, older tram systems may not provide an entirely smooth ride. Low-floor BRT vehicles can be susceptible to surface imperfections on the busway that will result in a "bumpier" ride. High-floor vehicles with ramped entry service can better mitigate this issue through dampening

Figure 2.16. The smooth ride performance of rail-based systems makes added-value activities, such as reading or studying, easier to undertake. *Lloyd Wright.*

and improved suspension, at the expense of some vehicular capacity. However, in general, the ride smoothness of rail vehicles is superior to that of BRT vehicles.

2.4.5 Image and Status

The perceived image and status of the public transport system plays a role in attracting ridership, particularly from non-captive public transport users who have other alternatives. The best-designed public transport system in the world becomes meaningless if customers do not find the system sufficiently safe and attractive to use.

In most but not all cities, rail-based systems have maintained an edge with regard to creating a modern and sophisticated image, though usually at a significant cost. Such an advantage becomes particularly important when attempting to attract ridership from car users. At the same time, the traditional image of the bus is relatively poor. Attracting middle- and higher-income users to the bus can thus be difficult. Image issues, though, are not entirely restricted to bus technology. Older or poorly maintained rail-based systems may also evoke images that are not entirely favorable to attracting customers (Figures 2.17 and 2.18). In Mexico City, for instance, the surface BRT system is preferred by upper- and middle-income residents to the underground subway system.

Figure 2.17. Rail-based systems do not always offer superior aesthetic qualities like this system in Cairo. *Karl Fjellstrom*

Image is mostly determined by the quality of the stations, and secondarily by the quality and the look and the feel of the vehicles. BRT systems have done much to create a modern and unique identity, mainly by developing stations with architectural merit and by using special buses. The modern tube boarding stations in Curitiba helped make a dramatic new impression for the service. Modern vehicles that cover their wheels and emulate the rounded shape of LRT vehicles also help create a new image (Figure 2.19).

In all countries where BRT has become most accepted to the general public, (Colombia, Mexico), high-quality station design and buses played a key role in convincing the public that BRT was a premium service. Passengers in Bogotá say not that they are "going to use the bus," but rather that they are "going to use TransMilenio." The marketing of the system name and the quality of the service has been helpful in creating a metro-like image.

Figure 2.18. Rail-based system in Bucharest, Romania show problems of neglect and vandalism. *Lloyd Wright.*

Figure 2.19. Modern vehicles can give BRT systems a highly professional image. The vehicle in this photo is a Civis bus in Clermont-Ferrand, France, and not a light-rail vehicle. *US TCRP media library.*

2.5 Impacts

"The only limit to your impact is your imagination and commitment."

— Tony Robbins, motivational speaker, 1960–

The characteristics of different public transport technologies can result in different impacts as measured by economic, environmental, social, and urban indicators. Since public transport is often used as a policy measure to achieve a variety of social goals, an analysis of each system's impact is a legitimate part of the technology evaluation.

2.5.1 Economic impacts

Economic impacts can include the public transport system's ability to stimulate investment in the corridor and stimulate job creation.

Land Development

A prized objective with public transport systems is to encourage transit-oriented development (TOD), which refers to the dense walkable, bikeable urban development along corridors. If a public transport project is implemented successfully, the creation of dense urban corridors can help increase property values as well as shop sales levels.

Table 2.11. Transit Corridors Typology: TOD Investment in North America and Determining Factors

Corridor	Mode	The BRT Standard Score	Land Potential	Government TOD Support	Total TOD Investments (in millions)	Investment per Dollar of Transit Investment
Weak TOD Investmenti						
Ottawa O-TrainWeak	HRT	bronze	Limited	Weak	nominal	nominal
Pittsburgh ""The T"" Weak	HRT	bronze	Limited	Weak	nominal	nominal
Las Vegas Metropolitan Area Express (MAX) Moderate	busway	bellow basic	Limited	Weak	nominal	nominal
Pittsburgh West BuswayWeak	BRT	basic	Limited	Weak	nominal	nominal
Pittsburgh South BuswayWeak	BRT	basic	Limited	Weak	nominal	nominal
Moderate TOD Investment						

Denver Southwest CorridorModerate	LRT	bronze	Limited	Moderate	$ 160	0.71
Eugene Emerald Express Green Line (EmX) Moderate	BRT	bronze	Emerging	Moderate	$ 100	3.96
Los Angeles Orange LineModerate	BRT	bronze	Emerging	Moderate	$ 300	0.83
Boston Washington Street Silver LineModerate	busway	bellow basic	Emerging	Moderate	$ 650	20.97
Charlotte LynxModerate	LRT	bronze	Emerging	Moderate	$ 810	1.66
Pittsburgh Martin Luther King, Jr. East BuswayModerate	BRT	bronze	Emerging	Moderate	$ 903	3.59
Ottawa TransitwayModerate	BRT	bronze	Emerging	Moderate	$ 1,000	1.71
Boston Waterfront Silver Line	busway	bellow basic	Strong	Moderate	$ 1,000	1.39
Las Vegas Strip & Downtown Express (SDX)	BRT	bronze	Strong	Moderate	$ 2,000	42.28
Denver Central CorridorModerate	LRT	bronze	Strong	Moderate	$ 2,550	14.88
Phoenix MetroModerate	LRT	bronze	Emerging	Moderate	$ 2,821	1.99
Strong TOD Investment						
Seattle South Lake Union (SLU) Streetcar Strong	LRT	bellow basic	Strong	Strong	$ 3,000	53.57
Portland StreetcarStrong	LRT	bellow basic	Strong	Strong	$ 4,500	41.48
Kansas City Main Street Metro Area Express (MAX)	busway	bellow basic	Strong	Strong	$ 5,200	101.96
Cleveland HealthLine	BRT	silver	Emerging	Strong	$ 5,800	114.54
Portland MAX Blue Line	LRT	silver	Emerging	Strong	$ 6,600	3.68

Source: Hook, Walter, Annie Weinstock, and Stephanie Lotshaw, More Development for Your Transit Dollar, ITDP, 2013

There is little debate that in the right conditions HRT investments can leverage significant investment in transit-oriented development (TOD).

More Development for Your Transit Dollar, a study of the likelihood of both LRT and BRT investments in the United States and their impact on stimulating economic development concluded that both LRT and BRT had a similar chance of stimulating or not stimulating economic development, so long as they are of similar quality, as measured by *the BRT Standard*. (Hook, Walter, Annie Weinstock, and Stephanie Lotshaw, *More Development for Your Transit Dollar*, ITDP, 2013) (https://www.itdp.org/more-development-for-your-transit-dollar-an-analysis-of-21-north-american-transit-corridors/)

The study proved that the level of TOD investment that results from a transit investment is primarily related to two characteristics unrelated to the transit mode: the level of government intervention to promote development at the site, and the inherent value of the land as a development opportunity. A site where the government has rezoned the area for development, invested in new infrastructure, provided tax breaks and other incentives to attract developers, and otherwise intervened to promote development around a transit station was far more likely to attract investment, regardless of whether the system is BRT or LRT. The inherent development potential of the land also mattered. A new transit line serving a downtown in a process of revitalization, or a popular new waterfront destination, is likely to stimulate more development than a blighted low-income area regardless of the type of transit investment made. However, the study also concluded that because the BRT investment was cheaper, the amount of new investment per dollar of public transit investment was far greater for the BRT investments. For this to hold true, however, the transit investment needed to be of equivalent quality.

In lower income countries, the development impacts of LRT are not well known, as there are few LRT systems in lower income countries. The evidence of economic development impacts of BRT in lower income countries has yet to be systematically studied, but there are a few studies available.

It is clear that massive development occurred along most BRT corridors in Curitiba. Zoning was the primary tool used to concentrate development along the BRT system. The zoning rules were changed before the city went through a significant growth in population, so much new development was channeled along the BRT corridors.

Figure 2.20. The high-rise development along the Curitiba BRT system illustrates the ability of public transport to focus city development. *City of Curitiba.*

A recent study by the World Bank of the development impacts of BRT systems in Guangzhou, Bogotá, and Ahmedabad (*Transforming Cities with Transit: Transit and Land Use Integration Towards Sustainable Urban Development*, 2012) indicated that densification at levels higher than observable in other parts of the city did occur in Bogotá, but only in Phase II corridors, where there was more land available for development. Unlike in Curitiba, there was no particular zoning incentive in place in Bogotá to channel new development to the BRT corridors. In Ahmedabad, the system was still too new to determine the degree of land development impacts. Ahmedabad recently enacted zoning changes that allow for higher density development along its BRT system, but the zoning changes are too recent to determine their impact. Land assembly is harder in India than in China, and large plots of institutional land along the BRT corridor inhibit development along some parts of the BRT system, while pre-existing built-up structures inhibit new development in other areas. In Guangzhou, extremely high-density development occurred on the parts of the Guangzhou BRT corridor where the system crosses the metro system, and in the lower density parts of the corridor farthest from the CBD.

Figure 2.21. BRT corridor in Guangzhou, China. *Karl Fjellstrom, ITDP.*

In Guangzhou, there was no specific zoning incentive to build along the BRT system or the metro system, so the high-density development that occurred was largely the result of market forces.

In all cases, then, supportive zoning and the availability of developable land appear to be critical factors. These factors would affect all transit modes equally. In conclusion, there is a growing body of evidence to suggest that BRT and LRT will result in a similar level of new economic development if all other variables are equal, and these other variables are much stronger determinants of economic impacts than the selection of transit mode. Because BRT is generally cheaper to build, however, **the economic development impacts of BRT are superior to those of LRT and probably those of HRT per dollar of transit investment.**

Employment

Employment generation is another economic measure of a project's impact. Public transport projects generate employment through the planning and construction phase, equipment provision (e.g., vehicles), and operation. While there have been few systematic studies of the relative merits of different transit investments for job creation, a useful metric would be jobs created per dollar of public investment.

The employment generated during the construction phase is mostly determined by how extensive the required construction is and how labor intensive the construction process is. HRT systems naturally will tend to generate more construction jobs because the construction involved with elevating or tunneling is much more extensive than for surface systems.

BRT and LRT, which make similar changes to the street, will tend to generate similar levels of employment. Per dollar of investment, BRT may generate a few more jobs because the construction techniques required are similar to those for normal roads, and as such more likely to be adaptable to labor-based road construction methodologies. Labor-based road construction is something that has been understudied, but extensive studies in South Africa indicate that the labor content of road construction techniques can be significantly increased with contracting procedures that create the right incentives.

The fabrication of mass-transit vehicles also offers the potential for local employment gains and the transfer of new technology to a nation. Bus assembly is by far the easiest element of the rapid transit vehicle manufacturing process to introduce locally. Major international bus manufactures have established bus body production facilities in BRT cities such as Curitiba, São Paulo, Pereira, Colombia, and Bogotá, as well as normal buses usable for BRT in Guangzhou, Shanghai, and Beijing. Indian bus manufacturers also produce all of the buses operating in Indian BRT systems. South Africa also assembles buses. Fewer countries manufacture bus engines and chassis, but bus engine manufacture is also spreading to lower income countries. A bus engine is essentially a truck engine, so massive economies of scale can be realized in the production of bus engines. All of these help develop local business and create local employment.

Rail-car production is generally not as transferable. The economies of scale with rail-vehicle production imply that it is difficult to transfer fabrication from headquarter plants in countries such as Canada, France, Germany, Spain, and Japan, though Bombardier recently opened a metro car fabrication facility in India. The importation of vehicles carries with it particular costs and risks, such as import duties and long-term currency fluctuations. Additionally, the importation of rail vehicles tends to create an awkward situation where tax funds in low-income nations are supporting employment and technology development in wealthier nations.

All new public transport systems present both an opportunity and a threat in terms of operational employment. The specific opportunity and threat depends entirely on the services being planned. If the vehicles specified for use in the new transit system follow the recommendations made in Chapter 6, then in most cases similar numbers of BRT and LRT vehicles would be needed, as well as similar levels of employment. That LRT and HRT systems frequently use larger vehicles, however, means that these systems tend to be more capital intensive and less labor intensive, having fewer employment benefits.

Normally, a new transit system will replace an existing transit service, usually either formal or informal bus operations. All of these systems may imply a reduction of employment when many smaller vehicles are being replaced by larger articulated vehicles moving at faster speeds. However, most new BRT systems are designed to be roughly employment neutral, in order to protect the livelihoods of working people. In Bogotá the loss of informal bus driver jobs was mitigated by the fact that the BRT drivers are working shorter shifts and making equal or better incomes. Previously, a single driver would work as many as sixteen hours per day. In the current system, more drivers share the same vehicle. Likewise, new employment was created through new positions related to fare collection, administration, management, and security.

2.5.2 Environmental Impacts

In any transit system, more passengers means greater environmental benefit. To know the actual environmental impact of a public transport project, one has to look at a number of factors: the impact the project has on modal shift (how many former motorists are using the new transit system), the vehicle miles travelled by the transit fleet before and after project implementation, the emissions related to construction, and the vehicle-specific emissions from the transit vehicles. This guide recommends the use of the Transportation Emissions Evaluation Model for Projects (TEEMP), or the modified version developed for the Global Environmental Facility, for estimating these impacts (https://www.itdp.org/transport-emissions-evaluation-model-for-projects-teemp-brt or http://www.thegef.org/gef/GEF_C39_Inf.16_Manual_Greenhouse_Gas_Benefits).

One of the major environmental downsides of HRT projects is that they involve extensive heavy construction and the use of concrete and steel. Construction and the production of concrete and steel produce CO2. Some estimates indicate that the greenhouse gas emissions generated by construction and the production of the concrete and steel used to build an HRT system will take about twenty years to be recouped from reduced traffic emissions (see TEEMP study). LRT will also consume more steel than a BRT but otherwise the construction involved should be similar.

LRT and HRT have local environmental and public health benefits over standard diesel-powered BRT systems, as they run on electricity and generate no localized air pollution. While NOx and CO are concerns for BRT systems using diesel, by far the biggest health concern systems using diesel fuels and engines that are Euro III or worse is particulate emissions that tend to concentrate in stations. Unhealthy levels of particulates were measured in TransMilenio stations when Euro II vehicles were in use.)

These emissions should be mitigated in BRT systems using Euro IV vehicles with a particle trap or cleaner vehicles (Euro V, Euro IV, etc.), so long as the necessary low sulfur diesel fuels are available. Alternatives such as electric trolleybuses are used in some cities (Quito, São Paulo), and CNG in others (Jakarta, Seoul, Lima), which have solved the particulate problem, though these alternatives often introduce other problems. Maintenance of the electric catenary is expensive in electric trolleybus systems. When the municipal power company is in control of the catenary and not particularly responsive to the trolley operator, as has been the case in São Paulo, maintenance problems can cause severe operational difficulties. CNG resolves the particulate problem but generates as much NOx, NO2, and CO as diesel. It also requires more expensive engines and a sufficient number of refueling stations. Jakarta's use of CNG helped reduce particulates at the stations but added a lot of dead kilometers and CO2 emissions because there were too few refueling stations near the BRT corridors.

Electric power's environmental impacts depend on how that power is generated and where it is generated. If the source is coal-fired power plants, then the system may actually produce more CO2 than normal diesel vehicles do. Complications in calculating the environmental impacts of electricity has been one of several reasons why to date only BRT projects have been approved by the Clean Development Mechanism for funding.

Both BRT and LRT have the potential to reduce bus sector emissions by replacing a large number of old polluting buses with a smaller number of cleaner BRT buses or LRT vehicles operating at higher speeds. These impacts are highly dependent on the service plan. A well-designed service plan for an LRT system with proper bus-based feeder services should be similar in its environmental impacts to a trunk and feeder BRT system with a similar service plan.

2.5.3 Social Impacts

Social impacts can refer to the ability of a new public transport system to help create more social equity within a city, or to the ability to reduce accidents and improve traffic safety. Social impacts can also refer to changes in the safety and sociability of the streets.

The social impacts of a new rapid transit system are likely to be similar for BRT, LRT, and HRT, with the exception of the following considerations: in lower income countries, the lower operating costs of BRT have meant that these systems tend to be operated at a profit or with very modest operating subsidies, placing less of a strain on municipal budgets. In Mexico City, for instance, the BRT network operates at nearly full cost recovery, while subsidization of the subway system constitutes a major drain on municipal finances, taking resources away from other social needs. In higher income countries, BRT systems tend to be operated by subsidized transit authorities, and operational savings in the bus system tend to be put back into service improvements. As the users of bus systems in the United States tend to be lower and middle income, the systems directly benefit the working poor. Rail property investments, by contrast, have often led to bus service cuts in lower income areas, leading at times to lawsuits, such as the famous lawsuit of the Bus Riders Union in Los Angeles against fare increases and service cuts implemented at the same time as the Red Line subway was implemented.

Further, in lower income countries, BRT has been used to encourage locally owned business enterprises. Most BRT operators in such countries came from former informal bus operator consortiums or enterprises whose businesses would otherwise have been adversely affected by the new rapid transit system. This incorporation of the affected bus and minibus owners and operators into the ownership structure of the BRT operating companies (see Chapter 9: Strategic Planning for Communications) was a major selling point for the South African National DOT when promoting BRT in South Africa, as it was trying to promote black- and people-of-color-owned businesses and minimize unemployment. South Africa also hired locally for many elements of station operation and construction, design, bus fabrication, and other elements of the BRT business. Rail systems, by contrast, are unlikely to have nearly as many upstream and downstream local economic benefits, as the suppliers of the equipment, rolling stock, and spare parts tend to be concentrated in a few countries (Japan, France, Germany, and Canada).

For most other social impacts, there is no particular reason why BRT, LRT, or HRT should have better or worse social impacts than the other modes. Both BRT and LRT projects should be seen as opportunities for redesigning surface streets to make them safer and more hospitable to cyclists and pedestrians.

2.6 Why BRT?

“Because things are the way they are, things will not stay the way they are.”

— Bertolt Brecht, poet, playwright, and director, 1898–1956

As the world become more urban with ever-larger cities, the combination of dense development and high-quality mass transit, which reduces travel times and pollution, will be crucial to providing the access and mobility to maintain a high quality of life and economic prosperity. The alternative—cities centered around private automobile use—quickly leads to congested urban streets, neighborhoods, and cities, rendering these areas polluted, chaotic, and unlivable.

As discussed in this chapter, BRT can be an optimal public transport option for cities as the transit part of the equation. BRT combines the efficiencies and quality of metros with the flexibility and relative low cost of buses, while offering significant environmental benefits. BRT achieves comparable levels of speed, capacity, and passenger comfort and convenience as rail-based systems, but can be built at a fraction of the cost and construction time, allowing cities to expand access without sacrificing financial health. BRT has been shown to attract riders across all income levels and provides a level of flexibility and scalability unavailable with rail-based transit systems. Furthermore, it provides cities with a pragmatic and affordable solution to ensure that their transit systems keep pace with both urban growth and increasing prosperity.

3. Project Set-up

"Of all the things I've done, the most vital is coordinating the talents of those who work for us and pointing them towards a certain goal."

— Walt Disney, 1901–1966

Few BRT projects share a common origin or startup. In some instances, a certain amount of technical groundwork for a BRT system may precede the championing of the project, thereby adding feasibility and conceptual studies to the political impetus and motivation. Other BRT systems have originated through the drive of a single political champion, only gaining technical support and input once the concept is accepted and approved.

Most BRT projects, however, only truly commence once the political approvals and mandates are in place. The resulting budgetary and legislative support provides the kick start for the project setup, the appointment of the project team, and the commitment to a project program. Giving the structuring and management of the planning phase due consideration at the outset significantly strengthens the BRT project.

Contributors: Susan Smitt, *HHO Africa*

3.1 Setup Process

Identification of the need for a BRT system by authorities and the passion of local leaders to improve a city's public transport both trigger the planning of a BRT system. Although the key components of a BRT project will vary according to the local context and the forces behind it, the basic elements to plan for are similar.

During the project preparation phase, the planning team requires a clear understanding of the local context, specifically the transport-demand analysis. This will result in the selection of appropriate corridors for BRT and the best transport technology to fit the system requirements. This phase also includes the project setup, effectively dealing with securing funding sources, any statutory approvals required for the inception of the project, and the appointment of the planning team and other professionals required to initiate the project. The communications and liaison processes should ideally start in this phase as well.

The operational design and the formulation and adoption of the business plan for the BRT system should precede the physical design of the infrastructure and technology, thereby setting a realistic business and operational structure in place for which to design. The system capacity, the level of priority measures required from the system design elements, such as intersections, signal operations, and station capacity, will thus be based on network information and balance through the financing plan.

This implementation plan should be subjected to continuous evaluations and reviews. The review process must, however, be managed in such a manner that it focuses on adjusting the project as new information is confirmed, without detracting from the goal or the timeline for implementing the system.

A basic checklist illustrating the key components of the planning phase of a new BRT system may be a useful tool at the outset of the project (Figure 3.1), but should not be considered standard for all projects or exhaustive by any means.

Figure 3.1. Example of a basic overall checklist, which could be elaborated on to include subcategories of actions, as discussed in some of the sections in this chapter. *ITDP*

3.2 Legal Basis

"When men are pure, laws are useless; when men are corrupt, laws are broken."

— Benjamin Disraeli, British politician, 1804–1881

3.2.1 Statutory Approval

In most examples, a statutory or legal mandate is required before the BRT project gains recognition or acceptance. Statutory approval signals the potential for the allocation of public funding to the project, thereby also allowing the employment of dedicated staff to work on the project. The actual authorization process will vary depending on the local, provincial, and national legislation and delegations. Despite the efforts of a political champion or support group, several steps may still be required to formalize the project. It is only once this legal authorization is in place that the actual forming of a project team, the development of a work plan, the drafting of a project budget, and the full financing of the BRT planning project can commence.

Maintaining an open and transparent process throughout is fundamental to the success of the project. If the project is not implemented in an entirely legitimate and pluralistic manner, long-term public and political support can be undermined. If the proper statutory authorization processes are not followed, opponents of the project could find easy ways to stop the project. The proper legal mandate will also serve to establish the BRT project as a citywide priority across all levels of administration.

Beyond an initial mandate to begin the planning process, other approvals or authorizations may also be required. These authorizations may include the establishment of a special BRT unit or the transformation of an existing agency, the approval of the project budget or loans, and the adaptation or promulgation of legislation and policies regarding the funding, implementation, and operation of the BRT. As most of these approvals may require formal political and administrative processes, this phase of the project could take considerable time and effort. It is best to identify these formal requirements at the outset of the planning process. Although it is advised to make use of existing legal frameworks rather than depending on radical changes to facilitate the project, some projects may require the establishment of an adequate legal framework to structure the BRT implementation.

3.2.2 Context within Existing Legislation and Policies

The vision of the new public transport system should be in accordance with the intent and objectives of existing legislation and policies. A lack of consistency in this regard will provide detractors of the system the opportunity to legally delay or block the initiative. It is therefore possible that the BRT concept may require some amendments or additions to existing legislation and policies before it can be fully endorsed and implemented.

While BRT itself may not be explicitly noted in an existing transport master plan, stated objectives to improve public transport are most likely present. Drawing a connection between the new vision and the master plan is worthwhile to ensure overall integration of the new system with the existing direction of the city's transport plan. If improved public transport is not a stated objective within the master plan, or if BRT will somehow contradict existing objectives, then a review of the master plan may be in order.

Likewise, economic development, environmental authorizations, and land use plans should be examined for consistency with the proposed initiative. Typically, the reduction in congestion associated with a new public transport system will directly connect economic objectives to the BRT project. Existing land use plans should reference transit-oriented development (TOD) and/or the densification of residential and commercial sites along key corridors. Such references would be consistent with the objectives of a BRT initiative. Land use and environmental policies should be adapted to incorporate the concept of mass public transit. This must occur as an early priority in the project to minimize later delays for approval processes.

Making use of international or donor funding may require the need to amend local financial legislation or policies to allow for the incorporation of this funding in

Figure 3.2. BRT plan in the context of existing policies. *HHO Africa Infrastructure Engineers.*

existing budget structures, or, in some cases, the protection of this funding by setting up alternative budget-management structures to protect the funding from being used for purposes other than the planning of a BRT system.

3.3 Procurement

"Opportunity arises for the prepared mind."

— Louis Pasteur, chemist and microbiologist, 1822–1895

Once the commitment to the BRT project has been established through the political and statutory processes, the procurement of the technical and professional services for the project planning must commence. This procurement process will vary depending on the local protocols and the dictates of the funding sources. However, a transparent and legal process is not negotiable.

3.3.1 Tendering and Contract Documentation

Often, the first step in any competitive tendering process is to issue a call for Expression of Interest (EOI). The EOI document basically requests that all firms and individuals interested in bidding on the project submit a document stating their interest. The EOI should be distributed as widely as possible to all potential consultants and firms. Since many consultants may have other commitments or interests, not all targeted firms will likely respond. The most knowledgeable consultants tend to gravitate to the projects with the best chance for success, and will need to be convinced that a particular project is worthwhile for them to invest the resources required for a bidding process. Simply sending out the EOI will generally not be sufficient, but this does remain a critical part of the process.

Furthermore, the EOI aids the relevant officials in developing a shortlist of potential consultants who may then be called on to submit more detailed proposals. The EOI process permits a wide range of consultants to extend their interest without the necessity of a lengthy and costly formal proposal.

The EOI document is usually basic and brief in composition, without unduly detailed contents. Any background information on the relevant city or the potential system concept may be available separately. Authorities should carefully consider the content provided, as this may prejudice quality teams against making a submission or offer undue guidance to teams, thereby stifling potential inventive approaches to the planning process.

Expressions of Interest should focus on gaining a clear understanding of the individual professionals in a team, rather than general information on the bidding companies, as a team consisting of a group of key, appropriately experienced individuals will benefit the planning process more than teams of generalist professionals in the related fields such as infrastructure or transportation. The EOI should be structured to gain maximum information on the key experts, rather than the track record of the firm.

As BRT has grown in popularity, the number of self-proclaimed BRT experts has also grown, and as much additional research as possible should be done into the qualifications of the specific team being proposed. The managing authority may even resort to interviewing some previous clients of the key consultants, establishing the reputation of the team members on earlier relevant projects. The international community of true BRT experts is unfortunately still very small. This does, however, simplify the process of vetting the submissions of a team submitting an EOI.

No specific principle exists on the number of teams to be invited to submit a formal tender from the EOI process. Although a large number of tenders may require a more complex evaluation process, this may offer the potential for a highly competitive process. Generally, the preference is to have only a manageable number of submissions to evaluate, limiting the effort and time associated with this phase of the process. Furthermore, requesting proposals from individuals and firms with limited or no experience, and with no chance of meeting the technical criteria required, can place undue strain on the authorities and the applicants. Thus, creating a short-list of three to seven teams to ask for detailed proposals or tenders should provide a sufficient level of competition without becoming an unwieldy administrative burden.

The next phase of the contract procurement process may typically involve the development of Terms of Reference (TOR). Whereas the EOI sets a general framework for soliciting professional services, the TOR should detail the full requirements from which the detailed proposal will be developed. The TOR may not necessarily list every detailed action required, but should note the specific products and deliverables required. For example, the TOR may call for the delivery of specific plans, such as operational plans, infrastructure plans, architectural concepts, detailed engineering plans, financial plans, and marketing strategy plans, and will most likely include a detailed description of the requirements of the planning process. A well-crafted TOR will allow for the creative input from the professionals on the way in which these plans or results could be achieved.

The proposed project cost is usually the principal decision-making factor in awarding the project to a professional team. However, the importance of the relevant experience and qualifications of the team should never be ignored in the adjudication process. As most authorities are legally bound to award the contract to the lowest bid, and no mechanism is allowed to prequalify only teams with appropriate experience and technical abilities, the BRT project could suffer from the results of such an appointment.

The particular mechanism by which bid adjudication and award could occur may depend on local legislation. Some authorities are legally bound to a fixed price system. But by introducing some degree of competitive price bidding, the authority will gain a better understanding of the differences between the competing firms or teams. Some cities may use a fixed maximum price or a range of acceptable prices in order to limit bids within the established or available budget. In such cases, all firms may simply bid the maximum amount or the median of the given range. Thus, any preset limits will tend to reduce the competition and may increase the actual costs over that which could be achieved in a truly competitive market.

An open bidding process could, by comparison, have several benefits. First, without preset limits, firms will tend to lower bids in order to effectively compete with others. Open bidding usually encourages innovation and creativity among the competing firms to find the most cost-effective way in which to deliver a quality plan. Second, the range of bids received provides feedback to the authority on the actual anticipated costs of the required product. With a preset value, firms will potentially adjust the team input levels and the quality applied to the final product in order to achieve the fixed budget. Third, open bidding makes it easier to distinguish between different bids. The likely spread of bid values provides a more discernible gauge to evaluate the proposals.

The risk associated with an open bidding system would be that all the firms bid an amount that exceeds the maximum allocation available to the authorities. This could result in program delay, as the authorities may need to secure additional funding or reconsider the scope of work to align this with the available funding. In some cases, this may even lead to starting the procurement process to align the budget with the project expectations from the start. Authorities may be advised to include a contract clause whereby the bidding process could be cancelled and the process started again from the beginning if the bidding prices are considered too high or not in keeping with a realistic expectation of the quality of the product required. This clause may also be invoked in circumstances where none of the bidding entities are sufficiently qualified to deliver the project products.

Figure 3.3. Types of procurement pricing methods. *ITDP*

Some authorities may also be able to legally stipulate that bids may be excepted even if the price exceeds the (undisclosed) budget. Bids that exceed an undisclosed maximum may not necessarily be automatically disqualified. These TORs could specify that the bid price is not final, but a consideration along with the technical competence and other key factors in the selection of a winning bidder. An overbid may bring a penalty, but could add value to the end product if paired with key skills and competencies. At this point, the winning bidder may even be requested to submit a similar quality bid, but within the available budget.

In all of the above, it is essential to set quality criteria, as the risk exists that the lowest bid will be awarded, without the team having the expertise or qualifications to deliver the most basic of planning products. This will be elaborated on in section 3.8.

The decision-making process for both the EOI and the TOR must be confirmed and generally known before the procurement process starts. Ideally, the evaluation criteria should be created in an open and transparent manner, with input from a variety of sources, including contract or legal input to ensure that best procurement practices are followed and technical specialists to evaluate the content of the bid and the team experience. Placing the full decision-making control on one individual could create an unfavorable impression of the process and the project.

Clear and consistent decision making could benefit from a quantitative scoring system, while a process that favors only qualitative evaluations can be vulnerable to mismanagement. Should the evaluation criteria or decision-making process be considered questionable or objectionable by the unsuccessful teams, legal challenges could be lodged that would severely impact the project development.

As there is no commonly accepted definition of BRT and projects associated with the concept of BRT can vary significantly, it may be necessary to further qualify the type of BRT experience being sought, to ensure that the team with the most appropriate experience and qualifications is selected. Equally, the selection of a team or individuals that have sufficient BRT experience must be combined with clear local knowledge and understanding. This may be particularly useful in an example where the BRT system being planned is likely to require the restructuring of existing public transport routes, as opposed to a system that does not plan to alter existing routes, or in a local context with particular political challenges.

Despite the best efforts to clearly articulate the project objectives in the professional contracts, misunderstandings can arise. In such cases, consultants may work in a project direction that differs from the intent of the project initiators. By phasing the professional input, such misunderstandings can be corrected before a large amount of work is done. The phase approach essentially requires that consultants obtain approval from the relevant authorities prior to progressing to the next phase of the project. Rather than waiting until the final report is submitted to review the planning project, officials review intermediate findings and give their approval (or not!). Such project milestones should be explicitly stated in the professional contract or agreement at the time of procurement and appointment.

The above scenarios can be avoided by maintaining a close dialogue and working relationship with the consultant team and the relevant officials. Weekly, or even daily, engagements will continuously confirm the project's direction and allow for adjustments as circumstances require. As an alternative, and particularly in cases where the local authority has very limited in-house resources, a separate team of process managers could be hired to act as agents in this regular engagement process.

3.4 Planning Team Structure

> *"The strength of the team is each individual member. The strength of each member is the team."*
>
> — Phil Jackson, basketball coach, 1945

The planning and establishment of a new public transport system within an existing urban environment is a huge challenge. Although the initial concept may have germinated in the context of existing planning duties, it is advisable to structure, motivate, and select a dedicated BRT team to develop the planning phase of the system. A quality BRT system can only be achieved within the desired time frame through the appointment of a dedicated, full-time team of professionals in a carefully considered employment structure.

3.4.1 Team Entity

There are two different philosophies regarding the selection of a development entity for the new public transport initiative. Some cities assign the project to one of the existing agencies, departments, or cost centers with responsibilities related to public transport. These responsibilities may currently be limited to infrastructure, public services, or transport regulation and policies. Related responsibilities could also include finance, air quality and pollution control or other environmental responsibilities. The other philosophy is to create an entirely new organizational entity to plan and implement the BRT system. This new entity may draw upon existing agency staff, but in general would represent an entirely new team.

Each of the two options has its advantages. Utilizing an existing agency means that the development team would be familiar with the current public transport situation. The existing relationship between the agency and transport operators could also be advantageous if a history of trust and cooperation is present. Furthermore, by not creating a new entity, existing groups should not experience professional territorial conflicts. Any newly formed BRT organization may have overlapping responsibilities with the existing agencies, resulting in duplication that may cause confusion, administrative conflict, and ineffective use of resources.

An entirely new organization offers the advantage of bringing a new perspective to the local public transport system, whereas existing agencies may be too involved with the current context to take the lead on a new initiative. In some cases, the existing agencies may be held accountable for the existing poor quality or lack of efficient public transport in a city. An entirely new entity will not be as susceptible to the constraints of existing customs, biases, and processes. Additionally, the skills to deliver a successful BRT system can be quite different from the skills required to regulate conventional public services. BRT development tends to be significantly more customer orientated and more entrepreneurial in nature. Some cities find that a dramatic improvement to the public transport system can only be achieved through the efforts of a completely new structure or entity.

Some cities may decide to defer the final choice of agency supervision for a new system until later in the BRT development process, and employ a temporary, ad hoc team for the oversight of the BRT planning phase. The decision on the eventual organizational structure can then be determined through the planning process itself. At the outset, a decision can be made that the planning team will essentially be disbanded once the work is completed and the system is fully operational.

There are examples of each type of approach. São Paulo, Brazil, and Santiago, Chile, developed their new BRT efforts through existing organizations. São Paulo's Interligado system was coordinated by the secretary of transportation, with the participation of the bus authority (SP-Trans) and the traffic authority (Institute of Traffic Engineering). São Paulo's organizational design was likely influenced by the fact that

Interligado was a priority project of the mayor and a strong institution already existed.

Santiago created a BRT project office within the national Ministry of Transportation. This office coordinated efforts of the other contributing organizations, such as the Secretary of Transport Planning (SECTRA), which was responsible for the technical aspects of the BRT system development. Santiago also formed a project committee consisting of cabinet-level officials and other key leaders, including the Ministry of Housing, Ministry of Finance, and the president of the Santiago Metro. Santiago's BRT planning team structure reflects the strong nature of central government institutions in overall decision making.

In contrast, Bogotá, Colombia; Lima, Peru; and Dar es Salaam, Tanzania, have all created new entities to develop their systems. From the outset, Bogotá created a project office that reported directly to the mayor. This project office also coordinated efforts from other city agencies, and eventually became the formal oversight agency for the implementation and operational management of the TransMilenio system. Other Colombian cities have followed the same model, particularly due to the fact that national legislation in Colombia makes a specialized agency compulsory in order to receive national grants. In a similar manner, Lima has also created a special BRT project office, which has now transformed itself into a city agency called PROTRANSPORTE.

Due consideration should be given to the fact that the most ambitious BRT plans have emanated from newly created project offices or agencies. Bogotá and other Colombian cities stand out as high-quality BRT systems. By contrast, the São Paulo and Santiago systems are possibly further from being considered full BRT, especially when compared to systems that have been developed from a new institutional perspective. Thus, newly created entities may have an advantage in terms of being able to go well beyond established thinking and develop a superior quality public transport system.

In South Africa, a variation of the above has been employed, where new departments have been created within existing municipal structures, complemented by strong professional teams. The level of rollout of the individual systems in the major cities in South Africa will still have to be evaluated over time to understand the level of success in this methodology.

3.4.2 Team Members

Through the process of initial motivation and approval for the BRT system and the start-up phases of the project, the number of dedicated team members could vary, but should generally be relatively small. The initial team should likely have a flat structure, where each individual carries sole responsibility for a function. Unless a concerted restructuring process occurs, this initial team would then form the basic structure for the future BRT team.

Although it may be feasible and more advantageous for the relevant authority to outsource some of the functions or actions to consultants, the technical competence and commitment of the in-house team are crucial to ensuring the appropriate levels of and time frame for decision making.

It is widely assumed that the core team members should focus predominantly on large budget items during the start-up and planning phases, such as infrastructure and vehicle specification. This assumption is supported by the fact that these items generally have the longest implementation or manufacturing lead times. However, ignoring the operational and system planning at this stage will result in the infrastructure team's working in isolation from the future operational requirements, or being forced to also assume the role of operational and system planners.

The natural tendency to populate the team with engineers, as engineers usually lead transport projects, has merit in terms of their ability to formulate and motivate the original concepts. True value is added by bringing on board team members that are proficient in liaising with public officials, politicians, corporations, various players in the transport industry, media, and affected groups.

The ability of the team to communicate, be innovative, and formulate strategic interventions will be central to the success of the project. As with all new interventions that would change and challenge the status quo in the urban environment, the success of the team may lie with individuals who relish the challenge, are passionate about public transport, and are not risk averse!

Special care should be taken when selecting the project coordinator or executive. This individual should have well-developed management and communications skills, extensive experience in the creation and consolidation of new concepts, and must have a close and positive working relationship with the project champion. Although it would be advisable and advantageous for the project executive to have a keen understanding of the concepts and execution of public transport systems, it is essential that the project executive is focused on the management and coordination of the project and the project team. Depending on the project executive to fulfill key technical functions of the project will detract from the impetus of the project in a wider context.

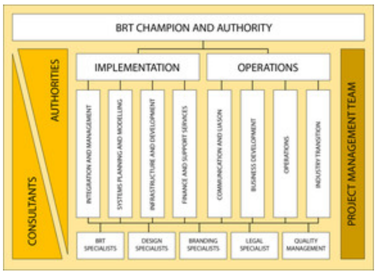

Figure 3.4. Typical BRT team structure and components. *ITDP*

As BRT is growing from a relatively new concept to an accepted contribution to public transport on six continents, more information sharing and technical training opportunities are available. This is widening the general knowledge base and the number of appropriately trained professionals, thereby allowing the further population of the BRT project teams.

Once the BRT concept is adopted and the initial planning phase has commenced, the project champion and project executive should target a more appropriately staffed team to better deal with the fast number of work streams and targets to be achieved for the successful planning and implementation of the BRT system.

Careful attention should be paid to the continued training of in-house project teams, to keep up with the knowledge and implementation experience gained by private consultants who are more likely to work on different BRT projects in their careers. Opportunities for knowledge transfer between consultants and officials should be facilitated.

3.4.3 Consultants

Appropriate Role of Consultants

The appointment of consultants on a BRT project could be a cost-effective way of gaining key technical experience, if managed appropriately. The skills offered by consultants who have already been involved in, or, more important, responsible for the implementation of successful BRT projects elsewhere, will benefit the project and in-house team without the cost implications associated with full-time employees within the organization or local authority.

Perhaps more important, consultants assist in avoiding the pitfall of needlessly reinventing lessons already learned elsewhere. International consultants with significant BRT experience can help smooth the path from planning to implementation. It is highly likely that such consultants have experienced or witnessed firsthand many of the problems facing the local team, and can therefore propose and plan for effective solutions. A local team working in conjunction with experienced international professionals can ideally result in a combination of world best practices and local context.

In looking closely at recent BRT projects, the positive influence of consulting expertise from previous successful projects is noticeable. With Curitiba's early success in BRT, Brazilian consultants were particularly involved with the subsequent initiatives in Quito and Bogotá. To this day, Brazilian consultants are closely tied to several other initiatives, including BRT projects in Cali, Pereira, and Cartagena, Colombia; Dar es Salaam, Tanzania; and Johannesburg, South Africa. Subsequently, Bogotá's highly acclaimed success has boosted the careers of those associated with TransMilenio. These consultants have been involved in a wide range of initiatives, including projects in Cape Town, South Africa; Lagos, Nigeria; Guatemala City, Guatemala; Lima, Peru; Mexico City; and Santiago. Consultancies from more developed nations have also made their impact, with consultants from the United States and Spain making substantive contributions to projects such as those in Bogotá and Lima. Thus, a BRT project may not only enrich a city with a new and efficient public transport system, it may also spawn a new local service industry catering to the exportation of BRT expertise. This is currently evident in South Africa, where several other cities are now benefiting from the BRT lessons learned in the inaugural projects in Johannesburg and Cape Town.

A city should not become overdependent on international consultants. The local context is still best realized by local staff with a fully staffed agency, or with the support of local consultants. The responsibility for key decision making must ultimately still rest with local officials. Although this is usually the protocol embedded in the existing statutory processes, it also adds to the depth and value attached to these key decisions by the public and other stakeholders.

Consultants are one of several valuable resources that lead to knowledge sharing. A prudent strategy could involve building the capacity of the local staff while simultaneously making selective use of consulting professionals. Local consultants can gain international best-practice knowledge and experience working with international experts, absorbing this knowledge to apply in the local context, and contributing to the capacity of local staff. This not only shares existing knowledge of BRT, but adds to the international knowledge base, as local context leads to alternative solutions and applications of the core principles of BRT.

Consultant Selection and Appointment

While some cities have developed well-designed systems without significant assistance from outside consultants, many cities find it advantageous to at least partially make use of people with previous BRT experience. However, procuring consultant services can be difficult for authorities with limited reference to the BRT experience available in the form of international consultants. There is often a bewildering number of people who claim to have BRT experience. Given the vast variety of BRT definitions and experiences, the perspectives and abilities of the consultants can differ greatly. Thus, establishing a rational process for evaluating potential consultants can help ensure that governing authorities find and appoint the most appropriate and professional members to the team. The appointment and selection of the most appropriate consultants for a particular project adds to the importance of the project, and is also a way in which to avoid planning mistakes (Section 3.8).

Consultant selection should foremost be characterized by an open and transparent process. Secondly, structuring the process of appointing consultants to be as competitive as possible ensures that the project developers have selected the most qualified team members at the most cost-effective rates. This may not always be the case, however, and particular care should be taken in the technical evaluation of consultants. It is critical that the technical abilities and experience of consultants match the vision and goal of the particular type of BRT system and the local context.

While designing an open, transparent, and competitive selection process may at first appear to be a time-consuming endeavor, this part of the project planning is fundamental to the future success of the project and, if dealt with correctly, can be relatively easy to implement.

3.4.4 Project Management Structure

Once the project is officially announced to the public, a clear project management structure should be firmly in place. While pre-project fact-finding activities may be sufficiently conducted with a few staff members and/or consultants, the formal project should be given a definitive personnel structure at the outset. The specific organizational structure will vary with local circumstances, but in all cases the structure should reflect the importance given to a new public transport system for the city.

Perhaps most important, the chief political official overseeing the project should be seen as the project champion. In most cases, this position should be held by the local political leader, while the hands-on oversight of the deliverables should be the responsibility of the political representative for transportation.

This type of direct leadership involvement could ensure that the project remains a political priority throughout the development process. Caution should, however, be taken that the project does not suffer from cross-party political manipulation or the merit of the system be lost through the association with only one political party.

The management structure of a BRT project will benefit from internal and external advisory committees or teams. The internal advisory committee usually consists of other local authorities or entities with some interest in or interface with the project. The external advisory committee would generally consist of key outside stakeholders, including national government representatives, trade and labor unions, commuter organizations, and local and international technical experts. Formal inclusion of all key stakeholders in the process can promote the necessary buy-in to make the project a reality. Giving voice and ownership roles to the various groups will ideally create a spirit of shared commitment that will carry the project toward implementation.

The inclusion of related agencies and departments, such as public works, transport, urban planning, finance, environment, and health in the steering committee could ensure cooperation. Furthermore, at some point the support and knowledge of these representatives could prove invaluable. Their inclusion could also limit the risk of future competition for budget allowances or priority, and facilitate interagency cooperation during the implementation of the BRT project.

3.5 Timelines and Phasing

> *"Even if you are on the right track, you will get run over if you just sit there."*
>
> — Will Rogers, humorist, 1879–1935

3.5.1 Work Plan and Timeline

Once a vision is set for the BRT system and an initial team is formed, a detailed work plan and time line focused on achieving the formulated vision will be required. Through a systematic process, both the BRT team and the public will have a better understanding of the scope of the project and the necessary activities and commitments to achieve this goal.

Invariably, cities underestimate the amount of time required to complete a full BRT plan. A BRT plan can be reasonably completed in twelve to eighteen months, but this time line can easily be longer in more complex and larger cities. However, as experience with BRT planning increases, some cities may be able to greatly reduce the required planning period, particularly when making use of lessons learned and best practices from other teams, and as more general acceptance of the concept of BRT occurs. The January 2006 launch of the Beijing BRT system came after just five months of planning. The actual duration of the planning process will depend substantially on the complexity of the project and on other local conditions.

Completing the work plan and time line will help ensure that important elements, such as public communication and education, are not inadvertently neglected. Sharing the work plan and time line with politicians, the media and the public could also ensure that all interested and affected parties have a realistic understanding of the progress of the project.

Despite well-considered planning, the passage of time and unexpected events may necessitate adjustments or amendments to the original work plan and time line. The work plan and time line should be periodically revisited and revised during the planning process. It is worth considering the value of using appropriate software packages to detail the project components so that each step is carefully evaluated from a timing perspective. A detailed time line will also clearly link associated activities and trigger alerts if critical milestones are compromised. Despite the intrinsic value of a detailed work plan and time line, individual stakeholders may still benefit more from a carefully abbreviated representation of these documents, highlighting the salient items relevant to their individual perspectives rather than employing the detailed work plan and time lines in all circumstances.

3.5.2 Project Phases

Benefits of Project Phasing

A BRT can be phased in over several distinct periods or built in a massive single effort. Typically, cities choose to construct a system over a series of phases, necessitated by a combination of several factors:

- Financing for the entire system may not be immediately available;
- Results from the initial phase can help improve the design in subsequent phases;
- The limited number of local construction firms may not be sufficient to construct a system across the entire city;
- Phased construction reduces the disruption that the construction process brings to the citywide traffic flows;
- Decision makers may want to test the response to the initial BRT system planning before committing to a particular concept or elements thereof for the future rollout.

The initial vision of the overall BRT system will likely evolve as circumstances change and time lapses. Despite the fact that the evolving nature of the urban landscape means that corridors and concepts may be altered, in general, the overall concept of improved, affordable, and reliable public transport (BRT) will still be valid.

The factors that may change over the development horizon of the project include:

- Demographic changes in population numbers and density;
- New property developments that significantly alter travel frequency around major origins and destinations;
- Cost factors for both infrastructure and operations;
- New vehicle or operational software technologies;
- The type and availability of funding sources.

Additionally, the lessons learned during the first phases of the system will undoubtedly affect future planning and designs. The BRT-development process should be a dynamic one, with constant improvement to best serve the customers in a changing city environment.

In contrast to the above, phased implementation will result in distinct types of operations coexisting, each with different rules, actors, and conditions. A large-scale adaptation of the new system across the majority of the city can reduce the confusion and inconsistencies created by a phased approach. While a large-scale approach is typically unlikely due to physical and budgetary constraints, some small and medium-sized cities may be able to deliver the bulk of their entire network through a carefully planned single phase.

A Whole-System Vision

Even when a system is to be built over a series of phases, it is still worthwhile to formulate and adopt a vision for the entire BRT system. Such a vision may consist simply of a route map showing a schematic representation of where all the planned BRT corridors are intended. This enables residents and stakeholders to appreciate the long-term benefits of the planned system, even if personally unaffected by the initial implementation phases.

Furthermore, the confirmation of a holistic network vision will be seen as a legacy from the existing political administration to future administrations. If the concept of an entire network is firmly entrenched, then there is less likelihood that future administrations will forgo implementation of the full system. This has particular benefit if the initial planning and implementation delivers a reliable and sustainable system.

The loss of political will is always a risk when moving from one political administration or dispensation to the next. In many instances, the political instincts of the incoming administration are to jettison everything proposed by the previous administration.

A phased approach also should not be an excuse for an overly timid first phase. An extremely limited initial phase may not produce the necessary results to justify further phases. BRT along a single corridor may also not attract sufficient customer numbers to become financially sustainable, thereby causing public uncertainty toward the entire concept. If this is not evaluated in the large context, and the financial model fails in the first phase, the project may lose impetus before a second phase can be planned and implemented. A single-corridor strategy depends heavily on an intense mix and concentration of activities in close proximity to the BRT system. This highly idealized and mostly theoretical set of circumstances typically means that a single corridor cannot achieve sufficient customer flows to be self-supporting. The limited usefulness of a one-corridor system will also be detrimental to the general support for the future system.

Evolution Versus Revolution

The critical question is whether to approach a BRT system by a strategy of evolvement (evolution) or intervention (revolution).

A revolutionary approach implies that the city commits to a bold plan for an entirely new, citywide transport system. This approach depends on a highly motivated project champion with the ability to gain widespread support for a wider vision. A revolutionary approach will implement all aspects of a full BRT system at once.

An evolutionary approach implies that the city should begin developing its new system slowly, by progressively implementing relatively small projects one at a time, or in basic increments. This approach may only implement a limited system or a number of BRT elements at one time, and is typical of a system with limited political support, or where support for the system is gained with successful implementation, such as was the case with the Rea Vaya and MyCITI systems in South Africa.

Both Bogotá and Curitiba achieved BRT success through the highly charismatic leaders or champions who developed a revolutionary vision for the systems in these cities. The initial corridors of these two cities were built in only a few years, but were of sufficient size to achieve financial sustainability even at the outset. Bogotá implemented virtually all elements of BRT in the initial phase of the project. Curitiba implemented most of the physical aspects of BRT in the early 1970s, but many of the critical management elements of BRT emerged only gradually.

In contrast with the above revolutionary approach, Jakarta initiated its BRT project with a limited single corridor only 12.9 kilometers long. The limited nature of the Jakarta system was further exacerbated by the lack of integrated feeder services. Unsurprisingly, ridership on the initial corridor has not met expectations.

The above examples show the impact the initial vision of system quality and political motivation has on the quality of the ultimate product.

To an extent, many of the most recent BRT systems have made compromises between system quality and quantity. The amount of resources expended per kilometer will ultimately affect the number of kilometers constructed at any given time. While BRT is generally more cost-effective than other public transport technologies, there are limits to all infrastructure financing. Therefore, it stands to reason that cities that target and develop high-quality systems may be effectively reducing the number of kilometers constructed, specifically over the short and medium term.

Bogotá and Cape Town represent perhaps the highest quality BRT systems developed to date in the developing world. The clean, modern vehicles, aesthetically pleasing architecture, and use of smart cards all contribute to a system that closely resembles a metro system. To date, Bogotá has completed two project phases and Cape Town only one. In the example of Bogotá, this totals 380 kilometers of busways.

However, the high quality of the TransMilenio system translates into increased construction costs that limit the speed at which financing can be obtained for the development of the system. The overall length of the system directly affects ridership, since a system's network of origins and destinations has direct bearing on the usability thereof. It should be considered that a commitment to build a very high-quality system will reduce the speed at which a full network can be constructed.

In contrast with the aforementioned cities, places such as Santiago, São Paulo, and Seoul, South Korea, are some of the best examples of a more citywide approach to system development. Both Santiago and São Paulo have effectively decided to restructure and reorganize the entire city bus system in one process. The entire network is being bid and concessioned at once. These systems have tended to incorporate more of the existing bus operations into the new system, whereas in Bogotá there is a sharp distinction between the BRT system and the non-BRT system, with the latter characterized by old, poor quality buses and minibuses.

To an extent, the type of BRT found in cities like Santiago, São Paulo, and Seoul may be seen as hybrids between BRT and standard bus services, akin to the definition of a "BRT light" system given in the introductory section of this planning guide. These systems have fairly modest station infrastructure, often incorporate existing buses into the system and as part of the feeder routes, and some even utilize curb-aligned stations, thereby causing buses to be negatively affected by turning mixed traffic. The hybrid systems also make use of fare verification on board the buses, greatly reducing stop efficiency and average vehicle speeds. Another detractor from "BRT light" would be the loss of universal accessibility across the full system when older, existing buses and infrastructure are used as part of a BRT system.

While the approach taken by cities such as Seoul can be interpreted as a trade-off between quality and quantity, the actual motivation behind this type of BRT planning may be found in the limited sector reform in these cities. Cities such as Bogotá, Curitiba, and Cape Town have benefited from highly motivated political leaders who prioritized public transport. In Curitiba this even resulted in the entire restructuring of the transport system around the customer. While it may require more time to create a full BRT network, the final product will clearly be car-competitive—and more appealing to the widest possible customer base.

Although there are clear politically motivated and technical reasons for each type of BRT system, neither approach is inherently correct or incorrect. Given the limits of financing resources and construction capabilities, there will always be the need to make some form of concession between quality and quantity. Political leaders and local planning officials must decide which type of system will be best suited to the unique political, cultural, social, physical, and economic realities of a given city.

3.6 Planning Budget and Financing

> *"Don't tell me what you value, show me your budget, and I'll tell you what you value."*
>
> — Joe Biden, vice president of the United States, 1942-

3.6.1 Budget

The realistic scope and depth of the BRT planning process is largely determined by the available funding. Notwithstanding available funding, the project planning should initially provide a total system cost based on the full project as detailed in the work plan. This cost estimate must include all the project activities, including payment for resources like staff salaries and professional fees, travel and study tours, communication, and administrative support. Although some cost items may be embedded in existing staffing structures or administrative functions, all elements should be itemized and the funding sources nominated.

The cost estimate for the planning phase must also allow for escalation or inflationary trends, as this phase of the project will often run over fiscal years. Projecting costs and compiling budgets is generally susceptible to unexpected or unforeseen changes, thereby necessitating budget adjustments. Thus, it is considered prudent to include a realistic contingency plan. This is generally indicated as a percentage of the total project budget.

Budgets should be as realistic and detailed as possible. Overly optimistic projections will ultimately be compared unfavorably to actual results, thereby tarnishing the image of the project from the initial stages.

BRT planning costs have historically shown considerable variation, depending on the scope and complexity of the project. Due to the fact that staff salaries or professional fees are usually the largest contributor to the project costs, the budget can vary greatly depending on the staffing and resources model that is used for a particular project.

BRT planning projects generally cost relatively less than other public transport options, and an additional planning budget should be obtained to ensure the most effective planning process. Skimping on the provision of resources for the planning process and rushing the implementation process to adhere to deadlines dictated by political imperatives can prove costly in the long term. Proper planning helps cities avoid basic mistakes that can significantly drive up costs. Section 3.8 of this chapter elaborates on this statement.

3.6.2 Funding and Financing Sources

Funding refers to the general provision of monetary resources for a project. Financing refers to the mechanism required to cover the difference between the available funding and the total amount required for the project. Financing may refer particularly to circumstances where there is an additional cost associated with procuring funds (e.g., interest-based loans). In the case of BRT planning, financing is usually not required, and the political commitment to the project is potentially a greater determinant in the decision to undertake the planning process, rather than any fiscal limitations.

Local, provincial, and national entities are the logical starting point for identifying funding sources for BRT planning. However, the cost effectiveness of BRT has also meant that many international sources are supportive of BRT planning efforts.

Local, Provincial, and National Funding Sources

In some instances, a local municipality may hold sufficient budgetary resources to plan a BRT project without any outside assistance. This is particularly true in scenarios where the municipal leader is firmly committed to a new public transport system.

The viability of self-funded efforts will also depend on the technical capacity of the government bodies charged with the planning and design of the system. If the technical capacity is relatively strong, and many of the staff members already have experience with BRT, a large part of the planning could be accomplished internally. In such cases, the planning costs may be covered through existing operating budgets, thus resulting in nominal planning costs. These types of short-term cost savings often carry significant long-term liabilities.

In cities with limited in-house technical capacity, external and/or international consulting expertise may be required. In these cases, the higher planning cost may make sole reliance on municipal funding for the planning process more difficult.

In most cases, cities require local, provincial, and national government contributions from the outset of the BRT project. International support organizations often consider the scale of the local contributions as an indicator of the commitment of a city or country to the actual implementation of BRT. Any city would likely accept a free BRT plan, but without any local commitment of funds, there is very little commitment to the delivery of the system. Thus, many external funding sources require a significant local contribution (often half of the budget) as qualifying criteria to receiving international planning funds. Provincial and national commitment could be measured in the same manner.

Additional funding input from provincial and national agencies may be another option that could limit the need for outside funding. In some cities, provincial and national agencies may actually be responsible for BRT planning and implementation. Examples of provincial funding sources that have provided impetus for BRT planning can be found in Bangkok and Jakarta. In Colombia, the national planning agency has played a central role in exporting the TransMilenio concept to other cities, and in the South African context, the national transport authority provides financial and technical support to cities such as Cape Town, Pretoria, and Durban.

The addition of technical experience available with provincial and national agency involvement creates the added advantage of guiding budgetary spending provided by these agencies. It should, however, be expected that additional agency involvement in the project can also imply increased managerial complexity and potential conflict, specifically when the different levels of government are represented by different political parties.

In some instances, the local transport situation can deteriorate to the point where the private sector may take it upon itself to seek a viable alternative. Private sector involvement may stem from local officials essentially abdicating responsibility for managing and promoting public transport. Clearly, private sector involvement will also include some level of self-interest, in which the private sector groups expect the improved public transport system to deliver corporate profits.

Vehicle operating companies may view the BRT system as the principal means to improve their profitability. Operators may also be responding to increased competition from the informal-transport operators of minibuses and vans that are filling a market gap left by poorly organized and managed formal services. The development of BRT in Curitiba is possibly the reason Curitiba is the only major Brazilian city where informal vans have not infringed upon the formal public transport system. This concept is underscored by the consortiums of private operators that have led BRT planning efforts in several cities, including San Salvador, El Salvador, and Santiago.

Another example where private entities may have an interest in BRT development can be found in Manila, where a local property-development company has initiated BRT efforts in districts near business parks owned by the firm. A formal public transport system in the immediate area would create value to the property company through improved property values and better access for employees.

Private manufacturers may also have a vested interest in BRT. An example would be vehicle manufacturers that could benefit from increased sales stemming from new

BRT vehicles. Additionally, as in the example of Dhaka, Bangladesh, fuel suppliers may also see an advantage to BRT promotion if their product is likely to be chosen for improved environmental performance. Based on these and similar examples, local authorities may find it beneficial to form alliances with private sector associations that would be mutually beneficial allies in BRT development.

International Funding Sources

Development banks and international organizations have recognized the successes of BRT. The lack of large capital debts and necessary operational subsidies results in these organizations typically identifying BRT as an option to promote and facilitate.

The plethora of international organizations now interested in BRT means that cities have a healthy supply of funding options. The role of international organization is particularly relevant to the planning process. The mandate of many international organizations revolves around issues such as capacity building, information dissemination, and project facilitation. All of these are directly related to planning. Furthermore, most international planning assistance arrives in the form of grants and not loans. Planning funds, therefore, typically do not carry any additional funding costs.

The international resources often also bring the additional advantage of increasing access to professionals with international BRT experience. An international organization may have a relationship with top BRT consultants, many of whom would not ordinarily be available or affordable to a particular city. A local government within a developing nation may have little knowledge about which international consultant to confer with or engage in an impartial audit of a BRT project. International organizations may be involved in several cities or countries simultaneously, and therefore able to identify and recommend the best-performing consultants for a particular new planning process.

Likewise, some leading experts, both local and international, will not work directly for municipal governments because of potential risks in terms of delict and probity. By contracting directly with international organizations and not the government, the consultant will be more confident in accepting the assignment.

International organizations can also suggest and ensure that local and international consultants work as a united team. As noted earlier in this chapter, local consultants possess critical knowledge of the local context, while international consultants may have greater BRT experience. As BRT is rolled out to more cities and hubs, the local and national knowledge gained is potentially consolidated, thereby offering local consultants a greater role in BRT planning within a country.

The local and international consultants may not work in a complementary manner if each group feels that the other is inadequate, either from lack of BRT experience or the lack of appropriate local knowledge. The presence of a respected international organization, such as a bilateral agency or development bank, could mediate such differences and create a context for team cohesion.

The main disadvantage of involving international funding sources can be the amount of effort required in the application and motivation process. International organizations may require an extensive analysis of the city's transport history, assurances and commitments from all relevant agencies and departments, calculations and checklists for all mutually targeted benefits, and a detailed framework and time line for targeted goals. While this application process proves valuable in terms of the inadvertent requirement for project preparation, the amount of time and effort involved may not be feasible in the current context of the resources available to the project at the early stages of the process. Furthermore, several such applications may be required before the anticipated support and commitment are secured.

3.6.3 Funding and Financing Examples

Bogotá

As perhaps the premier BRT system in the world today, Bogotá's TransMilenio benefited from some of the best consulting assistance offered to date. Since few high-quality projects had been completed prior to TransMilenio, Bogotá essentially paid for the development of many groundbreaking concepts in the BRT field. Projects have benefited from Bogotá's knowledge and experience ever since. The planning costs of new projects, therefore, have had the potential of being significantly reduced due to the efforts of Bogotá.

In Bogotá, the largest contract was for a management consultant firm (McKinsey) to provide overall project management, as well as to set up TransMilenio SA, the operating authority in charge of the BRT system. McKinsey's participation was funded by the municipality through an account with the United Nations Development Programme (UNDP). For almost three years, the municipality of Bogotá held a technical-assistance agreement with UNDP, which the municipality would pay into a UNDP account. These funds would then eventually be applied to international technical assistance. Since these funds were already committed, the municipality simply allocated the money to the BRT project.

Figure 3.5. A BRT station in Bogotá. *Karl Fjellstrom, ITDP.*

The remaining consultant contracts were also supported by municipal funding. The planning, design, and engineering work was paid for largely out of the ongoing budget allocations from Bogotá's Department of Transportation. This work was contracted to an international planning firm, Steer Davies Gleave. In turn, Steer Davies Gleave subcontracted some of this work to Brazilian experts from the firm Logit. Due to this consulting team's efforts, the TransMilenio system has proved to be fully self-financing, and an exemplar of BRT planning and implementation. Thus, the large planning expenditures have helped save the city financial resources perpetually.

Quito

Like Bogotá, Quito used ongoing budget resources to finance all of the BRT planning. However, other than one international UNDP expert brought in during Phase II, all of the planning and design work was done in-house by the planning department of the Municipality of Quito. The costs were much lower than Bogotá's, and are difficult to define precisely, as they were covered by the normal ongoing budget of the planning department. The total planning costs are estimated to have been approximately US$300,000.

While Quito represents an admirable effort for a city with limited resources, the exclusive use of in-house staff may have contributed to some of the system's operating and financial difficulties. On the first BRT corridor, the Trolé line, the selection of electronic trolley bus technology helped minimize the environmental impacts, but this technology undermined the overall cost effectiveness of the system. The use of electric trolley buses and the infrastructure requirements thereof meant that the total corridor cost came to approximately US$5.1 million per kilometer. This amount represents a cost of nearly US$4 million more than subsequent corridors that did not utilize electric trolley bus technology. Since the Trolé line has not been entirely self-financing, the corridor has remained in the hands of the public company. However, Quito has since attempted to privatize this corridor.

Figure 3.6. Inside a BRT station in Quito. *Karl Fjellstrom, ITDP.*

The two new corridors in Quito have also suffered from operational difficulties, especially with respect to the business structure. The concession contracts given to existing operators for the Ecovía and Central Norte lines have limited municipal control over system quality and effectiveness. Further, since none of Quito's corridors are integrated with one another, the system offers little in terms of customer convenience. It is possible that many of these problems could have been avoided if the city had solicited input from international BRT experts. Quito is subsequently in the process of reorganizing contractual arrangements along the Ecovía and Central Norte lines.

Mexico City

Planning for the Mexico City BRT system has attracted considerable international donor support. The total amount spent on system planning is estimated to be more than US$1 million. The detailed planning work for two BRT corridors in the Federal District and very preliminary analysis in the State of Mexico was financed by a World Bank–sponsored grant from the Global Environmental Facility (GEF). The Federal District used this money to hire local consultants to develop designs in the Insurgentes (Getinsa) and Eje 8 (Eteysa) corridors. The Shell Foundation and the Hewlett Foundation paid for international experts to review the Federal District plans. This international-review process was largely managed by WRI-Embarq's Center for Sustainable Transport, along with support from ITDP to review pedestrian access issues.

Figure 3.7. At-grade pedestrian access to a BRT station in Mexico City. *Karl Fjellstrom, ITDP.*

The German Technical Corporation (GTZ) funded the State of Mexico's plans, which were developed by the consulting firm of Cal y Mayor. In turn, ITDP funded international experts to review these plans and to prepare a financing plan for the system. The State of Mexico has also contracted the Jaime Lerner Institute, the organization headed by the former mayor of Curitiba, to develop another pre-feasibility study of the system.

Delhi, India

In Delhi, approximately US$500,000 has been spent on planning the Delhi High-Capacity Bus System. The financing for this plan has come from three sources: the Delhi government's general tax revenues, a grant from USAID to ITDP, and a general grant from the Volvo Foundation to the Indian Institute of Technology's Transportation Research and Injury Prevention Program (IIT TRIPP). The funds from the Delhi Government (approximately US$300,000) were used to contract out to IIT TRIPP and several private planning firms.

In the case of Delhi, most of the planning work has focused on operational and detailed engineering design. Little to no initial investment has been made for the purpose of demand analysis. As a result, the planned corridors may well contribute to the further congestion of mixed-traffic lanes without providing substantial time-saving benefits to public transport customers. The so-called cost of this design flaw will manifest in the form of congestion imposed on the mixed traffic, translated to increased fuel consumption and time cost.

Jakarta

The TransJakarta system in Indonesia was planned with funding from the provincial government (DKI Jakarta). The government contracted three local consulting firms for different elements of the planning phase: Pamintori Cipta, Ernst & Young, and the University of Indonesia's Center for Transportation Studies (UI CTS). With supplemental funding from USAID, ITDP has organized a review of the plans produced by international consultants. Additionally, the USAID funds have supported study tours for key staff, work on demand modeling, public relations activities, and NGO efforts to facilitate public participation.

Dar es Salaam, Tanzania

Dar es Salaam's BRT planning efforts have been financed to date through four different sources. The largest share, of approximately US$1 million, was part of the World Bank loan package known as the Central Roads Corridor Improvement Project. An additional US$500 was awarded through a UNEP-sponsored GEF project that is being managed by ITDP. This GEF-funded component is focusing on planning of the institutional and business model, capacity building, and non-motorized transport facilities. The municipality of Dar es Salaam contributed an additional US$600,000 to the two-year planning process. Another US$100,000 was awarded through a USAID grant that was also managed by ITDP.

Figure 3.8. Even with the system's challenges, TransJakarta is a great alternative to private vehicles. *Karl Fjellstrom, ITDP.*

Dar es Salaam provides one of the best theoretical examples of funding diversity. By approaching multiple sources, Dar es Salaam is not dependent on a single organization. Further, since different funding sources tend to focus on different project aspects, this funding diversity also brings two other advantages:

1. Provides access to multiple sources of consulting expertise;
2. Ensures all aspects of the planning process are adequately addressed.

Building a synergistic package of funding sources should thus be a priority in any funding strategy. It should, however, be noted that this strategy would require a strong and competent management base to coordinate the various funding sources and the associated teams, to maintain a central focus and product goal.

China

In China, technical support for the first BRT system in Kunming originated from the Swiss government via the Zurich Sister City Project, with matching funds from general municipal government budget revenues. Technical support to Shejiazhuang came from general municipal government budget revenues, with some loan funds from the World Bank. Subsequent technical support to Beijing, Chengdu, Xian, Jinan, Hangzhou, and Kunming stems from the Hewlett Foundation and the Energy Foundation, always with matching municipal funds for project staff and surveying work. The Rockefeller Brothers Fund originally provided technical support in Guangzhou, but more recently the project is being supported through the funding assistance of the Hewlett Foundation.

Figure 3.9. The Gangding BRT station during Guangzhou's evening peak rush hour. *Karl Fjellstrom, ITDP.*

3.7 Probity and Risk Management

> *"Take from a man his reputation for probity, and the more shrewd and clever he is, the more hated and mistrusted he becomes."*
>
> — Marcus Tullius Cicero, philosopher and politician, 106 BC–43 BC

BRT planning and, in particular, implementation projects have considerable political profiles and the potential for massive international, national, and local investment, and are therefore very susceptible to corruption. Various opportunities for corrupt practices could occur from the early planning stages to the operational phases of the project, and at every facet in between. Vigilance and careful planning for probity and risk management should be considered. The potential types of corruption could include anything from financial mismanagement or fraudulent budget practices to misrepresentation of technical ability by consultants during the procurement process.

Mismanagement or corrupt practices at any stage of the project have the potential to discourage financial investment and tarnish the image of the system in the minds of potential customers. Corruption could also reflect negatively on the political drivers of the project or any of the team members associated with other aspects of the project.

The initial risk-management principles may be implemented by the political driver of the project, the contracting authorities, or the funding sources, but should ideally be addressed by all involved in these early stages. This responsibility most often rests with the national or local authorities responsible for the BRT-planning project, through the various legislative procedures guarding against corruption in government, or through the terms of reference imposed by the funding sources, in particular international development banks and similar institutions. This high level of probity during the legislative and financing phases of the project can then be structured to continue through the project, with risk management built into the other stages as financing rolls out (such as structured budget reporting on a monthly, quarterly, or annual basis), or professional contracting through transparent procurement processes.

Furthermore, professional consultant contracts can be written to include penalty and incentive clauses to encourage the required level of professional performance. Such clauses for planning work typically relate to the timely delivery of the contracted product. However, incentives can also be applied to the quality and acceptability of the product. The crafting of incentive language must be carefully phrased, as ill-conceived performance measurement clauses can cause unintended results.

Ultimately, the best defense against problems relating to quality and productivity is to work with firms that have a known reputation or record of delivery of quality products. This will result in long-term relationships based on confirmed integrity and trust between the authorities and the professional teams. When risk management becomes a problem, then professionals with long-standing experience and good track records of professional insurance are a preferred option to authorities.

The continued review of all aspects of the project is discussed elsewhere in this chapter, but should equally be referenced in the context of risk management. While important, the management team should be alerted to guarding against the potential paralysis that may result from overemphasis of this safeguard.

3.8 Avoiding Common Planning Mistakes

> *"Sometimes when you innovate, you make mistakes. It is best to admit them quickly, and get on with improving your other innovations."*
>
> — Steve Jobs, cofounder and former CEO of Apple Inc., 1955–2011

At the outset of the project, the planning team should make every effort to observe the lessons learned to date from previous BRT projects. Both successes and failures of previous BRT efforts should be noted. In many ways, the problems and mistakes encountered from past efforts may be even more instructive than the successes. Recognizing and avoiding the most common errors can save a city considerable time and resources.

Although some of the following lessons regarding the avoidance of planning mistakes have been dealt with earlier in this chapter, it is useful to reflect on the most important elements in a separate discussion.

It is almost always less costly to get a system right the first time, rather than attempting to correct problems later. Once operator contracts are signed, it becomes more legally and financially challenging to negotiate changes. Attempts to integrate Quito's three independently operated busway corridors have been thwarted due to the existing contractual arrangements. Likewise, revising the system concept plan while designing the infrastructure can be both physically and financially difficult.

In Brisbane, a miscalculation of demand and the use of standard-sized vehicles resulted in severe busway congestion at one major station. The subsequent retrofitting of a passing lane through the station area resulted in an additional cost of US$11.4 million. This underscores the need for adequate project planning at the outset, and progressive approvals at regular intervals during each phase of the entire project. Although BRT systems are generally the most adaptable of all forms of public transport systems, fundamental changes late in the process can be very costly in terms of both the budget and the program. Fundamental changes could also damage the public perception of the system at critical times.

Bangkok proposed to construct its Phase I BRT system along the Kaset Nawamin corridor specifically because there was no traffic or congestion on the corridor. The lack of demand along the corridor was attractive because it meant that the BRT system would have no effect on mixed-traffic flows. However, at the same time, there was virtually no public transport demand along the corridor either. While building a high-technology BRT system along such a corridor might prove a testing ground for the concept, it would not likely be financially viable. Building a system where it is easy to do so is unlikely to serve the interest of public transport, enhance the image of sustainability in public transport, and raise questions regarding the political or administrative support to the initiative.

The long-term BRT planning in Bangkok has given relatively little consideration to customer convenience. The system calls for all corridors to terminate prior to arriving in the city center. Additionally, the system routing forces most customers to make multiple transfers prior to even arriving at the final stop, which is located outside the key city-center destinations. Once arriving at the periphery of the central area, customers are expected to either transfer to the rail system (which also serves a small number of corridors) or transfer to other options such as taxis.

The initial phase of the Jakarta system and the demonstration phase of the Beijing system both suffered design problems that inhibited the performance of the systems. The litany of initial problems that can be identified in the Jakarta system are as follows:

- Existing buses were allowed to continue operating in the mixed-traffic lanes along the busway corridor, resulting in congestion for private vehicles;
- Lack of competitive tendering for professional services;
- Lack of competitive tendering for the smart card system, resulting in a nonfunctioning fare system;
- No feeder services were provided in conjunction with the relatively short Phase I corridor;
- A subsequent attempt to integrate the BRT and the existing public transport fares failed due to existing operators not accepting the transfer tickets;
- The public procurement of vehicles resulted in vehicles too small for the given demand;
- Stations were also too small for the given demand;
- Vehicles with only one doorway resulted in slow boarding and alighting times.

The problems associated with the Beijing demonstration phase included:

- Construction of a BRT facility in a corridor with relatively minimal public transport demand;
- The only segment of the corridor that could have benefited from a dedicated busway was the one portion for which no exclusive busway was planned;

- Interior-seating design of the vehicles provided space for 1.5 customers, translating to the reality that an 18.5-meter articulated vehicle had approximately the same customer capacity as a standard 12-meter vehicle with optimal interior design;
- The 5-meter-wide busways were of generous width for a standard busway, but did not allow for passing width or two lanes.

Fortunately for both the Jakarta and Beijing efforts, the planning and design of subsequent phases have assisted in reversing or mitigating a large number of the problems listed above. Nevertheless, problems associated with the initial phases of a system can do much to damage the image of the system for future rollout. Thus, cities are encouraged to study the lessons learned elsewhere from the outset of the planning phase.

Perhaps the most serious type of risk to the planning and implementation relates to political continuity. There are numerous projects that have begun in a promising manner, only to stall or collapse due to a lack of political will or a change in leadership. In many cases, cities have expended significant resources in sending delegations on study tours and hiring consultants to develop scoping studies. Cities such as Dhaka, Bangladesh; Shanghai, China; Hyderabad, India; and Pueblo, Mexico, have experienced delays to the planning and implementation of their potentially feasible BRT systems due to several of these reasons.

The rest of this chapter deals with some lessons learned and ways to contribute to the success of planning, designing, and constructing a BRT system.

3.8.1 Appointing a Quality Professional Team

Although BRT planning, design, and implementation is a fast-growing part of international public transport, it is still often a new initiative in many cities. The associated learning curves challenge local teams to gain a good understanding of all aspects of BRT to ensure that they plan for the most appropriate system for the given context and that the resulting infrastructure meets the operational requirements. Therefore, when procuring a professional team, great care should be taken to set the quality requirements of the team at sufficiently high levels to ensure that a suitably qualified team can be appointed. Key personnel must have recent and relevant experience, and if teams want to meet the quality thresholds it might be necessary to recruit personnel internationally.

As much as the planning- and project-management teams require a full understanding of the international best practices of all the components of a BRT system, the team responsible for the implementation and operational phases of the project will equally need the skills to adapt and modify the international principles and to implement designs that meet local standards. As an example, the introduction of BRT lanes at signalized intersections may require the use of the existing traffic-signal policy, which may have been developed without any thought that BRT would one day be implemented. This often requires amendments to policies in close coordination with local policy makers and implementation agencies, and should be flagged early in the planning stage to minimize the impact of the (usually) slow or cumbersome legislative processes on the implementation stages.

International best practices and the appointment of the best possible team should trump the cost of the procurement of the professional teams, as the appointment of inexperienced professionals can cause far larger costs and budget overruns throughout the entire process, not only in the planning stages.

3.8.2 Regular Review Processes

As described earlier in this chapter, planning teams should, from the outset of the project, be made aware of the expectation that regular reviews or engagements for the purpose of auditing or regulating will be required. The concept that a regular review process is required and implemented should be a fundamental part of the entire BRT project, and included in all levels of the project team, from the political champion to the various consultant teams and technical specialists, in a cascading hierarchy.

BRT planning processes include a wide range of technical and decision-making input, and the various work streams should be audited and reviewed by the most knowledgeable authority in the relevant field, to ensure an appropriate review process. The homogenous nature of an individual review process within the larger project will ensure that the interaction is of an appropriate level, and can add true value to both participating parties.

The continuous, regular review of the planning phase of the BRT project will serve to install this way of process value-added in the project team at the outset, and this precedent should then be carried through in each subsequent implementation or operational project phase. Equally, the high level of review of the planning team should continue until this phase is complete. Project managers or authorities should then disseminate historic review data to ensure continuity and a frame of reference for future processes.

The availability of officials and key managers for regular review engagements is critical for an effective and efficient process, and should be scheduled and committed to in advance. The regularity of the review process is a further critical contributing factor to this process. Ideally, weekly engagements on a specifically agreed time and place will be the best approach. The immediate feedback and guidance derived from such regular meetings allows instant incorporation of or adaptation of new information or practical occurrences that impact the planning process.

The various funding providers may also require this review process to ensure that the level of technical input, project progress, and the budget take-up are appropriately matched. This element of the review process will be as critical to the future of the BRT project as any of the technical reviews on the implementation or operational planning of the system.

3.8.3 Accurate Budget Calculations

In BRT projects, the implementation and operating costs comprise a high proportion of the overall cost of a BRT system. An experienced planning team can deliver comprehensive and informed budget projections for these phases of the project. In contrast, the planning stage of a BRT project is often the least budget-hungry phase, while providing the opportunity to create and test the best plan for the future rollout of the entire project. Through the dynamic planning review process discussed earlier, the team can do relatively accurate budget calculations at an early stage of the project, which will drive the funding process, the cash flow predictions, and the general rollout of the rest of the BRT project. An experienced team can start delivering value-engineered implementation initiatives that will support the political drive and continued funding of the project.

Once a BRT system is operational, it needs to operate for many years without failure, as any disruption to the busways and stations will result in major disruptions to public transport services and inconvenience customers. Furthermore, cities can do without adding significant maintenance costs to their already small and underfunded maintenance budgets. This again emphasizes the need for accurate budget calculations at the planning stage of the project, with continued updating of the budget to allow for escalation or improvements resulting from the review process or the dynamics of a city. Chapter 21: Infrastructure Management and Costing contains a model of ITDP's BRT Cost Calculator.

3.8.4 Understanding All Elements of the System

Due to the expansive nature of BRT networks, as well as the fact that this is often a new concept introduced into an existing urban environment with the associated challenges, it is likely to be impossible for a city to build an entire BRT network in one phase. It is important for cities to plan the entire integrated public transport network early in the BRT planning stages, as the full system requirements need to be understood before Phase 1 is implemented. The initial phase may typically include infrastructure, such as a terminal building or depot, which will have to be sized and even built in Phase 1 to ensure minimal construction disruption to the operation of Phase 1 and the subsequent public transport services. Equally, decisions such as the type of vehicle fleet to be used or what kind of fare-collection system to utilize will have an impact on almost all other aspects of the implementation and operation of the future BRT phases, but have to be decided on in the planning phase.

This necessity for a comprehensive understanding of the BRT concept, and all the elements in which manifest in a specific system, again emphasizes the need for an experienced, competent team of officials and consultants that can lead the planning phase and, potentially, continue during future phases of the BRT project. The continued participation of at least a number of key officials and members of the project management team will serve as an invaluable reference.

To fully grasp the BRT concept, it is important to study existing operating BRT systems. It is important to speak to people who have been involved in developing working BRT systems, and to ride on the systems. Doing this develops an understanding for how the bus lanes have been located in the roadway, what materials have been used, how these materials accommodate bus loads, what strategies work, and which do not. When using the stations, it is important to note the type of architecture used, materials utilized, weather protection, safety features, and customer space and circulation. Is important to notice how buses dock at stations and what damage has been caused to buses and stations due to inaccurate docking and the docking mechanisms used. Terminal and transfer stations should be visited to understand multiple platform and staff facility requirements. It is also useful to visit a working and functional depot, to understand the design requirements of depots. These are only some of a vast number of details to be studied, evaluated, and made familiar by the planning team for the specific BRT project.

Due to the diverse lessons to be learned from existing systems, any study tour undertaken should not only be conducted to understand what BRT is all about, but also to assess what can be done better, and what is already functioning well.

Small touring parties with specific goals and appointments with key local representatives are more advisable than large groups travelling the system without active engagement with local BRT experts, officials, or operators.

As with all imported technologies, which is often the case with BRT systems, it is important to thoroughly interrogate all aspects of the system design to see whether design assumptions made in other countries hold true in the local context. An example may be in utilizing cost per kilometer for the implementation of bus lanes in South America, which may be very different to the equivalent cost in an African city, due to the use of different construction methods and materials, impact on existing services, geometric design standards, the levels or types of industry transition required, etc.

If possible, an international expert (or someone who has experience in developing and running a BRT system) should be part of the local project planning team to provide firsthand experience. This will avoid unnecessary reinventing of well-established design principles, something that most cities can ill afford in their BRT rollout program.

A BRT network could take between fifteen and twenty-five years for a city to fully develop. Over time, it is likely that technology will change, resulting in amendments to the full system design. On a local scale, BRT operations on a particular corridor may change over time, as land use changes occur and customer travel patterns change from what was originally anticipated. It is therefore essential that the planning phase should allow for flexibility without compromising the concept of BRT. Being aware of these opportunities and planning for these potential shifts will ensure that any BRT system is flexible to technology changes.

3.8.5 Integrated Planning

During the planning phases, the team should make use of the opportunity to utilize the BRT project to improve the urban environment. The potential improvements could be as basic as the architectural elements introduced in the design of the station and terminal infrastructure, but could also extend to urban regeneration and the densification of the public transport corridors along which BRT are to be introduced.

The insertion of a busway into a roadway is an opportunity to transform the entire roadway into a linear urban park. BRT customers arrive on foot from all directions and need to be afforded safe access to the system. The station environments need to be attractive and accommodating in order to heighten the customer experience of the system and ensure customer satisfaction, safety, and recurring patronage. The urban design of intersection areas and station precincts is therefore a key consideration, and worthy of detailed planning and design. Other associated elements such as landscaping, non-motorized transport facilities, integrated wayfinding, and enhanced illumination will benefit the urban environment and extend the positive improvements to all users of these spaces, not only BRT customers.

An added benefit of a BRT system to a city that should be recognized and included in the overall planning framework is the potential to attract urban regeneration and densification to the formalized public transport corridors. The improvement to the urban environment will be rewarded by increased investment in the transit node and higher utilization of the BRT system. This continued cycle of improvement should be anticipated and recognized in the early stages of planning and shared with the corresponding teams in the local authority responsible for associated areas of responsibility. In this manner, land use planning can be prepared for densification initiatives, or utility services not directly involved with the BRT infrastructure implementation can budget for improvements necessitated by the potential densification.

No BRT system should be planned in isolation. This chapter has dealt with the political champions of a BRT system, the authorities or officials involved in the planning thereof, the different and diverse teams of professionals required and has referred to the associated disciplines. The end users of the BRT system, customers, future employees, and groups affected by industry transition—basically most citizens of the city—are also considered key stakeholders in this process. Involving the public is an essential element of the integrated planning of a BRT system.

Shortly after the concept of a BRT system has gained political and financial support, the city should appoint a dedicated media-liaison team to ensure that the public is informed and to manage the entire public-engagement process in a structured and strategic manner. This team will also benefit the planning team, by providing the public with background information on the BRT concept, and smooth the way for the required mind-set shift. The management of change in the public domain is often the most challenging element, which starts in the planning phase, continues through the implementation phases in some of the most populated or intensely used parts of a city, and will provide daily information to customers on the operations and use of the system. The media-liaison team should react quickly to negative public comments on the system or during construction, to ensure that public perception of the system remains positive. This team may be tasked with engaging potential detractors or objectors to the system to discuss and explain more clearly the benefits of the system, and to become aware of any negative impacts that the objectors have experienced.

Although local legislation may prescribe certain levels of formal public participation, when new infrastructure is introduced in a city, the BRT team should integrate the project in the public environment through a continued flow of information, and not confuse statutory processes with the value of a truly integrated approach to public-information sharing.

Not only should a BRT system be planned as part of an integrated public transport system, but public transport must form an integrated part of a city on a spatial and functional level. The planning of a new BRT system, or the extension of an existing system along new routes, should be dealt with in an integrated manner involving the various levels and groups of stakeholders. The manner in which the planning team addresses this challenge can fundamentally affect the success of the future BRT system.

3.8.6 Conclusion

BRT is more than a busway; it is the establishment of a transformed world-class public transport service that is customer oriented and run on sound economic principles. With this in mind, it is key to underpin the project with sound economic, operational, and transportation input, so that the outcomes maximize the benefit to the customer while also providing a viable business model to transport operators and associated service providers.

With this in mind, it is imperative that all municipalities that embark on developing a BRT system gain a thorough understanding of the way these systems operate before breaking ground on the first infrastructure project. Taking note of the lessons learned internationally will greatly assist cities with their BRT rollouts and ease the burden of what is a very large and challenging, yet rewarding and worthwhile undertaking.

VOLUME II

Operations

Volume 2 runs through the necessary preparations and calculations needed to plan out the operations of the BRT project in order to optimize its service frequency, capacity, and ridership.

This requires surveying occupancy, boarding, and alighting in order to assess transport demand, whether through data aggregation or modeling software as discussed in Chapter 4. Using this information the project team can then analyze the demand of multiple corridors in Chapter 5, and they can evaluate necessary factors from land use and time savings to economic and political costs.

After analyzing what the overall BRT project might look like, Chapters 6 and 7 go deeper into fleshing out the service plan of the project, using technical equations that evaluate station saturation, travel time, direct services, trunk-and-feeder services, frequency, headways, vehicle sizing, speed, and capacity among other details.

Finally, Chapter 8 provides the guidance needed to assess the traffic impacts of the project given this service plan.

4. Demand Analysis

> *"The essence of mathematics is not to make simple things complicated, but to make complicated things simple."*
>
> — Stan Gudder, mathematician

The analysis of the potential customer demand for the planned BRT system is the foundation for most of the subsequent planning, design, and financial work. Demand estimates are critical to designing the system, planning operations, and forecasting the financial viability of the new system. Knowing where and when customers require transport services will help shape a system that is based, above all, on the *needs of customers*.

It is often tempting for a decision maker to want to put a new BRT system on a wide road or a ring road where there is plenty of space, but where demand is limited. Other times, decision makers will choose BRT corridors for political reasons, like putting one BRT corridor in each district, regardless of the relative importance of the corridor to riders, or locating the BRT system where its benefits would accrue to politically powerful people. In the United States, sometimes planners put BRT in places where they hope it will stimulate economic development, but where this development may be a decade away and current ridership is too low to justify the investment. While such factors will inevitably be a part of the decision-making process, BRT planners generally suggest putting a BRT system in a location that will benefit the most customers in the best way possible as quickly as possible, most directly through *time savings*.

The first use of demand analysis, discussed in Chapter 5, is generally to find out where the existing public transport demand is concentrated, and from this to extrapolate where the greatest potential BRT demand may be. The second use is to rank the existing public transport demand on all the main public transport corridors so that a full network of BRT corridors can be identified and a rough phase-in plan can be proposed.

Note that as a practical matter, many cities go into a BRT planning process with one or a few possible BRT corridors already identified. In this case, carefully reviewing the municipality's process of determining the proposed corridors can save BRT planners a lot of time and money because they can focus on a few select corridors, rather than all the main public transport corridors in the city, unless all of the proposed corridor options are poor.

Demand estimates play several key roles in the design of a good BRT system. First, the system needs to be designed with enough capacity to handle future demand while maintaining high vehicle speeds. Second, the demand estimate is also needed for creating the service plan and optimizing operations. Third, the demand estimate is critical for financial projections. For this, the demand estimates have to err on the conservative side to be credible to banks and investors. The critical factor is that the banks and investors trust the estimates, and for this the greater the accuracy of the projection, and the more methodologically credible, the better.

This projected future demand should start with an analysis of existing public transport demand, and then be expanded with reasonable expectations about customer growth. To be conservative, the system needs to be designed with sufficient extra capacity to ensure good performance when the system opens and sufficient additional capacity for at least a decade of future demand growth.

As discussed in this document, achieving capacity while maintaining high speeds depends on three main factors: the design of the infrastructure, the type and number of vehicles, and the organization of the services. It is easier to increase capacity by adding new vehicles and changing their schedules than by modifying the infrastructure, including right-of-way, junctions, stations, and terminals. If the system is designed with more capacity than it needs, it will be needlessly expensive and consume too much right-of-way that might otherwise be used for footpaths, cycle ways, public space, parking, or private vehicles. Alternatively, if capacity is too low, BRT stations will be overcrowded, and vehicle speeds might even be slower than current speeds, thus alienating customers. Any of these mistakes will significantly compromise the success and quality of service, the profitability of the system, and its ability to meet future demand levels.

This chapter outlines a step-by-step approach that provides a gradually better demand analysis as the process evolves. The topics include: overview of demand analysis; data collection; basic methods for estimating public transport demand; estimating demand with a public transport model; estimating demand with a full transport model; and risk and uncertainty.

Section 4.1 provides an overview of demand analysis—what is required and what is to be taken into consideration to properly accomplish it. It also stresses the need to gain a thorough understanding of current operations before attempting to improve on them.

Section 4.2 discusses the data collection effort required to support demand estimation, as it is necessary to gain a solid base for forecasting.

Section 4.3 describes a methodology to provide a *rapid demand assessment*. Rapid demand assessment will provide an approximate idea of likely BRT demand on major corridors using only traffic counts and occupancy surveys in key locations, accompanied by boarding and alighting and bus-speed surveys. With this information alone, a skilled BRT planner may be able to develop a reasonable demand estimate, but the BRT planner's previous experience is paramount.

Section 4.4 discusses how to estimate demand more accurately as a transfer from other public transport modes; this is achieved using a *public transport model*. The public transport model simulates only the public transport system, and can be strengthened with the addition of a customer origin and destination survey. With a basic public transport model, most critical decisions about the BRT system and many critical operational decisions can be made, but the public transport model can only roughly estimate impacts of the system on mixed traffic and on modal shift. Most BRT planners, including the team that designed TransMilenio, primarily use a public transport model.

Section 4.5 discusses the basics of developing a multimodal *transport demand model* for BRT. Such a model will provide full flexibility for testing multiple routing and pricing scenarios, a more robust estimate of plausible modal shift, emissions impacts, bus route optimization, and a host of other useful tools.

Finally, all forecasts are subject to uncertainty and risk, and decision makers must understand these when planning a BRT system. The two main risks in demand estimation are the overestimation of demand, thus requiring more infrastructure and fleet than necessary and exaggerating revenues; and the underestimation of demand, thus limiting the performance and success of the BRT system. Section 4.6 discusses these issues and suggests a few ways to handle them.

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4.1 Overview of Demand Analysis

"It is far better to foresee even without certainty than not to foresee at all."
— Henri Poincaré, French scientist and philosopher, 1854–1912

The objective of demand analysis is *demand forecast*, though in terms of choosing an appropriate corridor in a city for BRT it is about comparing alternative selections to determine where there will be the greatest return on investment. Demand forecasting for a new mode of transport requires a combination of sound analytic skills, the use of the right approach for each situation, and a good deal of experience with and understanding of public transport demand and operations. Experience and understanding are more important than the use of advanced modeling tools. Even more important than experience and understanding is having data; no amount of expertise can make up for not having enough information—or worse, having unreliable data from a poorly conceived survey.

For all purposes (as operation and infrastructure design, business plan) the forecast demand will be sufficiently described by *boardings and alightings to each route in each stop/station* for:

- Hours of the day;
- Days of the week;
- Seasons of the year;
- Future years.

Ideally, demand forecasting for a BRT system should be undertaken by professionals who are familiar with the existing public transport. If not, then the first step will be for planners to familiarize themselves with the current public transport services and how they are used by customers. When working in developing countries, one must try to understand what may appear, at first sight, to be a somewhat chaotic and dangerous arrangement. There is always some logic behind the apparent chaos of paratransit and semiformal public transport; these will often provide a service with greater frequency and fewer transfers than a full-blown BRT system. Of course, these services are often uncomfortable, dangerous, and perhaps expensive, but one must bear in mind that the new BRT system should be an improvement for the user not just in better buses but also in terms of journey speed, waiting time, comfort, and safety. In order to make sure that the new BRT is an improvement, professionals must experience and understand the existing system.

Box 4.1. Models

A model is a simplified representation of the real world systems that allows projections of future conditions. Transportation modeling is quite commonly utilized to determine expected demand for proposed supply conditions of future infrastructure supporting policy measures. Modeling helps project future transport growth, as well as allowing planners to run projections across many different scenarios.

However, it should be noted that transportation models do not solve transport problems. Rather, the models are tools that provide decision makers with information to better gauge the impact of different future scenarios. The type of scenarios considered and the type of city conditions desired are still very much the domain of public policy decision-making.

In mathematical models, the set of relations is what we call "the model itself" and the fixed values that make the model fit a particular instance of reality are what we call the parameters. In transportation models, the proposed relations are to mimic the travel decision-making process.

A whole commonly gets named after one main part, so both designers and decision makers must carefully understand what a model is (and its parts) as well as what a model is not, and carefully communicate this distinction.

Usually a demand study is accompanied by a main forecast model (made up of several models) and the results of the study are commonly mistaken for the model itself. If provided different input (that may be disclosed after the study or different proposals) the model will give different results from the demand study. At a lower level, the parameters of the model are commonly mistaken for the model itself. A model with the same input but different parameters will result in different results.

When developing demand estimates, there is always a trade-off between cost, accuracy, and timing. A detailed full demand modeling exercise, if done properly, will produce more accurate results, but developing a fully calibrated transport model is time consuming and expensive. Planners often do not have the time or resources to build and calibrate an entire model all at once. Rapid assessment techniques can produce acceptable accuracy faster and at a much lower cost. In choosing a demand estimation technique, the following must be taken into consideration:

- Amount and type of already-available data;
- The time and resources one has to do the estimate;
- The degree to which demand is likely to be unpredictable due to significant changes in services, rapid changes in land use, or modal split.

Many cities have already built travel-demand models, or at least models of some parts of their public transport systems. These models can vary significantly in quality, particularly in the developing world. Often what exists is something built by a team of consultants to justify a particular project or set of projects. These models frequently have quite limited validity (and therefore limited utility). As such, the quality of any existing model should be checked carefully to see whether it yields results that are readily observable on the street. If the model is reasonably good, then a lot of time and trouble can be saved by simply expanding and improving upon that model. If the model is of poor quality, it is usually better to start from scratch.

BRT projects need models of varying degrees of accuracy at different stages in the design process. Corridor selection requires a fairly rough demand analysis, whereas making subtle changes in service requires a higher degree of accuracy and detail. Modeling longer-term impacts on land use and modal shift, or larger areas of a city, is far more difficult. The more difficulty the greater the likelihood of inaccuracy, and the more work required to construct the model.

The authority responsible for developing the BRT system should develop the capacity to do full multimodal transport demand modeling or at least full public transport system demand modeling over time. However, if this capacity does not already exist, it is unlikely that it can be developed at the same time that the agency is engaged in a politically time-bound BRT planning process.

In most cities, time and money are restricted in the early planning phases, and local modeling capacity may be limited. In such circumstances, it is better to develop the modeling capacity of the agency over time, so that the local partners learn how to collect the required data and develop better models. Even with a limited start to the modeling process, the design team will at least have some preliminary information about demand in a timely manner to influence critical early decisions.

4.2 Data Collection

> *"The price of light is less than the cost of darkness."*
>
> — Arthur Nielsen, market researcher, founder of ACNielsen, 1897–1980

People travel from an origin address to a destination address, and may take one or more public transport services to get there; some walking and waiting will be required to complete the journey. The existing public transport services will be a good indication of where and how people travel. Therefore, analyzing existing public transport services and the conditions in which they operate is the first step in demand assessment.

A new BRT system is likely to change the combination of services that travellers will use. To understand how this will affect travellers, and whether or not this would be advantageous to them, it will be necessary to learn more about the pattern of trips, the origins, the destinations, and the volumes involved. This will require additional surveys capable of quantifying these patterns and enabling the construction of an origin-destination trip matrix for the study area. This information, combined with data about bus speeds in the network, will help in the design of a better BRT system.

Moreover, many travellers in a city have a level of choice about which transport mode to use, be it taxi (shared or otherwise), motorcycle, or car. Many of the environmental and economic benefits of a BRT system materialize if some of these users are attracted to BRT instead. The rate of attraction of BRT will depend on how good the routes are, and this will vary for different origin-destination pairs. If attracting car and motorcycle users is a key objective of BRT, then a more comprehensive transport model will be needed.

The next subsections discuss the minimum set of data that need to be collected to generate a reasonable estimate of demand for a proposed BRT system. These consist of:

- The routes of current public transport services; these can be mapped in GIS, transport modeling software, or Google Earth or Google Maps;
- The number of customers using key corridors by means of bus-route-frequency counts and visual-occupancy surveys;
- Bus frequency, preferably for every public transport route in the city, by direction, and in morning and evening peak periods;
- Bus speeds for each road section covered by a potential BRT route;
- Speeds of other vehicles on the existing road network;
- Boarding and alighting surveys (and supplementary spot counts at bus stops), to get a first impression of demand patterns.

In order to develop an improved public transport model it will be necessary to collect additional information; this is discussed in Section 4.5. For a formal, comprehensive transport model even more data will be needed, as discussed in Section 4.6.

4.2.1 Route Maps

The first step is to simply map, or test the accuracy of any existing maps, of the current route structure of bus and minibus services. While in developed countries existing bus route maps are increasingly available in one form or another, it is surprising how difficult it often is, particularly in developing cities, to get even a basic up-to-date bus map. Mapping the existing public transport routes provides the first indication of routes with significant customer demand. While the roads that carry the most bus or minibus routes do not always correspond to the highest number of public transport customers on a given corridor, usually there is a strong correlation. If public transport routes are fairly well regulated, then municipal officials should already possess detailed route-itinerary information through registration records and maps of existing routes, but these records are almost always not fully reliable. In many developing-nation cities, the majority of public transport customers may be served by minibus operations that are weakly regulated. In such cases, there may not even be official records of specific routes. In other cases, registered routes and fleets may bear little resemblance to the actual situation.

A growing number of cities, particularly in the developed world, are putting their bus routes and schedules into GTFS or “General Transit Feed Specification.” Originally called “Google Transit Feed Specification,” this is a standard data format that a growing number of US public transport authorities are using to map and publish their current bus routes and bus schedules. So GTFS data is also usable as a map of the existing scheduled bus routes. Often the data entry is imperfect, so the accuracy of the routes has to be checked carefully. Other cities or public transport authorities may have already coded their existing bus routes into Geographic Information System (GIS) software or a travel demand model software.

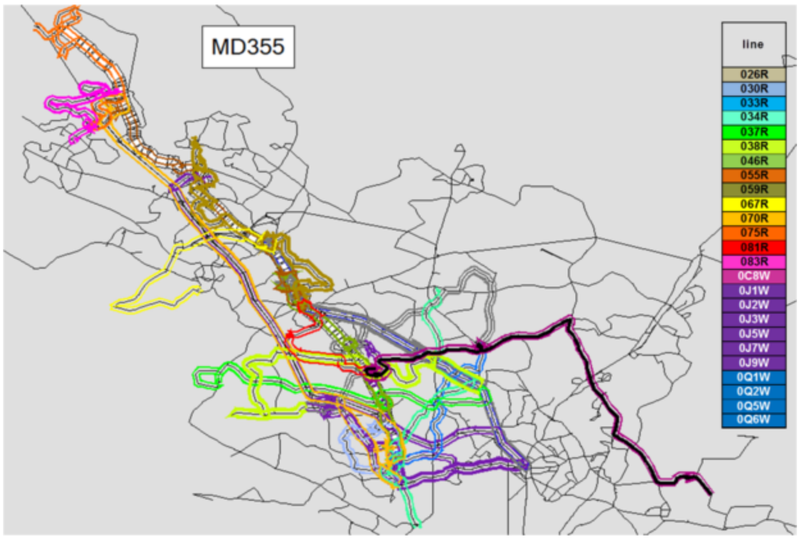


Figure 4.1. The figure above is a map of all the bus routes affecting the Maryland Route 355 Corridor in Montgomery County, Maryland, taken from GTFS data. *ITDP.*

Where neither of these data sources is available, it is best to simply ride all of the public transport routes using a simple Global Positioning System (GPS) device to record the geographic coordinates of all official bus stops and popular informal stops. Virtually all smartphones nowadays come with GPS and can be used as trackers, and a simple tracking device—with no screen, but capable of registering one day of movement each 10 seconds)—costs less than US$10. Apps for smartphones allow data, like bus stop information, to be entered immediately and tagged to the map. The issue with using these in the field will be the short battery life of phones compared to the batteries of strictly GPS devices. But with a GPS, more data cleanup will be necessary, such as labelling the bus stops.

The work can also be done without GPS devices, with printed estimated-route maps distributed to survey personnel, who will document bus stops along the route and make corrections to paper maps. GPS-based surveys will produce speed information as long as a travel log is associated with the survey, while performing a survey with paper maps will require that travel times be written down.

Depending on the data that is already available, itinerary surveys can be quite a big job in large cities, as they require developing a naming/coding system for the bus stops, identifying all of the routes, mapping the routes, preparing and processing survey data, and accounting for route variations. In a surprising number of cities this will be the only accurate public transport map in the city. Google Earth's ".kml" format is an excellent way to store bus route map data, and the satellite imagery provides great assistance in mapping routes.

The map in Figure 4.1 is one of the first efforts to map the existing minibus Car Rapide and Ndiaga Ndiaye in Dakar, Senegal. This activity is often a critical first step toward bringing such services into a transparent regulatory framework.

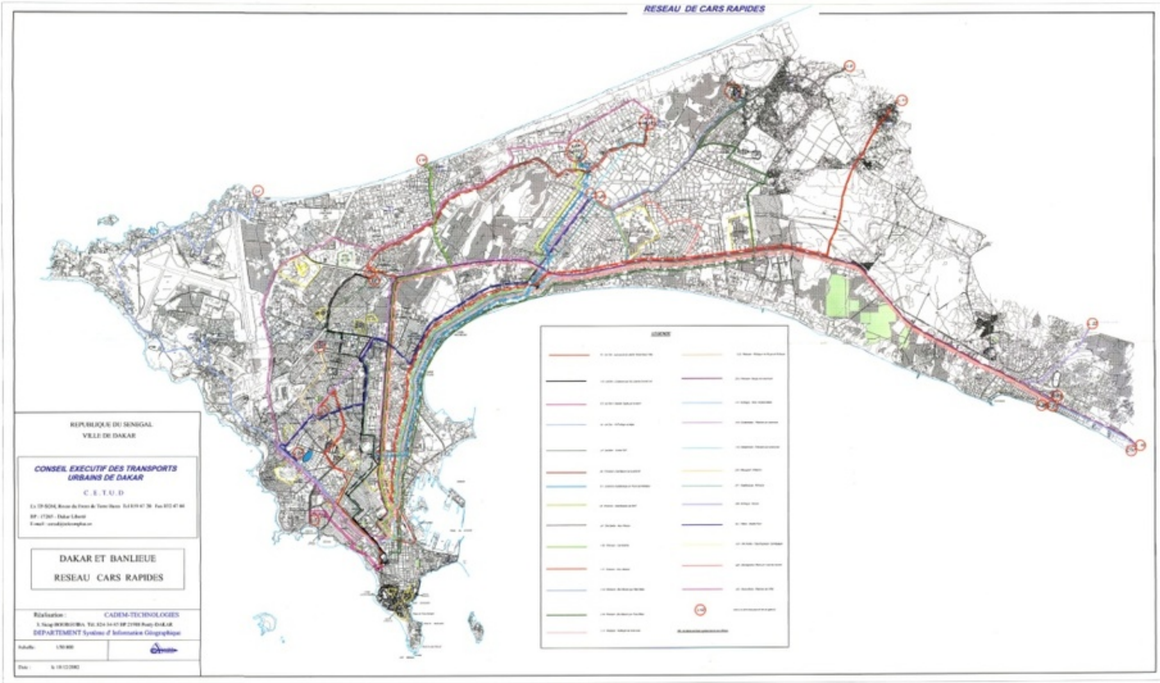


Figure 4.2. Map of 2004 minibus routes in Dakar. *CETUD.*

Once the coordinates of the bus and minibus routes have been collected and mapped, these itineraries can then be input into GIS and/or transportation modeling programs, with supplementary input from associated spreadsheet or database files; see, for example, Figures 4.2 and 4.3.

With just this amount of information, the main potential BRT corridors should already be obvious in most cities: the corridors where many bus and minibus routes converge.

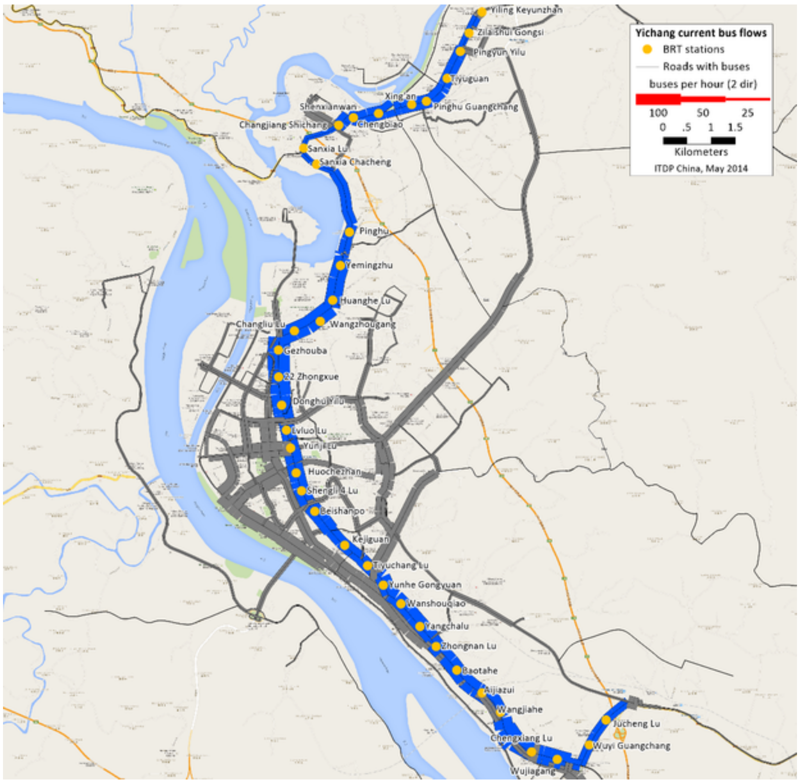
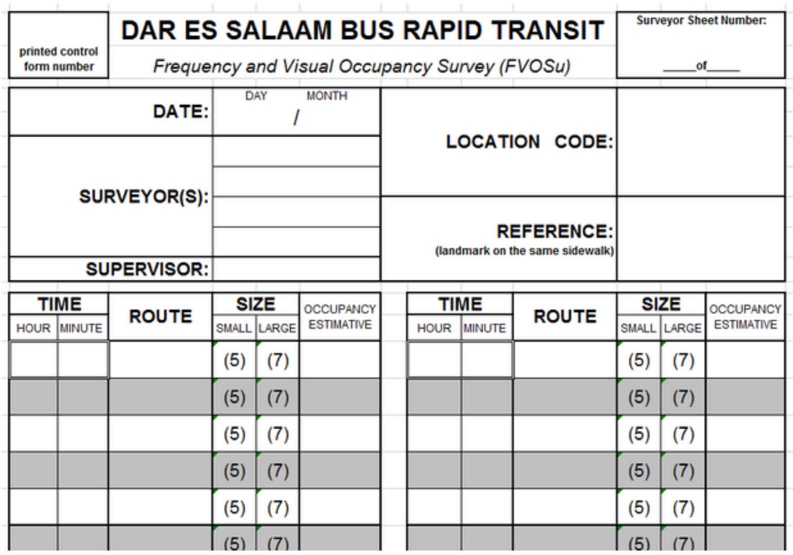


Figure 4.3. Software packages can be used to help model demand and can produce visual representations such as the above example from Yichang, China. *ITDP.*

4.2.2 Vehicle and Customer Counts

With the basic public transport route structure in hand, bus and minibus counts are the next step in translating bus-route frequency and occupancy numbers into rough public transport demand estimates. These counts can be used to calibrate an existing traffic model, to understand the public transport demand across the city, or to plan services along an already-identified corridor. The first step is to have a reasonable understanding of demand across the network, and then to focus on a particular corridor. The number of buses (or other types of public transport vehicles) per route, combined with their estimated occupancy rates (discussed in the next section), will already yield a crude estimation of a corridor's existing demand (Figures 4.4 and 4.5).

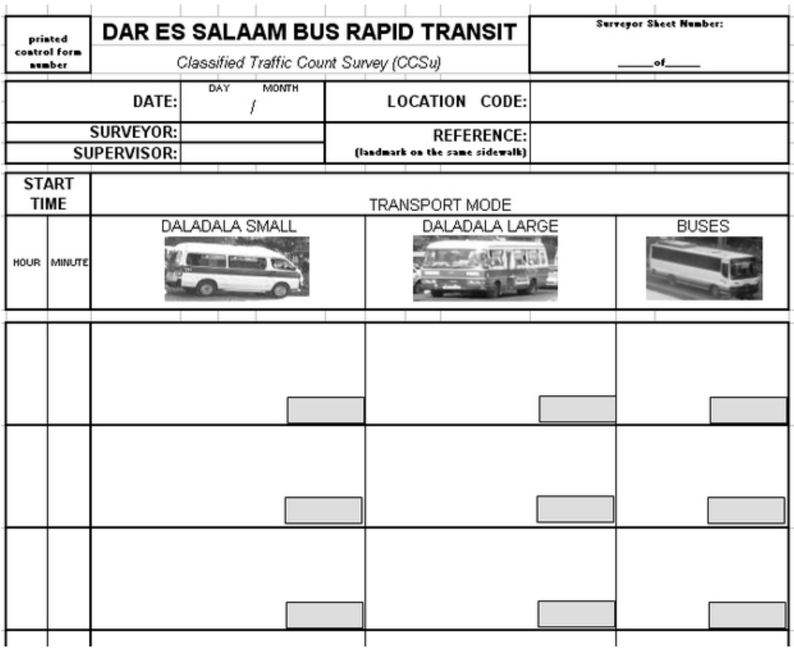


printed control form number	DAR ES SALAAM BUS RAPID TRANSIT *Frequency and Visual Occupancy Survey (FVOSu)*	Surveyor Sheet Number: ____of____

DATE:	DAY / MONTH	LOCATION CODE:	
SURVEYOR(S):		REFERENCE: (landmark on the same sidewalk)	
SUPERVISOR:			

TIME		ROUTE	SIZE		OCCUPANCY ESTIMATIVE	TIME		ROUTE	SIZE		OCCUPANCY ESTIMATIVE
HOUR	MINUTE		SMALL	LARGE		HOUR	MINUTE		SMALL	LARGE	
			(5)	(7)					(5)	(7)	
			(5)	(7)					(5)	(7)	
			(5)	(7)					(5)	(7)	
			(5)	(7)					(5)	(7)	
			(5)	(7)					(5)	(7)	
			(5)	(7)					(5)	(7)	

Figure 4.4. Example of a visual occupancy data collection sheet that was utilized in Dar es Salaam, Tanzania. Surveyors were trained to estimate the number of customers on a bus, according to its size. This method has no disadvantage when compared with the traditional method of informing occupancy percentage in increments of 25 percent. *ITDP.*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DAR ES SALAAM BUS RAPID TRANSIT

Classified Traffic Count Survey (CCSu)

Surveyor Sheet Number: ____of____

DATE: DAY / MONTH

LOCATION CODE:

SURVEYOR:

REFERENCE: (landmark on the same sidewalk)

SUPERVISOR:

START TIME		TRANSPORT MODE		
HOUR	MINUTE	DALADALA SMALL	DALADALA LARGE	BUSES

Figure 4.5. Example of a public transport count data collection sheet that was utilized in Dar es Salaam. *ITDP.*

The strategic selection of the points to conduct the traffic and occupancy survey will determine the extent to which the survey results will represent the actual situation. Determining where to do traffic counts can be more of an art than a science, but some general rules can be applied. Generally, the survey locations should allow most trips to be easily captured with a minimum of resources and effort.

When designing a BRT system we are looking for the highest potential public transport demand routes; traffic counts should be conducted in locations where public transport demand may be high. Using the map of existing bus and minibus routes, counts should be done on arterials where many routes converge. Arterials where local knowledge or simple observation indicates high volumes of buses should be counted as well. If a city has a fairly clearly defined central business district (CBD), and most of the trips start or end in the CBD, then it is sometimes possible to do traffic counts at the entry points along a “cordon” around the CBD. For example, in Dar es Salaam, the entire CBD can only be entered through five major arterials and by ferryboat, and few trips both originate and end within the CBD. By conducting traffic counts at just these six entry points, it was possible to obtain precise CBD demand data for each major arterial as well as the collective totals, and the frequency of nearly all bus routes in the city.

If travel into an area is fairly concentrated along a single direction, perhaps from north to south or from east to west, then the conditions may allow an even more selective application of counts. Cordon counts and screen line counts follow the same overall principle: while “cordon line” refers to a surrounding area, a “screen line” refers to the divide of an area into two sides (usually along a river or a train line) to learn the flow passing from one side to another.

Once it is determined that public transport ridership is concentrated along a few key corridors where there is potential to build BRT infrastructure, it is a good idea to do frequency and occupancy counts at several points along this prospective corridor, which also helps determine appropriate corridor length.

Ideally the frequency and occupancy counts should be done for each bus and minibus route. Even if the transportation department or the bus authority provides the bus route by bus-route frequency information and ridership information, it is always essential to do the counts anyway, because the data provided is rarely completely reliable.

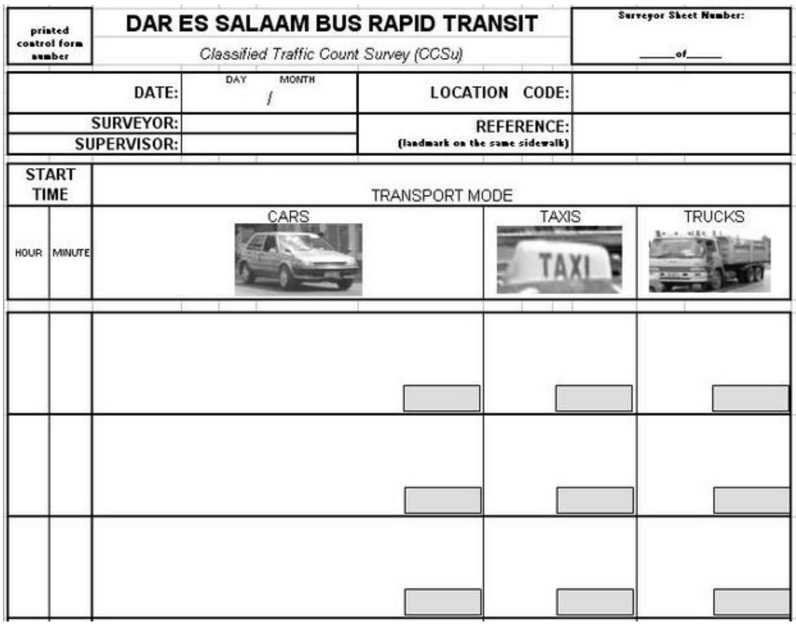
Even if the project team does not plan to eventually use a traffic model, it is a good idea to do a number of counts at a larger selection of critical points all around the city, strategically chosen based on a rough estimate of those locations where most daily trips would pass. These counts will be important in calibrating the public transport model. The model will try to predict existing public transport ridership in each corridor, but it may make inaccurate predictions and need to be adjusted; the counts are needed to determine if the model is an accurate reflection of reality.

One does not need to count so many sites that it becomes cost-prohibitive. For example, in the city of Dar es Salaam (population of approximately 2.5 million inhabitants at the time, nowadays more than 4.3 million) traffic counts in about thirty locations captured a large majority of the trips, and in Jakarta (metropolitan population of above 25 million inhabitants) bidirectional counts in about 100 locations were sufficient.

Often, when one is doing counts of public transport vehicles, one also does counts for the rest of the traffic. Later, these counts will be useful in calibrating more complex demand models, developing rough estimates of impacts on level of service, and other uses. (See Figures 4.5, 4.6, 4.7, and 4.8.)

Figure 4.6. Basic counts of private vehicles help estimate the potential for mode shifting, as well as indicating possible congestion impacts of the dedicated busways. Image of Bangkok, Thailand *Lloyd Wright.*

This information will also provide an important first clue as to how many customers might switch from private cars or motorcycles to public transport as a result of the new BRT system. Such data will be important to estimating projected greenhouse gas emission impacts, which may be critical to eligibility for Global Environmental Facility (GEF) funding.



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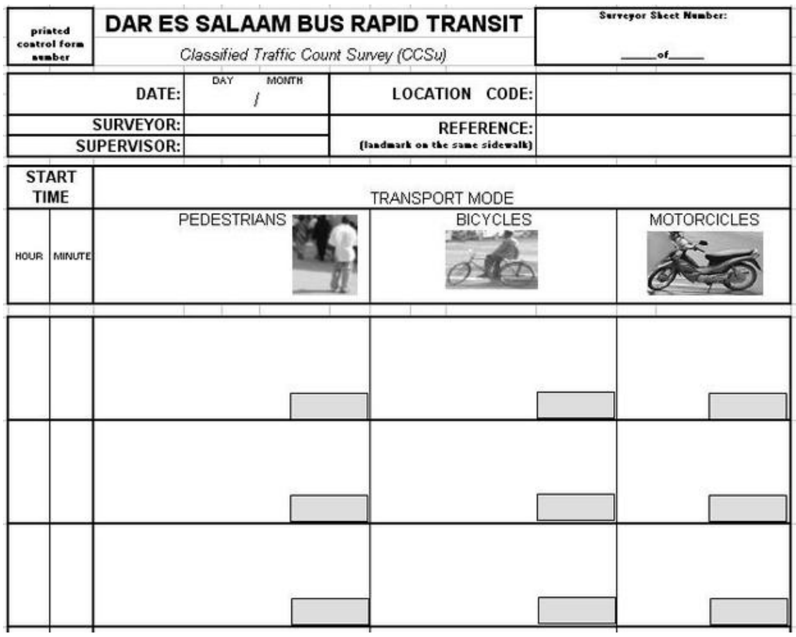
DAR ES SALAAM BUS RAPID TRANSIT
Classified Traffic Count Survey (CCSu)
Surveyor Sheet Number: ____of____
DATE: DAY / MONTH
LOCATION CODE:
SURVEYOR:
SUPERVISOR:
REFERENCE: (landmark on the same sidewalk)
START TIME
HOUR | MINUTE
TRANSPORT MODE
CARS | TAXIS | TRUCKS

Figure 4.7. Survey form for cars and trucks in Dar es Salaam. *ITDP.*



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DAR ES SALAAM BUS RAPID TRANSIT
Classified Traffic Count Survey (CCSu)
Surveyor Sheet Number: ____of____
DATE: DAY / MONTH
LOCATION CODE:
SURVEYOR:
SUPERVISOR:
REFERENCE: (landmark on the same sidewalk)
START TIME
HOUR | MINUTE
TRANSPORT MODE
PEDESTRIANS | BICYCLES | MOTORCICLES

Figure 4.8. Survey form for non-motorized modes and motorcycles in Dar es Salaam. Image *ITDP.*

Additionally, if a full transport-demand model is later used, then the existing data will be in a form that is readily adaptable to a more inclusive analytic package.

As the complexity of the counting process increases, though, the resources required to obtain an accurate count also increase (Figure 4.9). To identify all vehicles and produce a valid count across multiple traffic lanes, a counting strategy becomes vital. One option is to employ counting teams that involve many people at a single location in order to properly record all vehicle types in each of the lanes. Alternatively, video technology can be utilized to record traffic movement and to allow a more precise count at a later time. The video record allows quality-control sampling to ensure that the counting team is performing at a reasonable level of accuracy. With all counting strategies, survey personnel should be properly trained so that all participants have a common understanding of the task at hand.

Figure 4.9. Effective traffic counts require the right set of personnel, including supervisors of the surveyors, and resources. *Municipality of Osaka.*

4.2.3 Occupancy Surveys

The number of vehicles is only one part of the demand equation. Knowing the average number of customers in each of the vehicle types at any given time period provides the other half of the demand input data. Given the diversity of possible vehicle sizes, the occupancy data should be categorized and collected by vehicle type. The survey should thus identify vehicles according to their seating numbers or maximum-capacity numbers. For public transport and minibus vehicles, some of the possible categorizations could include:

- Seventy-seat bus;
- Thirty-five-seat bus;
- Sixteen-seat minibus (Figure 4.10);
- Seven-seat van/large rickshaw;
- Three-seat auto rickshaw;
- Shared taxi.

Ideally, the data on the number of vehicles and the occupancy levels should be collected simultaneously. Usually surveyors record the vehicle type, the number of customers (traditionally a percentage of possible occupancy set at multiples of ten or twenty-five is used, but there is no disadvantage in estimating the exact figure), the route number (if visually evident), and the time of observation. The occupancy provides the basis for a fine estimate of corridor demand. Recording the time is necessary to identify peak and non-peak periods, which should be identified at a resolution of ten-minute intervals. Such a resolution does not disrupt the survey and is enough to identify peak moments, even for a specific route; lower resolutions (five minutes) are not practical and are not of much use, unless we are interested in fluctuations due to traffic-light cycles. Peak and peak of peak period figures are needed for dimensioning the system, especially station capacity (see Chapter 25 for more on station planning).

Figure 4.10. The high flow rate of minibuses along the Soweto Highway in Johannesburg, South Africa, requires an organized counting strategy to get an accurate estimate of vehicles and occupancy levels. Image *Lloyd Wright.*

It is important to have a notation convention for surveyors to enter when they cannot identify the route number (which should be different from "I saw no visible identification") and to enter when they cannot estimate the occupancy (which is different from "no-occupancy," which would be zero customers). It is also preferable for a surveyor to pause (and record the pause) due to a distraction rather than trying to keep a poor record while dealing with it. A sampled occupancy survey is better than a bad occupancy survey. Figure 4.11 shows how much more information occupancy surveys reveal in comparison to frequency-only surveys.

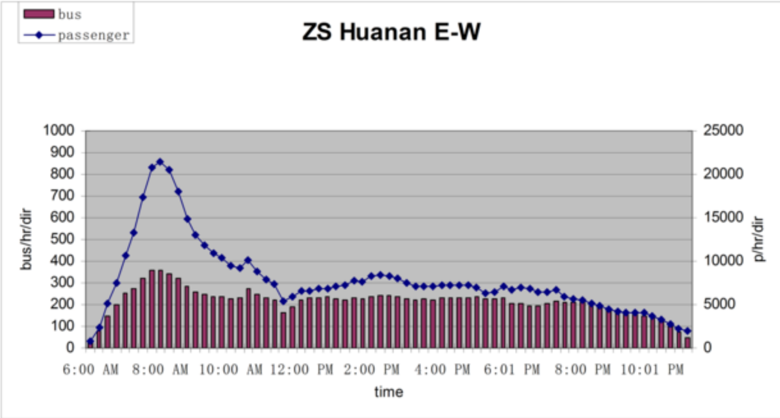

Figure 4.11. Sample graph of bus and customer counts in a single direction at a high demand location on the then-planned Guangzhou BRT in peak and off-peak periods, with customer flows exceeding 20,000 customers and 350 buses per hour in an east-west direction. *ITDP.*

4.2.4 Boarding and Alighting Surveys

Figure 4.12. A count of boarding and alighting at each bus stop along the prospective BRT corridor will be invaluable information in terms of prioritizing corridors, sizing vehicles, and sizing stations. *Maxwell Wagner Colombini Martins.*

Once the corridors with the highest levels of public transport demand have been identified through the route mapping and vehicle and occupancy counts, an additional boarding and alighting survey on selected public transport and minibus lines can be conducted (Figure 4.13) to further understand travelling patterns. This same data set will also show how many customers are on the bus at any given time.

Boarding and alight surveys can be conducted in two main fashions:

1. Surveys of all routes in one station (surveyor is at the station): one of the most important pieces of information when sizing a BRT station is how many customers will be boarding and alighting at each station, and the best way to estimate this is to see how many customers are currently boarding and alighting buses and minibuses in nearby locations.

2. Surveys of all stations of one route (surveyor is on the bus): in this type of survey, surveyors should ride the entire length of each major public transport route during rush hour and record how many people get on and off the bus at each stop. Once this is done for all the routes on a prospective BRT corridor, the boarding and alighting numbers and onboard bus numbers can be consolidated to determine the existing ridership for each stop and each link (bus stop to bus stop). Many good BRT systems have been designed with no more information than this same data set, which will also show how many customers are on the bus at any given time. Additionally this arrangement can:
    - Survey the network speeds (bus stop to bus stop) and the average speed (discussed below);
    - Relate every customer's boarding and alighting stops, by handing numbered cards to customers at the moment of boarding and retrieving them when the customer exits the bus. At each stop the number of the last card handed to customers boarding the bus is written and the cards returned from alighting customers are placed in an envelope used only for that station (this has also been done with surveyors handing bar-coded cards and carrying bar-code readers attached to a raspberry pie with GPS hanging on their belts).

If a city is already using automated passenger counters (APC) or electronic ticket machine data, this data is sometimes useful for getting accurate boarding and alighting data. In the best cases, it can provide bus-stop-specific boarding and alighting numbers hour by hour, for every bus route in the system. Sometimes it is difficult to correlate to specific bus stops, but usually this can be allocated to the nearest bus stop without major loss of accuracy. In a growing number of cities, data from modern fare-collection systems can also be used to get boarding and alighting numbers per bus stop.

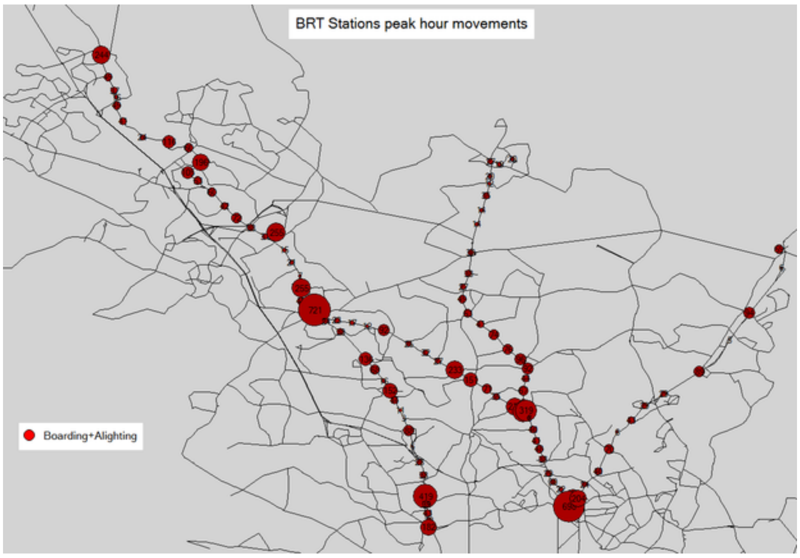

Figure 4.13. An example of peak hour existing boarding and alighting numbers mapped onto some possible BRT corridors based on APC data from Montgomery County, Maryland. *ITDP.*

If neither of these technologies is in place, manual boarding and alighting surveys will need to be conducted. Since this survey is relatively time-consuming and expensive, it can be done for a subset of routes in the city; for example, those routes that have a frequency greater than three buses per hour and overlap for more than 10 percent of their length with the BRT corridor. Properly sampled, and in combination with previous survey data, it is possible to draw an internal picture of current public transport system use (i.e., correlated users' entrance and exit points) in the influence area, in a way similar to that discussed in the next subsection.

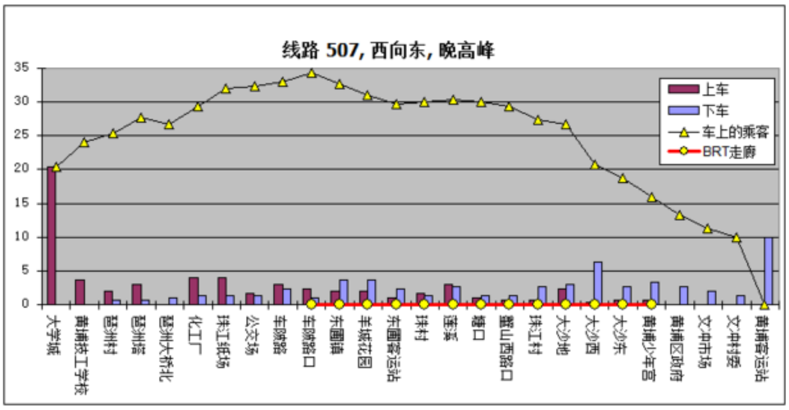

Figure 4.14. This is the display of a survey result taken in 2006 before the Guangzhou BRT was built. It shows the boarding and alighting along bus route 507. The stops with yellow dots connected with a red line are stops along the planned Zhongshan Road BRT system, with the line at the top showing bus occupancy. *ITDP.*

4.2.5 Methods of Developing an Internal Public Transport Origin-Destination Matrix

Recently, BRT system planners have been developing methods for creating an internal public transport origin and destination matrix (OD matrix) based on sampled boarding and alighting and ridership data. In a growing number of cities, ticketing systems collect information about where a specific ticket ID enters a system, but very few systems also collect data about where a specific ticket ID leaves the system. In the more typical case, ticket validation happens upon entering turnstiles, and it is possible to construct an OD matrix by locating the morning ticket-validation point as the trip origin (where the person first enters the system in the morning), and the afternoon ticket-validation point as the destination (where the person enters the system in the afternoon); intermediate validations may indicate transfers depending on analysis of the interval between validations. The main difficulty to this approach is that bus positioning systems and ticketing systems are independent and both generate huge logs, which require a lot of computational power to process (a few hours to process one day of data on a laptop). But this often generates a usable baseline OD matrix with a much larger number of data inputs than any survey method would ever gather. Currently, methods are being developed for doing this in faster ways.

While this, as well as the more detailed boarding and alighting survey, can generate a fairly accurate OD matrix of the boarding patterns in a bus system, it does not reveal the original starting point or eventual destination of customers whose trips involved more than one trip segment or mode, and may not provide a matrix to be directly assigned to the network. For example, if a customer surveyed travels from A to C via B, it will cover both the trips as A-B and B-C separately but will not predict a transfer at B. To determine this information, the onboard survey can be supplemented with an off-board interview survey at major transfer points that needs to be expanded using frequency and occupancy counts.

4.3 Basic Methods for Estimating Public Transport Demand

> *"Computers are useless. They can only give you answers."*
>
> — Pablo Picasso, artist, 1881–1973

The proper data processing of an appropriate sample size, with a few inference models, shall be enough to describe the demand of the current public transport system in the influence area of the BRT system. Modified by assumptions, this is a reliable indicator of the potential demand for a BRT system.

4.3.1 Estimating Demand by Aggregating Boarding and Alighting Data

The boarding and alighting surveys in section 4.2.4 will give a picture of how many customers are currently on each existing bus route, and how many customers are boarding and alighting at each existing bus stop.

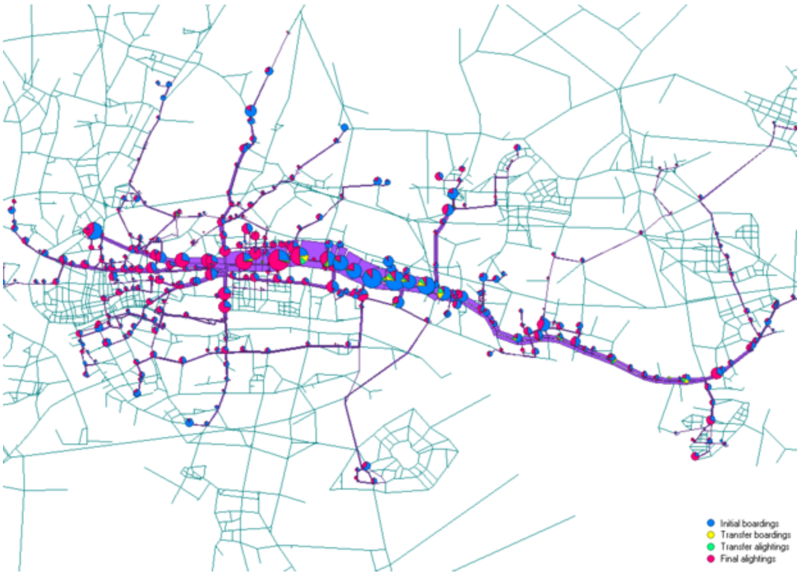

Figure 4.15. Aggregate data for boarding and alighting at current bus stops, allocated to future Guangzhou BRT stations (passengers per hour) in May 2009. (The system opened in February 2010.) *ITDP.*

This is done by simply adding up the boarding and alighting numbers from each of the bus routes at each stop, and calculating the onboard customers along each link. For cities that do not have defined bus stops, the BRT planner can divide the entire network into segments and total customer boarding and alighting at each segment.

This was part of the approach used by ITDP working with the Guangzhou Municipal Engineering Design and Research Institute to plan the operations and infrastructure in the Guangzhou BRT system.

Figure 4.16. The form above, from an MS-Access database, contains information about current bus stops stored in ITDP's preliminary demand model, used in the Guangzhou BRT planning. The lower portion of this form shows which BRT station the customer demand using stop "zs021" is allocated to. Twenty-five percent of the demand is allocated to the Shipaiqiao BRT station ("zsb02"); and 75 percent of the demand is allocated to the Gangding BRT station ("zsb03"). The allocation is based primarily on proximity, but also takes into account intersections and major demand points. *ITDP.*

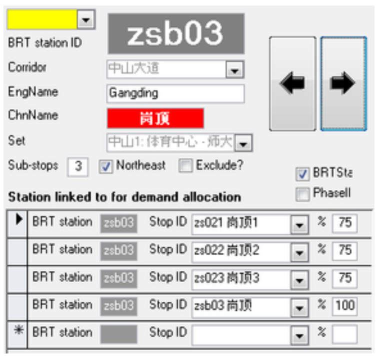

Figure 4.17. The database form for the Gangding BRT station (in this case the southern platform of Gangding station, serving west-to-east direction) shows that 75 percent of bus stop zs021's demand has been allocated to Gangding BRT station. (The remaining 25 percent was allocated to the previous station, Shipaiqiao.) *ITDP.*

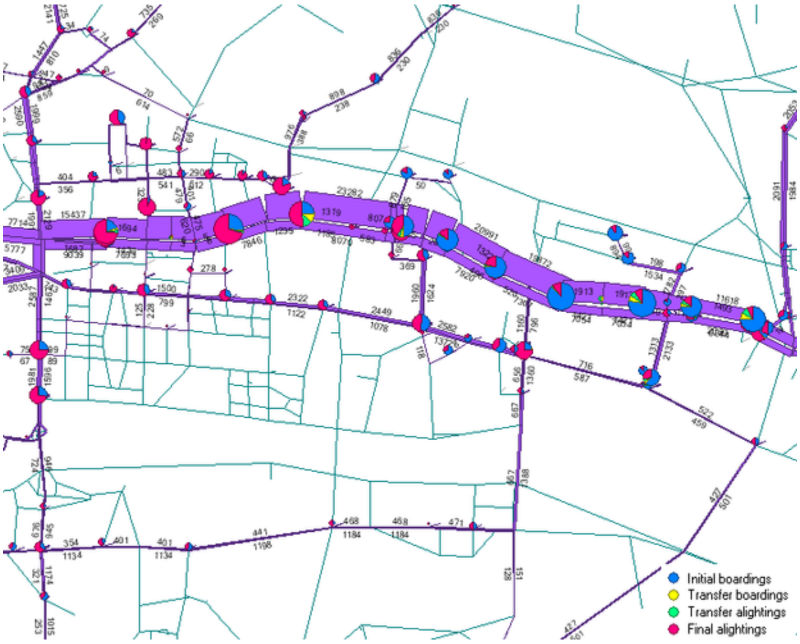

Figure 4.18. Projected morning peak customer flows along the Guangzhou BRT, with BRT customer volumes marked for each link along the corridor. *ITDP.*

The same data can be used to calculate the total customers onboard BRT vehicles along each link of a BRT corridor, and from this the existing maximum customer load at the critical link can be identified (Figure 4.18).

In cities that have both APC data and GTFS data, it is also possible to attribute the APC boarding and alighting data to each route mapped on GTFS to create a very detailed link-by-link, hour-by-hour map, and table of existing public transport demand. This process is currently quite labor intensive, as most GTFS data is not that clean and APC data is not that easy to attribute to specific bus stops. However, it is still faster and cheaper than doing system-wide boarding and alighting surveys. As cities standardize data input processes, and protocols are established for this, it should become even faster and cheaper.

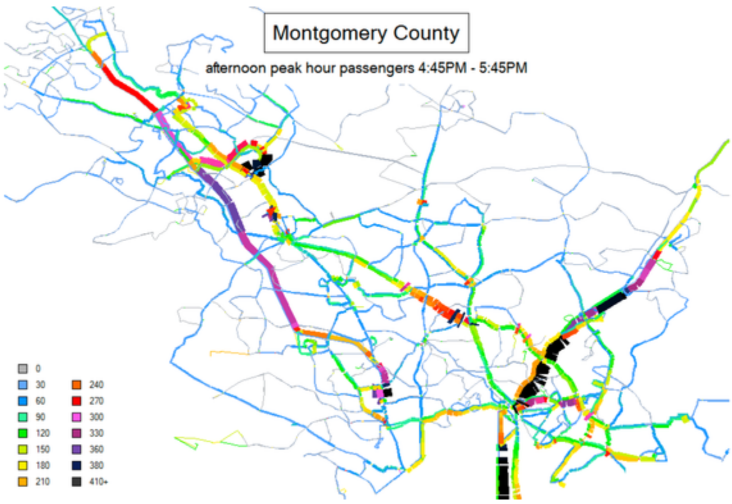

Figure 4.19. The image above was created for Montgomery County, Maryland, USA, to show the existing peak-hour demand throughout the entire county. This was produced in a matter of months and at a very modest cost. *ITDP.*

The demand on the future planned BRT system, however, will vary from the existing demand in a few key aspects. First, if not all the existing bus routes will be allowed to continue on the corridor and make use of the BRT infrastructure, then the demand will be only that subset of customers whose former bus routes have been either incorporated into the new BRT system's service plan, or cut and replaced with a new BRT route. Second, if the speeds on the new BRT system are higher than the existing bus speeds, the new BRT system will gain customers from other bus routes and from other modes.

Ideally, a thorough and well-thought-out BRT service plan would then be developed, and the demand for this specific service plan would be tested. At the early stages of the planning process, though, most BRT system planners use simple rules of thumb to get a preliminary demand estimate.

Normally, each of the existing bus routes that operate along a corridor selected for BRT trunk infrastructure will be ranked based on two parameters:

- The percentage of the existing bus route that traverses the corridor;
- Frequency (and the occupancy, if possible) of bus routes in each direction.

To determine which routes should be included in the system and which routes should be left to operate outside the system, rerouted, or cut, a certain minimum cutoff for the above two parameters is generally used, as was done in Figure 4.19, which applies a policy minimum of four buses per hour and at least 20 percent of the total length inside the BRT corridor, before a route can be considered for inclusion in the BRT system.

Routes with a higher frequency and higher percentage in the BRT corridor are preferred for inclusion in the BRT system. A similar approach was used in selecting the BRT routes in Guangzhou and the Pune, India, region, as well as in Mexico, where the existing bus operator also became the BRT operator.

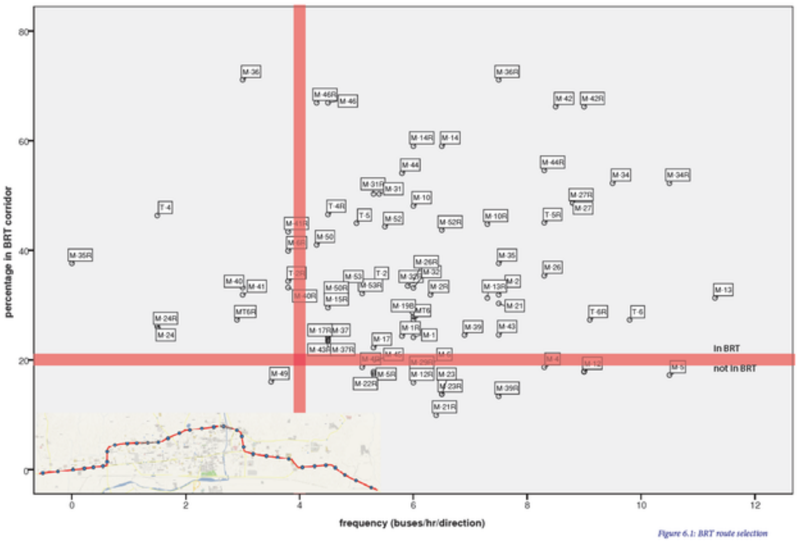

Figure 4.20. Peak frequency and percentage of route traversing the corridor. Example of BRT route selection in a proposed BRT corridor in Ulaanbaatar, Mongolia. Image *ITDP.*

Figure 4.20 is an example from the early planning stages of the Ulaanbaatar BRT system, where, after applying a policy preference for at least four buses per hour and 20 percent of the route length inside the BRT system, the remaining routes could be included in the BRT system. These percentages are not hard and fast rules. The idea is simply to capture as much of the existing public transport demand as possible in the most efficient way for the BRT system. Given that station space is at a premium and that operation of the BRT requires new buses, routes with higher frequencies and percentages in the corridor are prioritized. This is a preliminary step. Detailed subsequent service planning is covered in Chapter 6.

When building a BRT system, some bus stops are going to be eliminated and other stops are likely to be consolidated. Therefore, the current numbers of boarding and alighting customers from the bus routes that are to be included in the system need to be allocated to the new BRT stations. This is generally done by proximity: the existing boarding and alighting trips are allocated to the nearest new BRT station.

By collating the total number of boarding and alighting customers at each new BRT station stop from each of the existing routes that are likely to be incorporated into the new BRT system, the number of boarding and alighting customers per stop can be estimated. By collating the total numbers of customers on board for each link (taken from the same data set), the maximum load on the critical link of the new BRT system can be estimated. This maximum load will be a critical input into making design decisions for service and infrastructure planning as detailed in the following chapters.

The new BRT system, if designed correctly, should be able to achieve speeds of up to 29 kph on a major arterial if express routes are included, and 17 kph in downtown areas (with local service). Multiplying the number of projected customers by the difference between existing aggregate speeds and the projected BRT operating speed will yield the projected time-savings benefit of the corridor, but planners should keep in mind that it will not gain door-to-door travel time savings. The other main benefit that can be quantified is the fleet saving for BRT operators, taking into account the increase in bus speeds after BRT is implemented, and using bus fleet requirements as a proxy for overall operational costs. These two factors are what convinced the Guangzhou City Government to implement BRT in a heavily congested city center corridor, rather than in a peripheral suburban location.

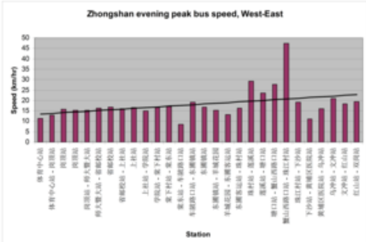

Figure 4.21. Using the same boarding and alighting survey, average vehicle speeds in the corridor can be calculated and arranged in a graph. *ITDP.*

4.3.2 Mode Shifts

Planners still need to make certain assumptions about how many new customers are likely to be attracted from other modes. To get a robust estimate requires a transport model, but an important clue will be the existing bus and private vehicle speed data. If existing public transport speeds are already at or above 26 kph, it can safely be assumed that the new system will not provide a significant time savings benefit. This lack of time savings will limit the number of new customers attracted to the system, although customers may be attracted for other reasons (safety, security, comfort, fare price, etc.). The lower the existing public transport speeds, the higher the projected modal shift (Figure 4.21). This also extends to private vehicle speeds—if speeds are low and travel times long, people are more likely to find BRT convenient and efficient.

Another factor to consider when estimating a likely modal shift is the existing modal split. In cities where public transport trips make up a small fraction of total demand, but shared taxis, minibuses, or three-wheelers make up a large share of trips, the potential modal shift is likely to be greater than in systems where the vast majority of trips are already made by bus.

A final factor is the system design's effect on mixed-traffic levels of service. If the project sponsor adopts a design that significantly degrades the mixed-traffic level of service yet significantly improves the speed of bus customers, the modal shift will also be higher. Normally, engineers try to avoid this impact, but there are occasional bottleneck situations where tough choices are hard to avoid.

Figure 4.22. If existing public transport services are slow or inefficient, the upgrading to BRT will produce a significant shift in customers to the new service. *Lloyd Wright.*

Projecting the modal shift using traffic modeling is sufficiently complex that simple rules of thumb may not be nearly as reliable. In BRT systems with speeds at or above 20 kph and considerably above previous bus speeds, the demand will be from 5 to 20 percent higher than the baseline demand for the existing bus system. It is unlikely that short-term modal shift will be more than 25 percent of the baseline demand from existing public transport trips, though the system should be designed to accommodate an increase of 50 percent above existing public transport demand.

However, in cases of uncertainty (for example, a large number of difficult-to-count shared taxi trips, or a deteriorated bus system that is underused), designing the system to accommodate as much as a 100 percent increase in ridership, or use of full demand modeling, is recommended.

If the majority of the vehicles on the corridor are buses, then the traffic benefits of the project will be broadly distributed between both bus customers and mixed traffic, but the modal shift impact will be less. If the majority of the vehicles on the corridor are private vehicles, then a busway will tend to have a stronger adverse impact on mixed-traffic speeds, a stronger positive impact on bus speeds, and therefore a bigger potential modal shift impact.

Making a final determination about potential benefits of the system and potential mode shift requires additional information about current vehicle speeds and congestion points.

Table 4.2 provides estimates based on observed impacts in BRT systems around the world. These estimates consider only the vehicle mix on each corridor and the level of congestion on those corridors.

Table 4.1. Projected modal shift impact based on type of BRT corridor

Type of BRT Corridor	Projected Modal-Shift Impact from Private Vehicles
Little congestion, buses > 30 percent of the vehicle fleet	5 percent
Some congestion, buses around 25 percent of vehicle fleet	10 percent
Many links congested, buses around 15 percent of vehicle fleet	15 percent
Very congested, few buses on the corridor	20 percent

4.4 Estimating Demand with a Public Transport Model

"The best way to predict the future is to invent it."

— Immanuel Kant, philosopher, 1724–1804

Aggregating boarding, alighting, and customer flows, as in the previous section, provide a useful "first cut" approach to demand estimation. However, this data does not provide information on where people wish to travel. In most cases, a new BRT system will make changes in bus routes, and knowing the origins and destinations of trips (as opposed to boarding and alighting) is important to ensuring that the new services are closely aligned with where customers want to go. In particular, full OD information can inform the design of direct services that reduce the need for customers to transfer from one line to another. As a BRT system expands into a multi-route system, there will be many opportunities to significantly improve services and system efficiency by modifying routes and services, and the potential financial savings should more than pay for the additional cost and trouble associated with building a robust public transport model. This requires two new elements: the construction of a trip matrix and a route-choice model.

This section will describe how to build a basic transport model that models only the public transport system. With this basic public transport model, it will be possible to develop a much more robust estimate of the demand on the existing system. It will also enable the planning team to much more easily test the demand for different alternative scenarios for fares, as well as to optimize operational characteristics.

In many cities, some sort of transport model will already exist. But these models have generally been created for a specific purpose, and the purpose has rarely been to design a BRT system. Sometimes, existing models were designed for highway or transport departments and are only usable for motor vehicles, with very limited information on the public transport system. Others may have been created for building a metro, and not usable without additional work. Data is also far too often of poor quality. If a good quality transport model already exists, it should be possible to simply put the public transport system and the proposed BRT scenario into the existing model. However, in most cases the BRT team may have to start nearly from scratch. The public transport system should be modeled first, as this will be the most important information for BRT planning.

4.4.1 Choosing a Modeling Software

The first step in setting up a public transport model is to obtain transport-modeling software. The development of transportation modeling software has greatly aided the process of transport supply and demand projections. Software models today can greatly ease the modeling process and increase accuracy and precision. But with the array of software products on the market, the transport planner can be left with an overwhelming set of options. Of course, there is no one software solution that is inherently correct. A range of variables will guide the software selection process. These variables include cost, familiarity of municipal staff and local consultants with a particular product, degree of user friendliness sought, degree of precision sought, and the overall objectives of the modeling task. The table below lists a few commonly used software packages on the market today.

Table 4.2. Options for Transport-Modeling Software

Software Name	Vendor	Comments
EMME	INRO	Good general purpose
CUBE	Citilabs	Good general purpose
TransCAD	Caliper Corporation	Good integration with GIS, easy to use

Visum	PTV	Good general purpose
QRS II	AJH Associates	Low cost but weaker on PT assignment
TMODEL	TModel Corporation	Low cost but weaker on PT assignment
SATURN	Atkins-ITS	Good for meso-simulation for congested vehicle assignment, but no PT assignment
AIMSUN 6	Transport Simulation Systems	Integrated package for micro, meso, and macro simulation model
TRANUS	Free software developed by Modelistica	Integrated land use – transport model
Paramics	SIAS	Microsimulation package with integration capabilities
VISSIM	PTV	Microsimulation package, good animations, good integration with VISUM

The strongest packages for general-purpose planning and design of BRT systems are EMME, CUBE, and VISUM, with TransCad offering close capabilities. All of these are expensive packages. However, in actuality, the most significant costs will be training staff to become familiar and adept with the software package. Older and more-sophisticated modelers, like the flexible Emme, allow staff to easily write subprograms, called "macros." More and more consultants are now using Emme in combination with other programs with better GIS capability or with micro-simulation facilities. SATURN is a meso-simulation package that efficiently models groups (platoons) of vehicles and treats delays and congestion accurately, but its public transport facilities are too weak for BRT design. Equally, TMODEL and QRS II are weak at modeling public transport demand and are not recommended for BRT.

TRANUS can model land use and transportation systems. The transportation model can be used separately and is easy to use and calibrate. The land use model might be difficult to use and calibrate, particularly if many land uses are included in the modeling. Paramics and Vissim simulate trip making at a high level of detail, in particular vehicle-by-vehicle, and in some instances include pedestrians and traffic lights. These are very powerful packages for studying priority at junctions and interactions and delays at stops. They should only be used for these purposes and in combination with the macro demand models listed above, as they are not appropriate for BRT-route analysis. AIMSUN 6 is an integrated package that combines these micro-simulation features with micro- and macro-modeling facilities.

4.4.2 Defining the Study Area and the Zoning System

Normally, the study area for a BRT system will be the areas currently served by bus and minibus services. If the decision maker has already preselected a particular corridor as the first BRT corridor, then the catchment area for this corridor will be the study area, but this may produce a lower demand forecast.

To analyze travel, the entire study area, as well as some locations outside the study area, need to be divided into a number of zones (Figure 4.22). As all origin-destination data will be collected and coded into this zoning system, establishing these zones is an important first step. Usually the zones are based on census tracts or political subdivisions that have been used as the basis of any existing census information or previous origin-destination studies. Using census and other administrative zones that already exist in the city will increase the chance of compatibility with the overlaying of different data types.

The information needed for modeling, however, is not exactly the same as the information needed for the census, so some census zones are usually consolidated into bigger zones or broken up into smaller zones. Transport modelers are generally less concerned about information outside the study area. As a result, they tend to consolidate zones outside the study area into fewer, larger zones. This consolidation is a simple matter of adding up the data associated with each zone.

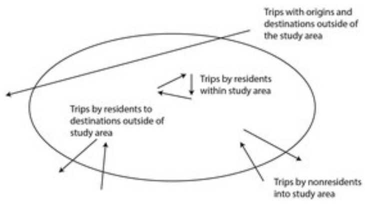

Figure 4.23. Representation of study area for analysis. *Ortúzar and Willumsen 2011.*

Typically, modelers need more-detailed information in the city center and/or along the proposed BRT corridor and its catchment area. So modelers will typically break up census zones into smaller zones, using more-detailed census data if available, or just dividing the zones using their judgment based on aerial photographs (Figure 4.24). Sometimes, households and employment will be concentrated into some parts of a large zone and not others, and it is important to break up the zone to capture this geographic concentration.

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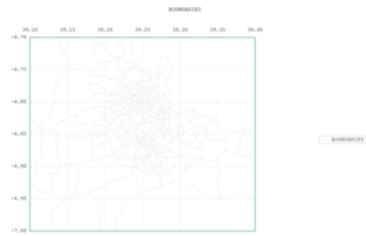

Figure 4.24. Geographic area divided into zones for modeling purposes. Zoning system for Dar Es Salaam BRT feasibility study. *ITDP.*

Selecting the size of the zones and the number of zones is a trade-off between accuracy, time, and cost. The size and number of zones will also depend in part on how the data was collected and how it will be used. Ideally, one would like to have a single zone associated with each BRT station/stop. However, this is not always feasible and some compromises are needed. For BRT systems in large cities like Jakarta and Bogotá, roughly five hundred and eight hundred zones, respectively, were used to analyze the main relevant BRT corridors. In a smaller city like Dar es Salaam, only three hundred zones were necessary for the main BRT-corridor analysis, though for detailed traffic-impact analysis, the city center was later broken down into an additional twenty zones.

Table 4.4 lists the number of zones that have been developed for various cities. Note that cities such as London have multiple levels of zones that permit both coarse- and fine-level analyses.

Table 4.3. Typical Zone Numbers for Modeling Studies

Location	Population	Number of Zones	Comments
Bogotá (2000)	6.1 million	800	BRT project
Jakarta (2002)	9 million	500	Strategic planning zones
Dar es Salaam (2005)	2.5 million	300	BRT project
London (2006)	7.2 million	2252	Fine level subzones
		1000	Strategic planning zones
Santiago (2009)	5.5 million	700	Strategic planning zones
Montreal Island (2008)	3.4 million	1425	Strategic planning zones
Dallas-Fort Worth (2004)	6.5 million	4900	Strategic planning zones
Ahmedabad (2009)	5.4 million	1,400	One zone per bus stop
Pune-Pimpri Chinchwad (2011)	5.3 million	1,855	One zone per bus stop

Source: Ortúzar and Willumsen (2011) and ITDP

Usually, models provide a good level of accuracy for trunk routes, but not necessarily for feeder routes. Feeder routes typically serve an area within a zone, especially outside of the direct catchment area of the BRT, where zones are normally a bit larger. Thus, those movements are not recorded in the model. A very detailed model to account for feeder routes, however, is not practical; so, besides using the modeling tool, the feeder system should be designed based on the existing system (field observation and experience) and allow flexibility to make changes during implementation.

These zones, and the road network, must be coded into the transport model. This process will not be described here in any detail, as it is a standard function of all transport modeling and is thoroughly described in the documentation of any commercially available transport demand model. The basic points of this process are summarized below.

Data is usually entered into a transport model either as a point, called a "node," which has a specific "x" and "y" coordinate, or as a "link," which is a line connecting two nodes. Normally, each intersection and each major bend in a road are assigned separate nodes. Nodes are usually numbered. Ideally, the x and y coordinates of each node should correspond to the actual latitude and longitude of that node. Making sure these nodes correspond to actual latitude and longitude is called "geocoding." Geocoding will ensure that data from different sources are consistent.

Normally roads are broken up into different links. Links are usually named from their origin node and their destination node.

For example, in Dar es Salaam, there was already an existing GIS map. If no GIS map exists, then staff can utilize a GPS device to record the coordinates of each of these points (Figure 4.25). In Dar es Salaam, the team initially defined 102 nodes, and later increased it to 2,500 important nodes. By the end, the nodes represented most of the important intersections in the city. Each node was recorded in a simple spreadsheet (Table 4.5). Alternately, the street network can be traced over a geo-referenced aerial photo.

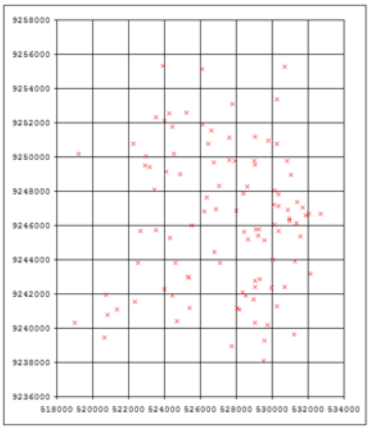

Figure 4.25. Nodes and links from the Dar es Salaam public transport model used to design the DART BRT system. *City of Dar es Salaam.*

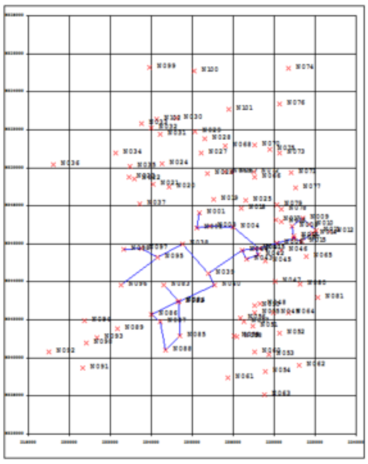

Figure 4.26. Fixme *copyright.*

Table 4.4. Node Coordinates in Dar es Salaam

Node identification number	X coordinate	Y coordinate
13	16340	26375
14	16835	26370
17	17212	26440
23	16433	26090
24	16835	26090
27	17339	26185
28	17580	26300
33	16435	25810
34	16835	26805
127	17110	26060
128	17540	25930
134	17285	25675

By connecting these nodes, a series of links are defined that represent different roads. For example, in Dar es Salaam, Morogoro Road between Sokoine Drive and Samora Avenue, is a link (the link between the nodes Morogoro Road X Sokoine Drive and Morogoro Road X Samora Avenue). Link data can also be entered into the transport model from an Excel spreadsheet (Table 4.6).

Table 4.5. Link Data for the Transport Model in Dar es Salaam

Link	Node A	Node B	Two directional
1	13	14	Yes
2	14	17	Yes
3	13	23	Yes
4	14	24	Yes
5	17	27	Yes
6	23	24	Yes
7	24	127	No
8	127	27	No

9	27	28	No
10	23	33	Yes
11	24	34	Yes
12	33	34	Yes
13	28	128	No
14	128	134	No
15	134	34	No

These links are generally further defined based on the number of lanes, direction of movement, and other characteristics. However for public transport planning it is not really necessary to further define at this point.

Zones are generally entered into a transport model based on the nodes of all points that are needed to define the boundary. In an Excel spreadsheet, each zone will just look like a series of nodes defined by their x and y coordinates.

Once the data is entered into a model, the zone is actually represented by a special type of node called a "zone centroid." This zone centroid is a node that is used to signify the average characteristics of the particular zone. In Dar es Salaam, for example, in addition to 2,500 nodes along roads, there were another 300 zone centroid nodes. Trips are generated and attracted to these centroids. It is therefore important to know how these centroids are connected in particular to stations in a new BRT design. Normally these zone centroids are in the middle of the zone, but if all the population is concentrated in one smaller part of a zone, it is better to move the zone centroid closer to the population concentration.

4.4.3 Origin-Destination Survey and Matrix

There are two basic ways to create a public transport system origin-destination matrix for public transport customers without doing a household survey. The most common approach is to conduct an onboard origin destination survey of an entire study area. This survey is one of a family of surveys called intercept surveys, where individuals in the process of making a trip are interviewed either on a bus or minibus, or while riding their bicycle, about their trip origin and destination (where they began their trip and where they will end the trip) and also often the purpose of the trip. Planners should remember that this type of survey will not provide estimates for possible mode shift for private vehicles nor induced demand. And if it only applies to a portion of the city, it may not take into account important changes in travel patterns in the public transport system when a BRT system is implemented.

Another approach that is becoming popular, as mentioned in Section 4.3.5. above, is to do a type of boarding and alighting survey where customers are given a numbered token when boarding a bus or minibus, and then they turn in their token when alighting. In this way, their precise boarding and alighting location is recorded. This creates an OD matrix that is specific to a bus route. When all the bus-route-specific OD matrixes are added up, one has a type of OD matrix that has one main problem: it is unable to distinguish between those customers whose origin and destination are near the bus stop where they boarded or alighted, and those customers who are transferring to some other public transport route or other means of travel. This problem can be partially corrected by conducting extensive transfer surveys at any likely transfer point, and using the transfer ratios to adjust the OD matrix. This method is often faster, cheaper, and easier to conduct, and as a result larger sample sizes are usually viable. There is also a reduced risk of coding errors. It also has its downside. If the transfer points are not very well known, or if buses do not stop in regular locations, many transfers may be missed, leading to distortions. This sort of survey also does not provide useful information about trip purpose, and precise destinations that may be quite far from bus stops.

Origin-Destination is not always used by transport agencies to forecast ridership. According to a survey conducted for a Transit Cooperative Research Program (TCRP) report on forecasting and service-planning methods, only 29 percent of transport agencies in the United States consider OD data to be a major part of demand estimation. Nearly half (43 percent) consider OD data when forecasting ridership but do not see it as a major part of demand estimation. Twenty-three percent of agencies did not consider OD data at all.

Overall, the survey found that 63 percent of transport agencies used OD data gathered from onboard surveys and 40 percent of agencies used OD data derived from modeling as a source when forecasting ridership. In comparison, ridership data collected from fare boxes and by ride checks were much more likely to be used. Eighty-six percent of agencies used data from the fare box and 80 percent used occupancy surveys. Ridership data collected by automated customer counters, a relatively new means of data collection, was used by 40 percent of agencies. Other data sources considered were: existing land use patterns (71 percent), forecast land use patterns (54 percent), census demographic data (66 percent), and economic forecasts (31 percent) and trends (29 percent).

Data Collection for Intercept Survey Approach

All the origin and destination information collected will be coded as between the zone centroids of two of these zones, and aggregated based on these zones. A trip between two zones is called an "origin-destination pair," or *OD pair*. The table of all the trips between each OD pair by any given mode, in this case public transport, is called the *OD matrix*.

To conduct an onboard OD survey, public transport users are interviewed either on board a bus or minibus vehicle (in that case it is not an interception point, but a section of a road between two intersections) or at stops and interchanges. Sometimes, with the cooperation of the police, minibus customers can be interviewed very efficiently by having the van driver pull over and allow the customers to be interviewed. In Dar es Salaam, with the cooperation of the police, the planning team, wearing DART (Dar es Salaam Rapid Transit) shirts, stopped Daladalas (paratransit vehicles) and interviewed all of the customers inside (Figure 4.24). Other data besides OD information can also be collected, if appropriate. Other useful information can include the fares paid and the services used, but the questions should be kept as simple as possible. Although it is tempting to ask about waiting times, these are seldom accurately reported by individuals and are best estimated by another method.

Onboard OD surveys of bus customers typically attempt to focus on customer flows during the morning peak period. However, it can be difficult to avoid capturing nonpeak trips as well, so normally data is collected for approximately four hours around the morning peak, and averages are taken or weighted.

Figure 4.27. Collecting data on origins and destinations and fares paid from customers using the Dar es Salaam "Daladalas" system helped define the operational characteristics of the proposed BRT system. *Maxwell Wagner Colombini Martins.*

The survey locations should correspond to the locations where the traffic counts were conducted earlier, if these points were chosen wisely. In the case of Dar es Salaam, the points where the OD surveys were conducted were the same thirty-four points of the original traffic counts. This precision was possible due to the assistance of the police in pulling over vehicles at particular locations. In Jakarta, the surveys were conducted on board the buses and minibuses, so surveys were conducted along key links that corresponded as closely as possible to the points where previous traffic counts had been conducted.

Sample Size

The sample size for intercept surveys depends on the accuracy required and the population of interest. The error for an intercept OD survey is a function of the number of possible zones that a customer might travel when passing through a particular point. As a simple rule, Ortúzar and Willumsen (2011) suggest the following table for a 95 percent confidence, with a margin of error of 10 percent for given customer flows:

Table 4.6. Sample size for origin-destination surveys

Expected Customer flow (customers/period)	Sample size (percent)
900 +	10 percent
700–899	12.5 percent
500–699	16.6 percent
300–499	25 percent
200–299	33 percent
1–199	50 percent

Usually, on potential BRT corridors, the flows are much greater than 900, so 10 percent of the total customer flow at any given survey point is a reasonable rule. In the case of Dar es Salaam, the average customer flow at the peak hour was 10,000, so 1,000 customers were surveyed at each point, or some 34,000 surveys for all the points. In Jakarta, 120,000 surveys were conducted, but only about 65,000 of the surveys were usable. This quantity was all that was possible with the budget available, and constituted roughly 3 percent of the peak hour flows. In Jakarta, the survey numbers were weighted based on the flows on the corridor.

Origins and destinations should be recorded as accurately as possible—for example, as the nearest intersection or other key identifier. These locations then have to be attributed to the zone in which they are located, so the origin and destination can be coded to the zone centroids.

Error Types

The data collection process is prone to two types of errors: measurement errors and sampling errors. Measurement errors arise from misunderstandings and misperceptions between the questions asked and the responses of the sampled subjects. Misinterpretation by the interviewer can result in the incorrect listing of a response. Frequently, during an OD survey, for instance, a person will identify the origin and destination of their trip, but neither the interviewee nor the surveyor are able to locate this location within any of the zones on a map. Sometimes surveyors will also not do the work responsibly and will make up answers. There may also be a degree of bias in which respondents answer questions in a manner that represents a desired state rather than a reality.

Avoiding measurement errors is a complex process that requires a lot of local knowledge, and should start at the survey stage. One method is to ask the interviewee the best local landmark, and have the local staff identify as precisely as possible its location on a map. Another method is to have the interviewees pick their origin and destination from a preselected list of areas and subareas, and specific popular destinations. The latter method will probably avoid a lot of trouble and confusion, but will lose some subtlety regarding walking distances. In countries where street names and neighborhoods are far from standardized, the latter method may be more effective.

Sampling errors occur due to the cost and feasibility of surveying very large sample sizes. Sampling errors are approximately inversely proportional to the square root of the number of observations, i.e., to halve them it is necessary to quadruple the sample size.

Origin Destination Matrixes

Once each OD pair is coded to specific zone centroids, a separate OD matrix is created for each survey point. For each survey point and each direction, it is simply a matter of adding up the trips surveyed between each OD pair for the peak hour.

This raw survey data will give you a preliminary OD matrix for each direction at each survey point. Table 4.8 outlines the general form of a two-dimensional trip matrix.

Table 4.7. General form for a two-dimensional trip matrix

Origins	Destinations					
	1	2	3	...j	...z	∑j Tij
1	T11	T12	T13	...T1j	...T1z	O1
2	T21	T22	T23	T2j	T2z	O2
3	Tij	Tij	Tij	Tij	Tij	O3
I	Ti1	Ti2	Ti3	Tij	Tiz	Oi
Z	Tz1	Tz2	Tz3	Tzj	Tzz	Oz
∑i Tij	D1	D2	D3	...Dj	...Dz	∑ij Tij = T

Source: Ortúzar and Willumsen 2011.

From Table 4.8, "T11" indicates how many trips were made within Zone 1; "Tij" indicates the total surveyed trips between Zone i and Zone j; "O1" is the total origins in Zone 1, and "D1" is the total destinations in Zone 1.

This simple matrix is still not a full OD matrix for the whole city's public transport trips during the peak hour. To get to that, the number of people surveyed needs to be related to the total number of public transport customers per direction per hour at each survey point. This process is called *expanding the matrix*. The total number of public transport customers at the peak hour is taken from the data that was collected earlier at each of the same points using the public transport vehicle-occupancy surveys. For example, in Dar es Salaam, on some corridors 1,000 out of 10,000 hourly public transport customers per direction were collected on some corridors, which yielded an expansion factor of ten. On this matrix, the observed OD trips need to be multiplied by ten to get the total public transport trips at the peak hour. On other corridors, where 1,000 interviews were taken for only 6,000 customer flows, the expansion factor is six, so the surveyed OD trips need to be multiplied by six. Each separate matrix needs to be expanded by its appropriate expansion factor (as indicated in Table 4.9.), or can be expanded using a single expansion factor.

Table 4.8. OD Matrixes Expanded by Expansion Factor

Point	Initial factor	Sample	PAX/Peak Hour	Daladala small	Daladala large
P01W1	12.9295302	298	3853		
P01W2	1.53046595	558	854		
P02W1	6.545655774	493	3227.008297	320.5	63
P03W1	5.833990702	515	3004.505212	68	68
P03W2	2.928214064	522	1528.527741	60	54
P04W1	14.87864833	619	9209.883319	409.5	95.50
P06W1	9.375530401	511	4790.896035	65.5	107
P06W2	4.431338691	358	1586.419251	83	62.5
P07W1	2.597194766	502	1303.791773	164	8
P07W2	9.968302596	449	4475.767865	210	16

P09W1	12.92116263	470	6072.946436	180.5	65.5
P09W2	6.609650125	485	3205.680311	181	47.50
P10W1	25.42999509	515	13096.44747	628.5	65.5

Because the point of each OD survey was chosen to pick up a discrete set of OD pairs, each individual OD matrix will largely cover a different part of the city, but there will be some overlap and therefore the risk of "double counting" trips will happen twice. The individual matrices will have some OD pairs with actual values, and some OD pairs with zero trips (Tables 4.10 and 4.11).

Table 4.9. OD Matrix #1 Eastbound Morogoro Road and United Nations Intersection

Origins	Destinations					
	1	2	3	4	5	∑j Tij
1	4	10	6	0	0	O1
2	12	4	2	0	0	O2
3	16	5	12	0	0	O3
4	3	2	0	0	0	Oi
5	0	0	0	0	0	Oz
	D1	D2	D3	D4	D5	Total

Table 4.10. OD Matrix #2 Southbound Old Bagamoyo Road and United Nations Intersection

Origins	Destinations					
	1	2	3	4	5	∑j Tij
1	0	0	0	12	15	O1
2	0	0	3	15	20	O2
3	5	2	15	8	10	O3
4	0	0	0	6	11	Oi
5	0	0	5	12	10	Oz
	D1	D2	D3	D4	D5	

To develop the full OD matrix for public transport trips in Dar es Salaam, a simple estimate would be to take the maximum value for any OD Pair in any observed survey. Strictly speaking, the correct value for each cell where multiple observations are expected depends on p_{ij}^a, the proportion of trips between origin i and destination j that pass through each intercept point a, on r_a, the sampling ratio at each point a (a number between 0 and 1), and on s_{ij}^a, the number of trips between i and j observed at point a. Then, the correct estimator for the number of trips when there are n_{ij} points that would have intercepted trips from i to j, is:

$$T_{ij} = \frac{\sum_{n_{ij}} \frac{s_{ij}^a}{r^a}}{\sum_{n_{ij}} p_{ij}^a}$$

Of course, if there is only one intercept point for that OD pair ($n_{ij} = 1$) and there is only one useful route from i to j ($p_{ij}^a = 1$), then the formula reverts to the familiar sample expansion:

$$T_{ij} = \frac{s_{ij}^a}{r^a}$$

For illustration purposes in Table 4.12, the values from the previous two tables have been combined to form a complete OD matrix (assuming that only two points are surveyed).

Table 4.11. OD Matrix Dar es Salaam

Origins	Destinations					
	1	2	3	4	5	∑j Tij
1	4	10	6	12	15	O1
2	12	4	3	15	20	O2
3	16	5	15	8	10	O3
4	3	2	0	6	11	Oi
5	0	0	5	12	10	Oz
	D1	D2	D3	D4	D5	Total

This methodology is used to avoid the double (or triple) counting of some trips. This double counting may happen because some journeys may have been intercepted by more than one survey station, either potentially or in the sample. In this case, steps must be taken to avoid exaggerating their importance in the matrix by weighting those cells appropriately—for example, taking the average value of duplicated cell entries. On the other hand, people may go in very different directions to reach the same endpoint, so using this method will undercount the total demand. For more details, consult Ortúzar and Willumsen 2011.

Validation

Due to these distortions, along with measurement and sampling errors, it is usually necessary to undertake corrective actions. A validation process is typically done at the conclusion of the data-collection process in order to provide a degree of quality control.

Validation is usually accomplished by looking at OD pairs route by route, and doing an informal trip assignment, assigning the OD trips to specific public transport routes, and comparing the aggregate total trips to the aggregate trip counts developed from the occupancy surveys and public transport vehicle counts (Figure 4.27).

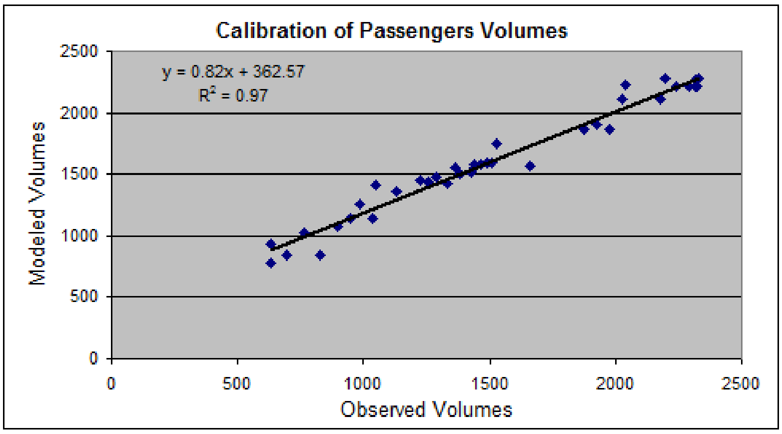

Figure 4.28. Modeled versus observed customer volumes in Jakarta. *Remi Jeanneret.*

Once the OD matrix has been cleaned and calibrated, the OD matrix can be input into the transport model, and the testing of different scenarios can begin. The OD matrix can also be used to generate an origin-destination map that gives decision makers an overall view of the density of origins and destinations in the city. The OD map will frequently illustrate the extent to which trips are distributed or are centralized within the city. The OD map of Bogotá shows that there is a heavy concentration of trip destinations to the central business district (Figure 4.28).

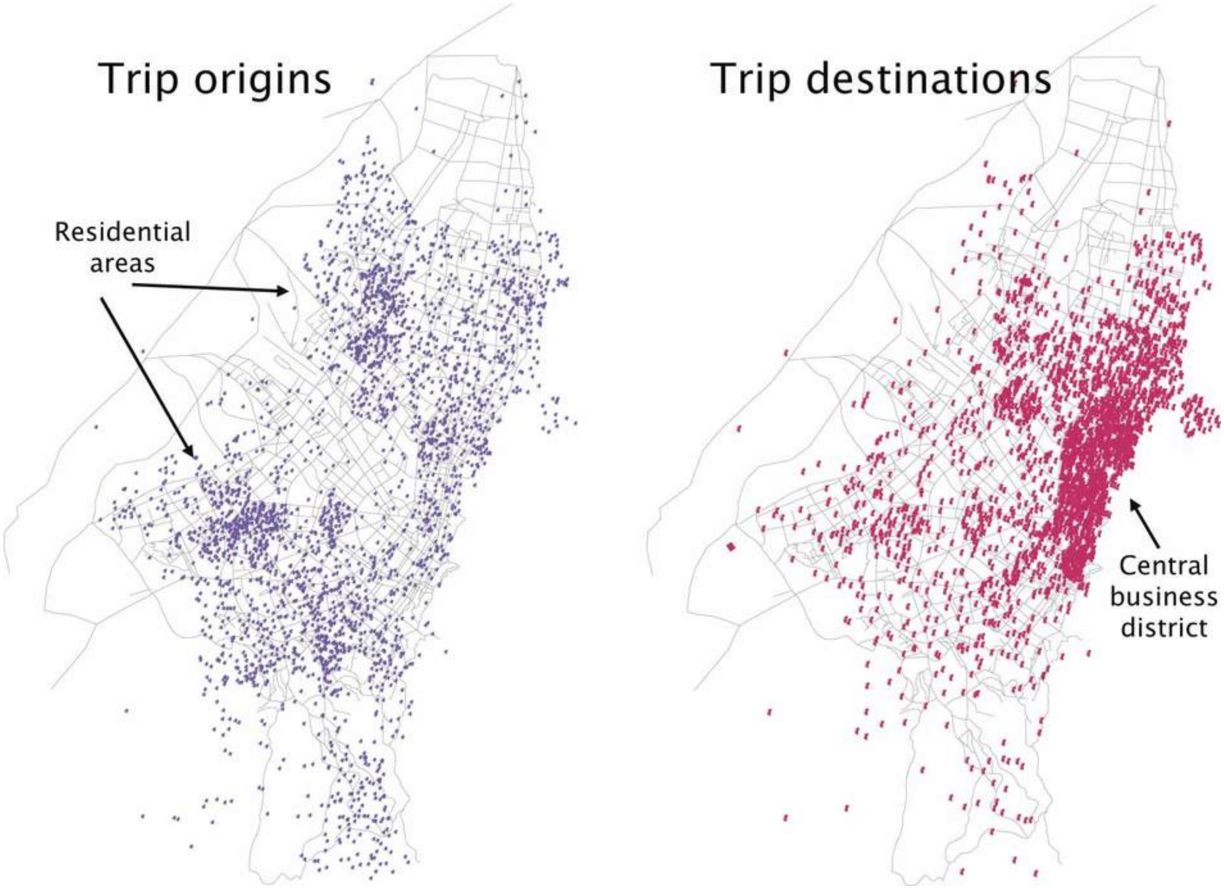

Figure 4.29. Origin-destination map for Bogotá. *TransMilenio SA.*

4.4.4 Outputs of the Public Transport Model

Once the road system and the OD matrix are input into the transport model, different scenarios for the BRT system can be tested. While the output from the public transport model will be used at various points throughout this guide, for the time being it will be used to generate demand estimates for specific BRT system scenarios.

The first step is generally to take a look at the existing public transport demand on all major corridors throughout the city at the peak hour. These results should now yield a much more accurate estimate of total existing public transport demand on all the major corridors in the city. This result is a valuable tool for prioritizing which corridors should be included in the BRT system. Figure 4.29 is a picture of the total existing public transport demand on all of the major corridors in Jakarta.

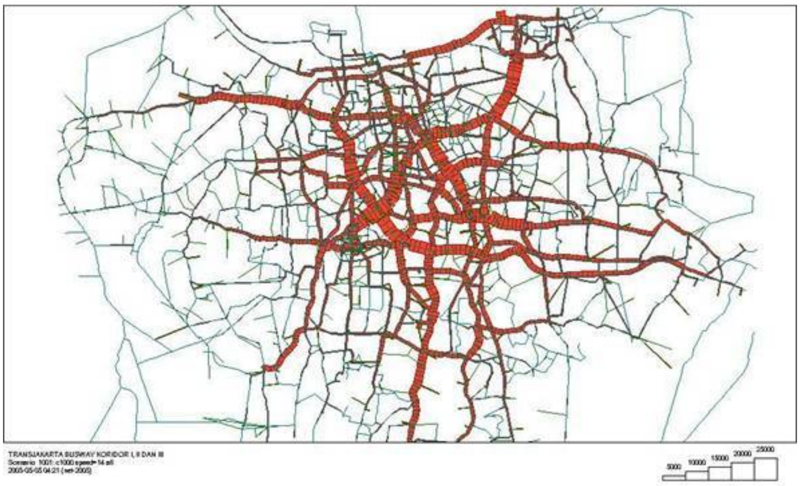

Figure 4.30. A graphical illustration of demand volumes from Jakarta. *ITDP.*

These total-demand estimates, or "desire lines," tell how many public transport customers are *currently* on each major corridor. It still does not say anything about how many public transport customers will be on a specific BRT system.

When first coding the existing public transport system into the model, the following additional information will be required:

- Vehicle capacity (total standing capacity is all that is used);
- Public transport (this will be a series of links; each direction needs to be coded separately because sometimes bus routes do not go and return on the same roads);
- Specific location of the bus stops (for most of the network, just assume the bus stops are at the intersections, but the BRT corridor nodes should be added specifically at the bus stop, and the links between the bus stops should be broken into separate links);
- Speed on each link (this will be taken from the bus speed and boarding and alighting survey);
- Bus fare (usually the models allow fare distance, and if there is a flat fare leave the distance blank);
- Bus frequency;
- Value of time (there are various ways of calculating this value, but in practice this value is based either on interviews with bus customers or typically 50 percent of the hourly wage rate for the typical bus customer).

At this point, the scenario to be tested should be carefully defined. In the case of TransJakarta, the scenario was essentially defined through a decision taken by the governor. The governor's design decision was as follows:

- TransJakarta would go from Blok M to Kota station with twenty-four stops at specific locations;
- TransJakarta would have fully segregated lanes and of certain design;
- TransJakarta would charge a flat fare of Rp. 2,500 (US$0.30);
- There would be no feeder buses and no (functional) discount transfers from any existing routes;
- Ten existing bus lines travelling between Blok M and Kota would be cut; all other bus routes would be allowed to continue to operate in the mixed traffic lanes at curbside bus stops;
- Fifty-four buses were procured to operate in the system.

When coding this BRT scenario into the public transport model, there is a small difference between coding a new BRT link and coding just any other bus route. In order to test some unique elements of the BRT system, the BRT link will be coded as an entirely new road link with special BRT characteristics, rather than assuming that it is a bus line operating on an existing road link that is open to paratransit vehicles and other vehicles. This new BRT link in the model will only be coded for use by a specific BRT vehicle that may be a new vehicle category that does not already exist. In the case of Jakarta, these vehicles are only used on the BRT system. This special coding of the BRT link is also required to give this route special fare characteristics, such as the possibility of free transfers between routes when the system expands to more than one route. Thus, coding a new BRT route is no different from coding any public transport route, except:

- The bus speed will be higher than for routes on the mixed traffic links. The BRT bus speed must be calculated specifically based on the system's design, but it is generally between 20 and 29 kph (see Chapter 6 for more information);
- Some new station locations will be created, which will affect walking times;
- Bus frequencies will be specific to the number of buses and the bus speed;
- If a lane of mixed traffic is being removed from the existing link, the definition of the characteristics of that link will need to be changed to reflect the loss of a lane. This change will only be necessary for running the full transport model in the future;
- It may be necessary to adjust the bus speeds downward for all the bus routes that are running in the mixed-traffic lanes. If there is only a public transport model, this will only be an estimated impact. If there is a full transportation-demand model, the model will help calculate this impact.

After defining the new BRT links and assigning them a new BRT route with the characteristics reflecting the political decision, the projected demand for this specific scenario can be calculated (Figure 4.30).

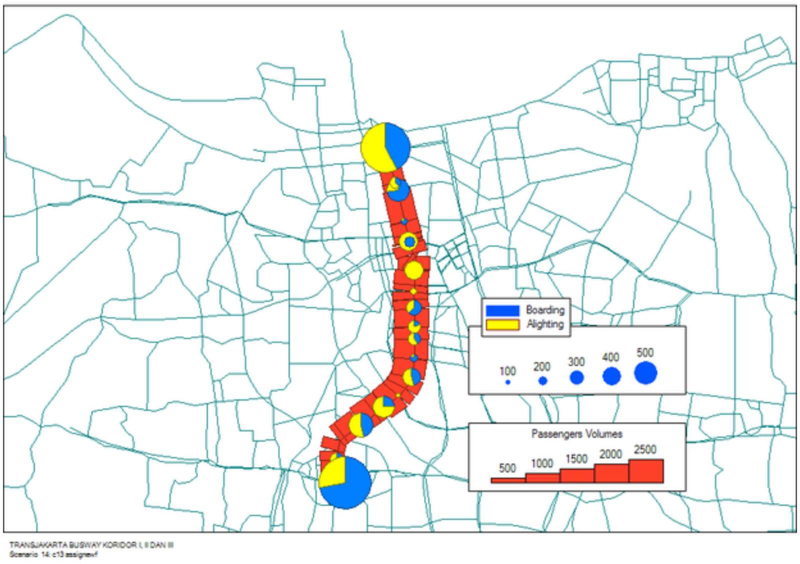

Figure 4.31. Demand estimate for TransJakarta Corridor I, Scenario I. *ITDP.*

In the case of Jakarta, the projected demand on Corridor I for the scenario determined by the governor was tested. Based on the lack of a feeder system and the unwillingness to cut bus routes that ran parallel to the new BRT system, the demand on the new system would not be very high. Because one mixed traffic lane had been removed, while few of the buses in the mixed traffic lanes had been removed, mixed traffic lanes would be more congested. However, due to the lack of a full transport model, the precise scale of this impact was not known. The planning team therefore encouraged the governor to expand the trunk system rapidly, to add feeder buses with free transfers onto the trunk system, and to cut more existing parallel bus routes.

Note that this demand estimate assumed that the new BRT system would only get the trips from existing public transport trips. It did not assume that any trips would be attracted from other modes, as the public transport model alone did not have the capacity to provide much of an answer to this question. Nevertheless, this analysis produced a very good conservative first estimate of the likely demand.

To include some possible modal shift from private vehicles, one can usually use the same rough estimate methodology recommended in Figure 4.2 above. In Bogotá, where a well-designed system actually decongested the mixed traffic lanes, the modal shift impact in the first phase was a modest 10 percent of private-vehicle users to the BRT system. The shift came from both push and pull factors. Most directly, competing routes by existing operators were eliminated or moved to parallel corridors. As the system has expanded, approximately 20 percent of current BRT customers on TransMilenio are former private-vehicle users. In Jakarta, where few bus routes were cut but the level of service for mixed traffic was more adversely affected, the mode shift was higher, at around 20 percent from taxis, cars, and motorbikes. In Ahmedabad, India, where there were very few bus customers originally on the corridor, there was an even higher modal shift (less than 30 percent), mostly from motorized three-wheelers and motorcycles, which before accounted for less than 70 percent of the existing modal split.

With this demand estimate, planners are better able to assess whether the physical designs proposed will have sufficient capacity to handle the projected demand, whether stations will be congested, and whether or not the system is likely to be profitable or operate at a loss. Planners can optimize the proposed-route network to increase load factors and minimize the need for customer transfers.

4.5 Estimating Demand Using a Full-Transport Model

> *"Those who have knowledge, don't predict. Those who predict, don't have knowledge."*
>
> — Lao Tzu, philosopher, 6th century BC

Most BRT systems in the world have been planned using only a public transport model, without having the full transportation system modeled. The lack of full modeling occurs because such modeling is only in its infancy in most developing countries, and it takes time to build up the data, the skills, and resources to develop a full transport-system demand model. Nonetheless, the tools provided by the full transport-demand model are very useful to BRT planning, and if time and resources allow, developing a full transport demand model is worthwhile.

4.5.1 Overview

By including all possible modes and replicating the decision process of all citizens to travel, in a full-transport model, there will be a much better sense of "potential" customers for the BRT system who may currently be taking motorcycles, private cars, bicycles, or walking. This model better captures the effects of congestion on different points of the network.

Guidelines for how to build and operate a full-transport demand model are beyond the scope of this guide. However, some basic information on transport modeling is included here to give BRT planners a general overview of how these models work, as they are likely to have output of these sorts of strategic models. Full transport models are normally constructed upon variations of the "classic four-stage models" discussed next.

While complex mathematical relationships underpin these full transportation models, the basic premise behind the modeling analysis can be presented in an understandable form to a wide audience. Figure 4.31 outlines the classic transport model. This model still serves as the basis for the various software products that today enable effective transport modeling. There are two distinct moments regarding four-stage models: the model development and the model application. The first is about understanding what factors influence people's decisions about what trips they make and how they make them; this is done by observing people's decisions and splitting them into groups that made similar decisions when faced with the same parameters. The second is about proposing new conditions (city growth, transport projects) and simulating the decisions people make under this new condition.

In short, the application of the model consists of the following:

- Defining inputs:
- Land use (existing or future) that points where activities are developed;
- Transport network (existing or future): road network with its features (eventual bicycle network included here), public transport network (modes, itineraries, frequencies). This changes throughout the day (even road directions can change), so typical moments of the day are to be considered.
- Calculating the travel matrix (there are usually several "market segment" matrices for each typical moment of the day);
- Simulating the matrix (demand) with the network (supply) to evaluate how each part of the system will be effectively used.

The third step alone is iterative, because as parts of the system get congested, people will try alternative paths.

The second and third steps together are also iterative (less iterations are required) as the travel matrix is a function of the travel times, and congestion will affect the decision to travel.

In the context of planning, the process is iterative, since it is based on the results that one will propose (or foresee) modifications both in land use and in the transport network.

The four-stage model is useful for the development of a strategic plan, because it makes it possible to consider new modes of transport to be created and to evaluate long-term land use changes. It is more useful to use a full transport model when faced with a lack of data from comparable services or services that do not exist yet, as it will allow for multiple scenarios and an iterative process that looks at the potential shifts in demand that result from new or additional services.. According to a survey on fixed-route public transport ridership forecasting and service planning methods appearing in a TCRP, 47 percent of US transport agencies reported using the four-stage model for the purpose of implementing a new system. The remainder of agencies use different means of estimation, or hire consultants to conduct a ridership forecast. Of the agencies surveyed, 11 percent use elasticities to determine the impact of implementing each planned bus rapid transit improvement. Another 11 percent considers the impact of improving existing travel times. Seventeen percent of agencies would hire an analyst to forecast ridership. The remaining 19 percent of agencies indicated that they would not analyze ridership impacts, but many were not currently considering implementing a new mode of public transport service.

The TCRP survey found that 44 percent of agencies used the four-stage model to determine long-term ridership. Thirty-three percent used trend lines, 22 percent considered service level changes, and 14 percent would not conduct such analysis.

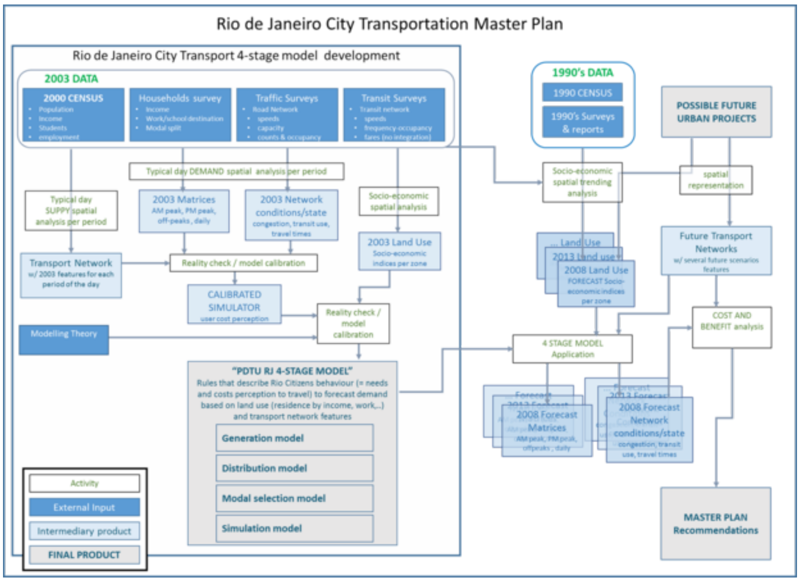

Figure 4.32. Inputs and activities example for the development and application of a classic four-stage model for the Rio de Janeiro Master Plan city. *Protocubo.*

4.5.2 Sub-Models

Market segmentation can be a key issue in deriving good modeling results. Different people react in different ways to changes in the transport system. Even the same person may behave in different ways when travelling to work, on business, or during leisure time. These differences affect design when considering the service during peak (mostly journeys to work and school) and off-peak periods (mostly shopping, social, and recreational trips). The proper segmentation of data can be costly since it requires more carefully collected data and greater detail in the modeling process. However, the benefits of segmentation can be a system well-tailored to the needs of the customers.

4.5.2.1 Trip Generation

When applying this model the *input* is the land use for a given area (zone), which may be expressed, for example, as:

- Number of households per income level and per number of residents;
- Number of residents per age;
- Level of education;
- Employment by activity sector.

These are usually projected numbers, based on trending projections considering development projects, in a table such as Table 4.13.

2030 Land use - conservative growth scenario

				Households with vehicle ownership															Households without vehicle														
				Income Level A					Income Level B					Income Level C					Income Level A					Income Level B					Income Level C				
				number of residents					number of residents					number of residents					number of residents					number of residents					number of residents				
Traffic Zone	Area (km²)	Name	District	1	2	3	4	5+	1	2	3	4	5+	1	2	3	4	5+	1	2	3	4	5+	1	2	3	4	5+	1	2	3	4	5+
4553002	0.86	Acari 1	COELHO NETO	16	24	73	73	40	3	8	24	24	13	5	16	33	55	55	9	14	43	43	24	3	6	19	19	11	8	25	51	85	85
4553003	1.65	Acari 2	ACARI	16	24	74	74	41	2	4	13	13	7	4	13	27	45	45	9	14	43	43	24	2	5	16	16	8	7	22	44	74	74
4550705	1.24	Aerop.S.Dumont	CENTRO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	4	25	15	12	20	35	40
4552920	2.54	Aeroporto da Barra	BARRA DA TIJUCA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	17
...																																	

				Students (M=morning, A=Afternoon, I = all day, N= night)																															
				Private School										Public School										Tertiary				Adult alphabetization				Other			
				Pre-primary			Primary			Secondary				Pre-primary			Primary			Secondary															
Traffic Zone	Area (km²)	Name	District	M	A	I	M	A	I	M	A	I	N	M	A	I	M	A	I	M	A	I	N	M	A	I	N	M	A	I	N	M	A	I	N
4553002	0.86	Acari 1	COELHO NETO	24	24	43	0	0	30	735	657	199	0	57	128	288	807	741	0	81	81	0	81	11	11	11	11	9	0	0	22	433	1064	0	0
4553003	1.65	Acari 2	ACARI	392	566	910	319	343	48	1225	1124	388	0	364	586	1415	161	161	0	89	89	0	89	12	12	12	12	12	0	0	32	756	1128	0	343
4550705	1.24	Aerop.S.Dumont	CENTRO	0	0	0	0	0	0	0	0	0	0	263	263	0	0	0	0	509	509	233	0	666	326	111	0	0	0	0	74	83	83	391	167
4552920	2.54	Aeroporto da Barra	BARRA DA TIJUCA	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
...																																			

				Employment																															
Traffic Zone	Area (km²)	Name	District	Informal sales	Informal dometic services	Informal others	Transformation Industry	Extraction Industry	Energy, Water Production/Distribution	Construction	Transportation	Telecomunication	Domestic equipment and vehicle repair	Sales	Restaurant	Hotel	Domestic services	Postal & Courrier	Real State	Financial	Government, Public Agencies	Private security, cleaning, maintenance	Information tecnology	Marketing & Communication	Scientific consulting, research and developme	Engineering, Architectural	Legal, Accounting, auditing, bookkeeping	Marketing & Communication	Medical and Dental	Veterinary	Health facilities	Education	Government, Public Agencies	Social Assistance	Other
4553002	0.86	Acari 1	COELHO NETO	3	90	51	51	0	49	12	7	25	90	95	50	25	13	515	10	286	357	75	205	280	21	45	43	12	5	14	0	350	5	42	150
4553003	1.65	Acari 2	ACARI	3	108	0	18	2	17	0	77	210	34	35	92	14	4	90	3	0	125	462	36	98	0	7	0	4	3	0	0	726	39	15	127
4550705	1.24	Aerop.S.Dumont	CENTRO	28	5	14	0	2	17	8	840	310	68	300	370	90	9	180	14	100	512	925	144	196	30	30	85	18	3	19	9	1	156	15	196
4552920	2.54	Aeroporto da Barra	BARRA DA TIJUCA	288	3	180	180	25	174	85	1550	4200	340	1500	1850	900	97	1805	70	1004	2501	9250	720	980	150	153	428	90	38	98	98	10	780	150	980
...																																			

Figure 4.33. Table *FixMe*

The “borders several OD matrices” are the output of this model; by borders we mean the total number of trips with origin and destination in each zone, as in the following:

Figure 4.34. Table *FixMe*

For one future scenario, the number of matrices’ borders generated can easily be over thirty by combining:

- *Moments of the day:* usually at least morning peak, afternoon peak and off-peak, but sometimes midday and night (this are usually proportionally divided based on traffic and public transport volumes if dynamic allocation will be made);
- *Trip purpose:* At least work, education, and others, but sometimes this may include: shopping, social, and recreational; health and personal business; and escorting other people;
- *Income level:* Splitting population into three to five income groups, depending on evidence of behavioral gaps observed in the model development.

Additional classification by person type can be included, typically focusing on personal characteristics that may include car ownership levels, household size, and household structure along with other factors such as residential density that play a role in determining the number of trips produced per household.

The development of the model consists in analyzing the mobility rate for trip purpose, including employment sector and school level for each market segment, normally on data from household and/or workplace surveys.

This analysis is complemented by land use census data (population, employment, education, and specific activity sectors from commerce, industry, and health agencies and unions) and crossed with current trip estimates based on traffic and public transport surveys and transportation sector operation reports.

The trip generation model is usually is divided into two other models: *production model* and *attraction model*.

4.5.2.2 Trip Distribution

The next stage in the application of the model is to fill the interior of the matrices, "the borders" of which were determined in the previous stage.

This can be seen as a dispute for the places where people will do their daily activities: work, study, shopping, others. At this point we know where people live and when and what activities they participate in based on their personal characteristics (income level, at least); we also know where these activities happen, but not everyone can do them in the same place, and we must assign each person to a location.

This dispute will be based on how people perceive the need to travel as a deterrent to their activities. In the extreme case of a small town where there is no congestion and the longest possible trip is five minutes, trips would be proportionally distributed from every origin to every destination. In a larger city, there will be more trips between closer zones.

Current or future travel times and costs between zones are a function of the existing or proposed transport network supply for the given time of day (public transport frequencies, road network, etc.) and subject to congestion, which is a function of the matrix we are trying to determine (one of many matrices we are trying to determine). Usually a simulation considering a past distribution or simply the distance as cost is used as the start of an iterative process; no more than two reiterations are typically required for reaching a stable solution.

Trips will be distributed with respect to the total cost of travelling from each origin and destination zone, in an attempt to be proportional to users' perception of the cost of travelling between the zones.

The perception of cost, including the time to wait and transfer, is discussed in Box 4.2. Those perceptions are cultural specific and affects the willingness of a given market segment to travel farther and how they travel. This can be calibrated from the survey data, normally home interviews, as they capture trips of all possible lengths.

This procedure is commonly referred to as the "Gravity Model," with its mathematical expression to satisfy the fulfillment of the matrix in the above condition given by trips (T_{ij}) between i and j (eq. 4.1):

$$T_{ij} = A_i \cdot O_i \cdot B_j \cdot D_j \cdot e^{-\beta c_{ij}}$$

Where O_i and D_j are total trips generated and attracted to zone i and j respectively, c_{ij} is the cost of travelling between i and j (generally a combination of time and fares) and β is a parameter that defines how cost deters travel. The component $e^{-\beta c_{ij}}$ is usually called a deterrence function, as it expresses the way in which distance (costs) prevents longer trips. As shown in the next figure, where the Y axis indicates how frequently a given trip would be seen for the travel time given in X: the lower the beta calibrated for a given market segment, the less the travel time (or travel generalized cost) is affecting the willingness of that market segment to travel farther to do its activity. The other two parameters, A_i and B_j are required to ensure the final trip matrix matches the total number of trips generated and attracted at each zone; these are estimated iteratively.

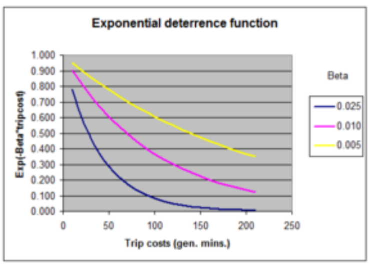

Figure 4.35. How the value of ß affects the deterrent effect of travel costs. *Luis Willumsen.*

Box 4.2. Generalized Costs

The "costs" of using a car or public transport in the transportation models are usually expressed as "generalized costs" that combine time and money elements. A usual formulation for this generalized cost is shown below:

For public transportation:

Equation 4.2:

$$C_{\text{pub}} = a \cdot \text{IVT} + b \cdot \text{WTM} + c \cdot \text{WAT} + d \cdot \text{TTM} + e \cdot \text{NTR} + f \cdot \text{FAR}$$

Where:

- C_{pub} = Costs of using public transport;
- a, b, c, d, e and f = parameters representing the weight attached to each of these elements in the journey;
- IVT = Time in minutes spent on the bus;
- WTM = Total waiting time to board the bus;
- WAT = Total walking time to and from the bus stop;
- TTM = Time spent transferring from one service to another, if any;
- NTR = Total number of transfers required for the journey, if any;
- FAR = Total fare paid for the whole journey.

The factors a, b, c, d, e and f are parameters representing the weight attached to each of these elements in the journey. This generalized cost can be represented in time or monetary units. For example, by dividing the whole formulation by f, the generalized cost would be measured in money units. It is more advantageous to divide the formulation by a and then measure generalized costs in (in-vehicle) time units.

Research results agree that walking, waiting, and transfer times are between 1.5 and 3 times more onerous than in-bus times, with the precise values depending on cultural and local conditions like the weather. Similarly, the need to transfer is perceived by customers as adding a notional three to six minutes to their journey. A good starting point is to assume that b, c and d to be twice as big as a, and that e/a is about five minutes.

This provisional formulation could then be written as (eq. 4.3):

$$C_{\text{pub}} = \text{IVT} + 2\ \text{WTM} + 2\ \text{WAT} + 2\ \text{TTM} + 5\ \text{NTR} + f/a \cdot \text{FAR}$$

Where:

- f/a = Inverse of the value of time savings.

An initial estimate could be the length of working time required to earn one unit of currency, for example how many minutes it takes for the average earner to earn US$1. The average earner in question is the type of user the new BRT is trying to benefit most. For example, if the average wage rate per hour for the population of interest is US$2, then is thirty minutes per dollar. The generalized costs in this case would be measures in generalized in-bus minutes.

For private transport:

The formulation would be similar for cars (or motorcycles), but in general it will be assumed that the waiting time is zero, walking is minimal (usually assumed to be zero as well), there will be no transfers, and instead of fares one must consider a combination of fuel and parking costs plus any toll payment (eq. 4.4).

$$C_{\text{car}} = \text{IVT} + g \cdot \text{Fuel} + h \cdot \text{Park} + i \cdot \text{Toll}$$

Where:

- C_{car} = Costs of using a car;
- IVT = Time in minutes spent on the bus;
- Fuel = Cost of fuel;
- Park = Cost of parking; journey;
- Toll = Cost of tolls;
- g, h and i = parameters representing the weight attached to each of these elements in the journey.

This implies that car users are only reasonably aware of fuel costs, but ignore maintenance and depreciation costs; there is some evidence that this is the case. For parking, the value of h is usually assumed to be half of g, implying that the parking costs are shared by the onward and return trips. The coefficient i for toll should be the same as g, except that paying cash for tolls is usually seen as more onerous than filling up the tank; nevertheless, the default value would be $i = g$.

Both expressions for generalized cost (public transport and car) ignore the fact that a car is usually more comfortable and convenient for many journeys. To accommodate this influence, it is customary to add a "penalty" to the less convenient mode, in this case public transport. This penalty is in the range of five to fifteen (generalized) minutes and this extends the generalized cost as (eq. 4.5):

$$C_{\text{pub}} = \text{IVT} + 2\ \text{WTM} + 2\ \text{WAT} + 2\ \text{TTM} + 5\ \text{NTR} + f/a \cdot \text{FAR} + \text{PENALTY}$$

Where:

- PENALTY $=$ Cost of public transport being less comfortable and convenient than using a car.

The revised expression for public transport and the expression for private transport are the versions of generalized costs used in Logit mode choice and Gravity models.

4.5.2.3 Modal Split

A complexity not previously mentioned is that costs need to consider private and public transport altogether. When new services are added or taken away, people may shift from one mode to another and some may decide on the least costly as the car.

In summary, the application of this stage consists in further splitting the previous (eventually fifty matrices) in two (adding up to a hundred), one for public transport and one for private transport. A model that includes "Park and Ride" splits the trip into two parts here, including one part in each matrix.

This would entail presenting travellers of a given "market segment" for each OD pair with the times and costs of several possible modes (under the proposed transport network) to see which mode of travel they would choose.

Even inside the same "market segment" the changing decision point is not clear—that is, it is not the same for everyone in that segment. The "answer" of the model is given in proportions, like this: "confronted with the proposed network costs, people travelling from O to D in the given market segment X percent will use public transport (eventually specifying which one), Y percent will use private transport (eventually which one), Z percent will use bicycles." X, Y, and Z will add up to 100 percent and eventually one (or more) of them will be zero.

The model development consists of analyzing how people make decisions when confronted with various alternatives.

From a policy point of view, perhaps the most important stage in the transport-modeling process is the selection of mode choice for different trips. Determining the number of trips to be made by public transport, nonmotorized options, and private motorized options will have a profound impact on future municipal investments. The factors that affect mode choice can be summarized in three groupings :

1. Characteristics of the trip maker:
    - Car availability and car ownership;
    - Possession of driver's license;
    - Household structure (young couple, couple with children, retired, single, etc.);
    - Income;

   - Residential density.
2. Characteristics of the journey:
   - Trip purpose (work, school, shopping, etc.);
   - Time of day when the journey is taken.
3. Characteristics of the transport facility:
   - Quantitative:
     - Relative travel time (in-vehicle, waiting, and walking times by each mode);
     - Relative monetary costs (fares, fuel, and direct costs);
     - Availability and cost of parking.
   - Qualitative:
     - Comfort and convenience;
     - Reliability and regularity;
     - Protection and security.

The mode-choice model will typically include these factors in estimating levels of usage between different modes. Segmentation will of course be very important. One should only include choices that are readily available to each type of user. For instance, driving a car is only an option for those in households that own a car. In some cases, travellers with a car provided by their company are in effect captive to that mode, as they have no choice.

If it has been decided that the BRT design must consider customers attracted from other modes, mode-choice modeling will be essential. However, this is a specialized undertaking that usually requires good modeling techniques and trained specialists. If it is not possible to conduct a full modeling process, then it may be appropriate to make a simplified assumption about potential demand increases due to mode shift. This shift is unlikely to represent more than 5 to 20 percent of the demand in the new system.

The most common type of model used to represent mode choice is a logit model (and its similar generalization for multi-class called logit multinomial). The Logit model is a probability distribution for a discrete choice, where the outcome is related to the characteristics of the user that makes a choice. A higher-income transport user, then, will have a higher probability of choosing a private car for his or her trip than a lower income user. This expresses the probability or proportion of trips that would use public transport (P_{bus}) below instead of cars as:

$$P_{bus} = \frac{e^{-\lambda C_{\text{bus}}}}{e^{-\lambda C_{\text{bus}}} + e^{-\lambda C_{\text{car}}}} = \frac{1}{1 + e^{-\lambda \left(C_{\text{car}} - C_{\text{bus}}\right)}}$$

Here, the only new element is the parameter λ. C_{bus} is the generalized cost for public transportation and C_{car} is the generalized cost for a car (this would be calculated for each OD pair). Figure 4.33 shows the influence of this parameter in making choices very dependent on (generalized) cost or less so:

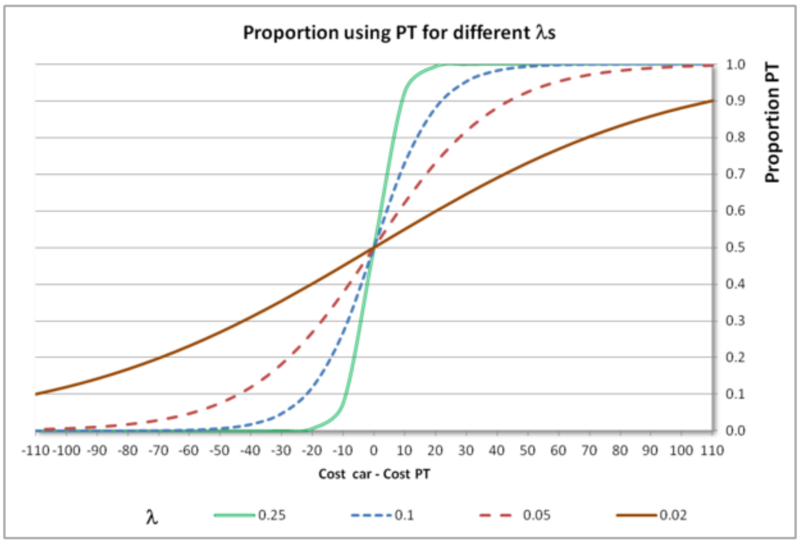

Figure 4.36. The influence of λ on mode choice proportions. *Luis Willumsen.*

As can be seen, a high value for λ (0.25) produces a very sharp mode shift for a small difference in costs; a small value (0.02) produces a gentler transition between modes. Both predict a 50/50 split when the car and bus costs are equal. The value of this parameter must be estimated locally to represent not only local behavior but also the size and nature of zones and networks.

4.5.2.4 Assignment

The previous stages in the modeling process focused primarily on the demand side of public transport services or generating OD matrices. The "assignment" stage is where the supply of public transport services is matched with these demand conditions in a *simulation*. This is done by calculating the times and costs required at every path segment of the network, combining it for all the possible paths for all OD pairs to define which will be taken (in which proportion) for each "market segment" (for that given moment of the day).

Within a BRT system, the assignment stage also helps identify usage levels among different routing and service options. For instance, it is quite useful to know the number of customers who will be utilizing express routes versus local routes.

In order to accurately model public transport route choice, it is necessary to represent the network with a good degree of realism. Near the corridor, many centroids and centroid connectors should be used to better represent access times to stations. Moreover, there is always an additional time to reach the right platform in a BRT or metro system. Transfer times and waiting times for the next available service should also be represented in the generalized cost of travelling along a particular route. People dislike transferring services because of the uncertainty involved, so there is usually a transfer penalty to consider, in addition to the time spent changing services.

Fares should also be accurately represented, and this may prove very tricky in some cases. If there is no fare integration, each change of service will involve paying a new fare. This additional cost may be represented as a "boarding charge." If the fare has an element proportional to distance, this amount must be added to the journey. For integrated and zonal fares, the issues may be more complex to handle, but most modern software can cope if skillfully used.

It is important to adopt a realistic assignment model for public transport. This is particularly important when dealing with corridors where many bus routes converge. If all bus services have similar operating speeds (a common occurrence on a corridor), earlier models will tend to allocate all trips to the service with the highest frequency. In reality, people will probably choose the first bus that comes along, and thus it is probably best to allocate trips to services based on frequency rather than on an "all-or-nothing" assignment to the highest frequency service. Contemporary software packages, especially those developed and tested for high public transport usage like Emme/2, Cube/Trips, VISUM, and TRANUS, perform better in this respect.

Congestion in the system is defined by users' route choice, and users' route choice is decided based on the congestion of the system. Equilibrium conditions within assignment are achieved when each customer has been assigned the most efficient route considering the congestion of the system. Equilibrium is very important in dealing with private vehicle assignment, but has an equivalent representation in public transport. Congestion effects may take place because buses are very crowded and users will experience losses in time and comfort (increases in generalized costs), similar to driving under congested conditions. Stopping times increase and customers cannot board a bus (or metro or light-rail vehicle) because it is full, and they must then wait for the next service. Replicating these conditions is important.

For the purpose of designing a new BRT system, excessive crowding and delays to customers because they cannot board a bus should be avoided. Therefore, congested public transport assignment should be less of an issue for design purposes. In any case, congested public transport assignment is tricky and requires good use of a suitable software platform; it should not be attempted without at least a minimum of assisted experience.

4.5.2.5 Calibration

Calibration is the process of, after choosing the (sub) model (i.e., defining how input and output mathematically relate), quantifying (adjust) the parameters that better explain what is observed from the surveys. Calibration is an activity that happens with the development of the model itself. For example, in the models discussed in the previous section, calibration is finding such values of βs that promote the best fit in the distribution model for each "market segment" or the best λs in the mode selection model.

Usually, when modelers say they are "calibrating the model" they are, in fact, adding detail to the public transport network (eventually calibrating parameters or creating sub-models to generate congestion), so that when they run the full model with present conditions, resulting flows reflect what is seen on the ground (traffic counts and occupancy surveys at that moment of the day). When they calibrate the matrix models, they usually say they are "making the models."

4.5.2.6 Validation

Models are developed to represent the reality, based on the isolated observation of several parts in the travel decision-making process. Each simplification is related to an assumption (i.e., everyone in a given market-segment behaves the same). Given the complexity of the travel decision-making process, the simpler the model, the more likely it will not be able to explain and generate details. On the other hand, the higher the aggregation (less detail), the more reliable (the aggregated) results are.

An additional problem is the fact that, in many cases, we do not know the full extent of the reality we are trying to model and cannot obtain that data. For instance, we often do not have the real OD matrix, but the ability to sample the public transport OD is cheaper and is one of the reasons for the reliability of public-transport-only O/Ds).

Further, the model is constructed to provide answers (in our case the demand on the BRT system, present and future), the error of the model to forecast answers, and its input requirements and the maintenance of its assumptions define the validity of the model.

A model that does not provide the required accuracy for business proposals may be valid for corridor selection (it can certainly point where more benefit will be generated) and valid for feasibility decisions (it indicates that demand will be above a certain level).

Validation is then a further requirement in which results from the model are compared with data that has not been used in its construction—for example, a subset of traffic and person counts set aside for this purpose.

Validation further requires that the responses of the model to changes in some inputs, like prices or the introduction of new roads and services, are reasonable and consistent with observations and model results elsewhere.

No model is without errors, but a good calibration and validation process ensures that any significant error is tackled and eliminated and that the model represents the reality of the base-year situation in the best possible way.

A common procedure is to adjust the matrices to match the traffic counts and occupancy surveys; such a procedure, although useful to validate other models for the present, completely undermines the reasoning of the classic four-stage model and severely limits the validity of the generation, distribution, and mode selection models.

4.5.2.7 Conversion of Demand into Revenue

The levels of demand estimated by the models will have to be converted via fares into revenues for the system. This financial modeling will require consideration of the proposed fare system (see Chapter 15: Fare Policy and Structure), the need to share revenue between trunk and feeder services, the existence of certain discounted fares, such as for students and the elderly, and the fact that there will be levels of leakage through fare avoidance and collection loses. For that reason, creating a financial model outside the demand model exercise is needed to understand what the fare should be (see Chapter 14: Financial Modeling). Once the fare is set, though, the demand model should be tested with that determined cost to see how it affects the demand.

4.5.2.8 Evaluation

The previous modeling stages have combined supply and demand factors to develop an overall simulation of a city's public transport services. The final stage of the process is to evaluate the robustness of the particular solution being proposed by the model. The model (and each sub-model) must be plausible, i.e., the proposed relations and parameters that relate input (independent variables) and output (results) make sense (*physical sense* in modeler jargon) by changing the output as expected.

Hopefully, the iterations inside the model and in the planning process will converge into a single, identifiable solution for the problem (reducing travel time). If several scenarios produce such a convergence, then the proposed solution is considered to be sufficiently robust. The lack of a convergence may imply that changes in the model structure are necessary before proceeding.

4.5.2.9 Assessment of the Feasibility of the System

Once some sort of public transport or full transport model has been developed, and a clear scenario for the BRT system has been defined, it should be possible to make a preliminary assessment of the feasibility of the system.

As a proxy for cost savings, the value of time savings can be utilized. However, it should be recognized that time savings is just one of the many reasons for encouraging public transport usage. Other factors include environmental benefits, fuel cost savings, urban design benefits, and social benefits. A more complete feasibility cost analysis would thus include these other factors. Further, time savings may be realized not just by public transport users but by private vehicle users as well.

A good litmus test of whether a new BRT system makes sense is to compare the existing generalized cost of an array of different trips (origin-destination pairs) as they exist before the BRT system, and what the cost might be with the new BRT system serving those trips.

It is important to consider this relationship and to sketch out how a new BRT system would reduce the generalized cost of travel for a set of relevant origin-destination pairs. This calculation can be done using information already available on existing services, fares, frequencies, and travel times, and compared to a new system that may have faster travel times on a trunk corridor, but require transfers and perhaps longer walking times. This would give an idea of how much faster the buses should operate on the trunk corridor to compensate most travellers for the need to add one or more transfers.

For example, consider the introduction of a trunk-and-feeder system that would replace a number of direct services. The following estimates should be made to check whether this scenario is going to improve travel for public transport users. It can be assumed that feeder services will have a similar performance to the current services, but perhaps a higher frequency for the relevant OD pair. It can also be assumed that waiting time will be reduced by two minutes each way, and that walking time will remain the same. The trunk-and-feeder service may require an average of, for example, 1.5 transfers per trip, whereas beforehand there was no transfer. Each transfer will require additional waiting time for the new service (say, two minutes each), so the original savings in waiting time will be lost. The trunk road will have to provide an overall time savings of three times two minutes (six minutes) to be better than the old system, provided that fares remain the same. Therefore, unless one can provide an average time savings on the trunk route of five minutes, it will not be worthwhile to introduce a trunk-and-feeder service. These calculations would have to be repeated for a number of representative journeys to support a decision one way or another.

The existing public transport system may be used to identify some key corridors where significant elements of demand will concentrate. Direct observations of the number of buses, with a reasonable estimation of their customers at peak periods, would enable an initial sizing of the new system. This determination can be achieved in a short period of time and without detailed information on Origin-Destination patterns.

4.5.3 Additional Data Needs

Much of the data required for the full transport demand model will have already been collected during the initial analysis period. It is fairly common for transport departments to do traffic counts, and if recent traffic counts exist in reasonable locations, this data should be usable. If counts for all vehicles were not done earlier, they need to be done now to calibrate the transport model.

Secondly, when the road network is coded into the transport model, it is no longer enough to simply identify existing road links, but the definitions of these links (lanes, width, hierarchy class [local, arterial], regulated speed, etc.) becomes important. Furthermore, all existing alternative modes such as commuter rail lines, subway lines, bike lanes, and so forth must be coded into the model.

Also, at this point, the demographic and economic activity data for each zone defined earlier becomes important, such as population by zone, employment by zone, average income by zone, vehicle ownership by zone, etc. This information is usually obtained from census data. Historical growth rates in population and employment by zone are the best first indicator of the likely growth rate of future trips in specific locations. Knowing household incomes and motor vehicle ownership levels will help indicate whether most people will take the bus, regardless of the price, or whether they will switch to a car or motorcycle. Mapping the income levels throughout the city will also help define price elasticities and target lower-income beneficiaries, both important to developing the fare structure. Thus, transport models are usually built up from demographic data on population, employment, and vehicle ownership.

Finally, for full transport-demand modeling, the planning team will need to conduct a household and/or workplace origin-destination survey. This survey is necessary since the team will only have estimates of origins and destinations for public transport trips initially. By contrast, the full-transportation model will require OD matrices for all modes, including walking trips and private-vehicle trips.

Surveying all members of a household regarding individual travel practices (destinations, mode choice, reasons for mode choice, travel expenditures, etc.) provides a very complete picture of where people are going, when, and why. Likewise, workplace surveys can also be an effective mechanism. Unfortunately, household and workplace surveys are probably the costliest of the OD survey techniques. As a result, careful sample sizing is required; knowledge about the variables that will feed the model, their variation, and how they will affect the model output are paramount to the surveys.

Many cities have been led to waste valuable resources with huge samples, in an attempt to obtain a detailed OD matrix

Even with very large sampling, it is certain that the resulting matrix will be very sparse; in other words, most cells will have no trips in them. As a rule of thumb one must have a sample size of 300 to assure that 95 percent of the surveys made will capture events that happen 1 percent of the time. In a 200 zone division, very few OD pairs (out of 40,000 possible OD pairs) would concentrate more than 1 percent of the trips and this means already surveying 60,000 trips [300 hundred for each possible origin zone]). The generation and distribution models are often the best method for matrix estimation with a much smaller sample.

> *"The first requirement [knowledge about the variables to be estimated for sample size estimation], although both obvious and fundamental, has been ignored many times in the past. The majority of household O–D surveys have been designed on the basis of vague objectives, such as 'to reproduce the travel patterns in the area'. What is the meaning of this? Is it the elements of the O–D matrix which are required, and if this is the case, are they required by purpose mode and time of day, or is it just the flow trends between large zones which are of interest?"*
>
> — Ortúzar and Willumsen (2011, 80) are quite incisive on this point.

A good indication that home base OD surveys are being requested without understanding of the basic statistical concepts can be found in many government contracts stating that "the sample for each zone should be enough to guarantee a 5 percent error with 95 percent confidence," without further stating in relation to what.

In general terms, if no household survey has already been conducted, one would like to collect at least some one thousand home interview surveys, and preferably three thousand, in order to produce a rough four-stage model in the study area. The trip data from these interviews will then be combined with that from intercept surveys to obtain a more accurate trip pattern in the study area.

4.6 Risk and Uncertainty

"Doubt is uncomfortable, but certainty is absurd."

— Voltaire, writer, historian, and philosopher, 1694–1778

However sophisticated, a model of transport demand is still a model, a simplified representation of a real-world scenario. A degree of uncertainty will always remain in any travel-demand forecast, and BRT planners should keep this in mind.

In terms of demand forecasting, there are two main sources of error:

1. Will the variables that define the future context (population, income, location, employment, etc.) and policy environment (car restraint, competition, pricing, and subsidies) for the BRT adopt the values forecast at the planning stage?
2. Do the models capture true travel behavior, and will the travel preferences identified (coefficients in the generalized cost formulation and the different sub-models) remain in the future?

The best way to handle these sources of uncertainty is to develop forecasts under different scenarios. In the worst circumstances, more-dispersed urban growth will continue to incentivize the use of conventional buses, taxis, and minibuses and compete, to some extent, with the BRT system, and that no car-reduction policy will be implemented. In the best-case scenario, urban growth will be focused on BRT, car-reduction policies will be implemented, competing modes will be kept some distance away from the BRT trunk network, and they will not be subsidized. An expected or probable scenario would assume a partial implementation of those policies. The definition of these scenarios will have to be agreed upon by all stakeholders, with some consultation of possible bidders and financial institutions.

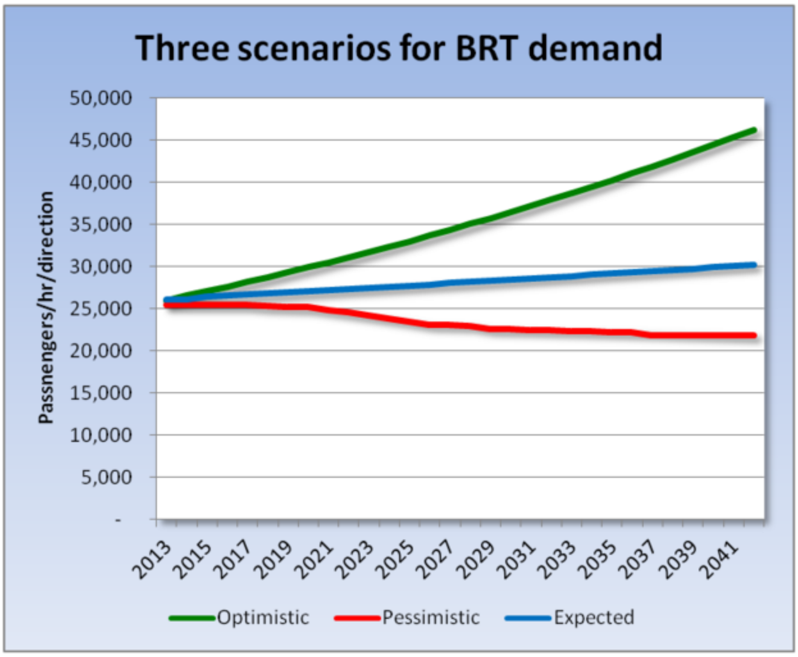

Figure 4.37. An illustration of how these different scenarios could be presented. *Luis Willumsen.*

Uncertainties about capturing the true travel behavior within the model can be treated in different ways. While it is difficult for a model to accurately capture travel behavior, the basis for the model will be the demand on the existing routes that currently run on the corridor. Those existing routes and their combination of services are reasonably predictable. Ideally, that demand will have transferred to the new BRT corridor if those previous services are no longer allowed to run on the corridor and that should form the basis of any forecast. This transferred demand will tend to grow with population, although this is perhaps less certain.

Other components of BRT demand will be those captured from semi-competitive modes not fully removed from competition: taxis and shared taxis. Other demand may be abstracted from cars if the BRT service is good enough and car restraint policies are implemented. Finally, some people may choose to change the destination of their trips, perhaps for shopping or entertainment, to take advantage of the better accessibility offered by BRT.

These sources of demand have been outlined in increasing degrees of uncertainty or confidence in our ability to model them accurately enough. It is desirable, therefore, to present the final demand estimations and deconstruct the individual components or contributions. This is illustrated in Figure 4.35. In this way, private and public sector stakeholders, concerned about the sources of risk in the project, can understand the most solid basis for demand and revenue projections.

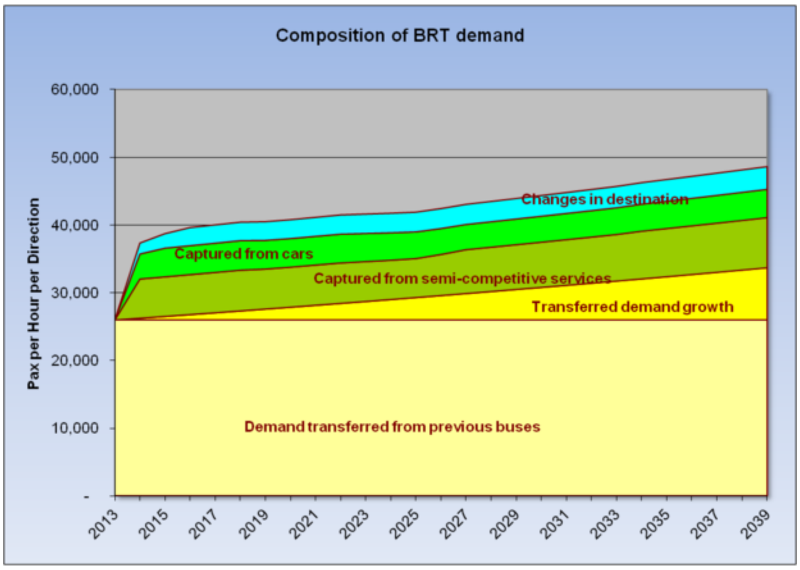

Figure 4.38. Decomposition of BRT demand estimates. *Luis Willumsen.*

Finally, some stakeholders, particularly in the financial community, advocate the use of stochastic simulations to address the issue of uncertainty in forecasts. In this case, the analysis involves the use of Monte Carlo simulations usually implemented as an add-on to a standard spreadsheet.

The first step is to agree with stakeholders on the few input or model variables that will be considered stochastic rather than fixed, and relate the outputs from the model to the stakeholders. Additional model runs will be needed to identify, for example, how variations in GDP growth affect revenues and therefore car ownership. This requires exercising the model in sensitivity tests, using different values of time in mode choice.

The next step would be to adopt some probabilistic distribution around the mean expected values of these variables. It is common to assume that these would be independent normal distributions, although this assumption was partly to blame in the risk models before the 2008 financial crisis.

The next step is to construct a model where this handful of variables affects demand, and where their probabilistic distributions are sampled repeatedly in a Monte Carlo simulation. Each run of a Monte Carlo simulation reflects one possible demand and revenue path diverging from the expected scenario. This is illustrated in Figure 14.36, where each path represents a diversion from the expected case normalized to

1; a revenue factor value of 0.95 in one year implies that collections in that case would be only 95 percent of the expected case for that year.

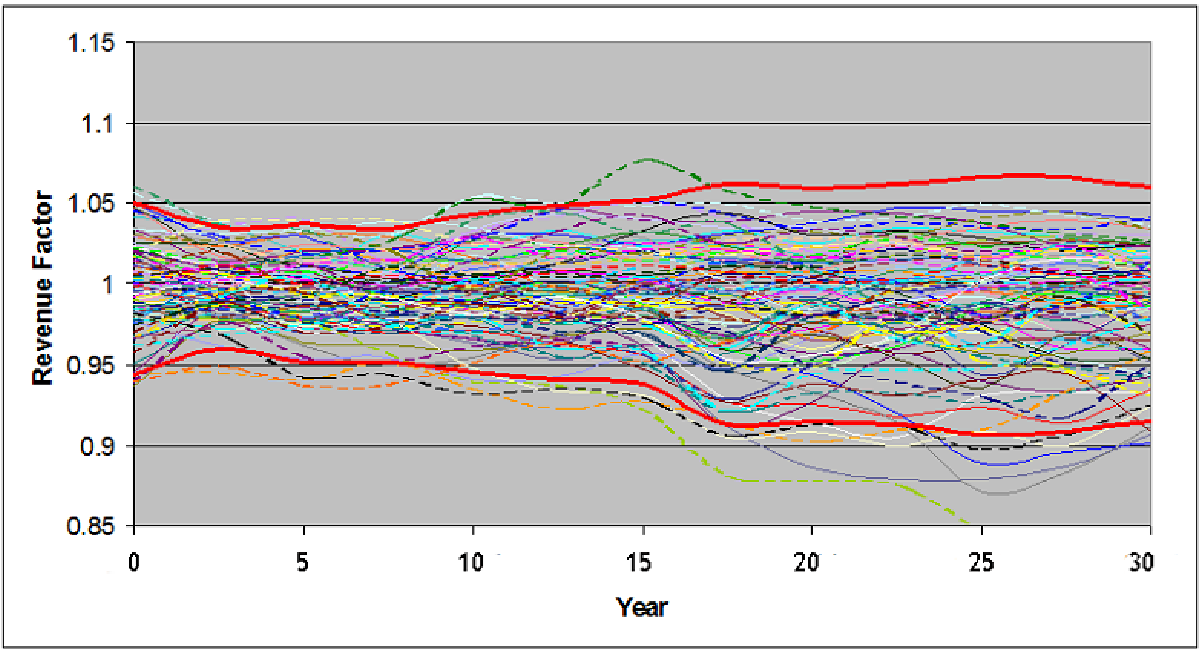

Figure 4.39. Possible revenue factors in a stochastic simulation. *Steer Davies Gleave.*

These results can be aggregated in different ways to express the probability that a particular level of demand (and revenue) will be exceeded, say, 90 percent of the time. This is usually referred to as the P90 forecast and it is sometimes used to finance private sector schemes.

The value of this treatment is limited in the case of BRT schemes where uncertainty resides more in transport and land use policy that is better treated through scenario analysis.

4.7 Conclusion

With either demand on the corridor from the rapid assessment model or through the transport model, many critical design decisions can be made with a reasonable degree of accuracy. This demand estimation forms the foundation for service planning (Chapter 6: Service Planning) to financial modeling (Chapter 14: Financial Modeling) to infrastructure planning, including station size for buses and customers, passing lanes, etc. (Volume 6: Infrastructure, Chapters 21–27).

BRT stations need to be sized in order not to saturate, and avoiding saturation requires designing stations to a specific volume of boarding and alighting customers and bus frequencies. Cities should establish their goals for percentage of overall mode share by bus-based public transport, and make projections accordingly with regard to future growth (and not just design based on existing demand). This approach has been taken to calculate BRT station sizes in Pimpri Chinchwad, India, where the region has set a goal of reaching 60 percent of mode share by bus-based public transport by 2013. The formulas for avoiding station saturation are included in Chapters 6: Service Planning and 7: Capacity and Speed.

With the data on the maximum load at the critical link, many other preliminary judgments can be made about the basic system design. For instance, if the number of customers on BRT buses at the critical link is above 7,000 passengers per hour per direction (pphpd), then a simple single-lane, single-route BRT system may not be able to handle the demand. If the demand is below 2,000 passengers per direction during the peak hour, BRT measures may not be very cost effective unless significant new land development is planned in the area or a high level of modal shift is likely due to very low mixed traffic speeds. If the demand is greater than 36,000 pphpd, it may be better to split demand onto multiple parallel arterials or consider grade separation.

Furthermore, using simple calculations about speed and route length, one can also begin to settle other issues like the size of the needed new bus fleet, and the appropriate size of the bus. The formulas for performing these calculations, once a basic calculation of the maximum load on the critical link has been made, are included in Chapter 6: Service Planning.

4.8 Bibliography

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5. Corridor and Network Development

"Look at every path closely and deliberately, then ask ourselves this crucial question: Does this path have a heart? If it does, then the path is good. If it doesn't, it is of no use."

— Carlos Castaneda, author, 1925–1998

The BRT Standard (2014) currently provides a definition of a corridor that can be evaluated as "a section of road or contiguous roads served by a bus route or multiple bus routes with a minimum length of 3 kilometers (1.9 miles) that has dedicated bus lanes."

It then uses a minimum definition of BRT, defined as a minimum score in the "BRT basics," to determine whether the investments in that corridor constitute BRT or simple bus lanes.

The choice of BRT corridors is critical. Not only will the selection of a good corridor increase the number of beneficiaries for the BRT investments, but a strategically located corridor can also, under certain circumstances, stimulate transit-oriented development with profound impacts on the future development of the city.

Ultimately, the selection of a BRT network and the prioritization of BRT corridors for implementation is both technical and political. Political decisions around corridor selection are necessary, as it is much more likely that a BRT project will get built where there is political support for the project. However, such a political decision should be made only after a detailed technical analysis recommends a set of corridors that makes sense.

Information should be grounded in empirical reality, quantifiable, and independently verifiable. Those harder to quantify, harder to determine factors should be discussed as part of the political process, but should not necessarily be included in the data collection process. This chapter provides a basic approach to defining a BRT network and prioritizing the corridors within that network for phased implementation.

Contributors: Karl Fjellstrom, *Far East BRT*; Walter Hook, *BRT Planning International*

5.1 Demand Analysis for Corridor Selection

"Without mathematics, there's nothing you can do. Everything around you is mathematics. Everything around you is numbers."

— Shakuntala Devi, writer known as the "human calculator," 1929–2013

The most important factor in determining whether a corridor is appropriate for BRT investments is the existing level of public transport demand. This is because the existing customers using a particular corridor are more than likely going to benefit from new BRT investments. A BRT built on a corridor with more existing transit customers is likely to have more beneficiaries than a BRT built on a corridor with fewer existing customers.

Figure 5.1. As this image of central Bogotá, Colombia, indicates, central business districts are a logical part of any complete BRT network. Photo *Oscar Diaz and Por el País que Queremos (PPQ).*

The methods for determining the existing level of transit ridership on a corridor are reviewed at length in Chapter 4: Demand Analysis. For the corridor selection process, the methodologies identified in Section 4.4 under "Basic Methodologies for Demand Analysis" offer a sufficient level of detail to make a simple determination of which corridors would benefit most from BRT.

Some planners have attempted to determine a minimum level of existing demand below which dedicating a lane exclusively to buses is difficult to justify. *The Transit Capacity and Quality of Service Manual* (TCQSM), a guide generally used in the

United States, recommends that a minimum ridership of 1,200 passengers per direction at the peak hour (ppdph) be a minimum threshold for an exclusive bus lane, as this is a reasonable average estimate for the number of customers that are generally able to use the lane when operating in mixed traffic conditions. In developing countries with much higher levels of transit ridership, it is likely that a higher minimum threshold would be set.

This guide does not mandate a minimum threshold of 1,200 existing bus or minibus pphpd, recognizing that there could be significant latent demand for high-speed transit in highly congested corridors or corridors with high rates of land development along them. The guide does recommend, however, that whatever the existing demand, at least a thousand pphpd should be attainable within the first year of BRT operations. Indeed, *The BRT Standard* (2014) deducts maximum points for systems that do not reach this. It should be possible to estimate demand for BRT during the first year of operation through a combination of existing bus or minibus demand, and some indication that there is likely to be new land development in the corridor, that congestion is likely to worsen significantly in the medium term, or that high existing bus, minibus, or rail demand in nearby corridors would shift due to overall travel time improvements.

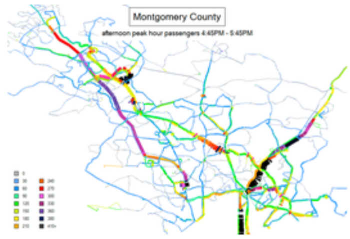

Figure 5.2. Peak hour passengers, Montgomery County, Maryland, USA. *ITDP.*

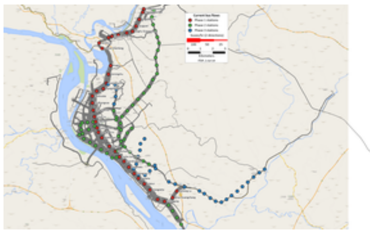

Figure 5.3. ITDP's proposed phase 1, 2, and 3 BRT corridors in Yichang, China. The phase 1 corridor opened in mid-2014, while phases 2 and 3 have been selected based primarily on current customer flows, fairly accurately reflected in the bus flows illustrated. The southeastern phase 3 extension is to a new area currently under construction. Note also that phases 1 and 2 both provide downtown, city center access. Map *ITDP.*

Other planners have claimed that BRT as a technology cannot handle more than thirty-five thousand ppphd, so if a corridor has a projected number of customers greater than this then it should be reserved for heavy rail metro investments. Again, this guide does not make a specific recommendation of this type. Under certain conditions, BRT systems are able to carry more than thirty-five thousand pphpd even with only two lanes of exclusive bus lanes per direction. For example, TransBrasil is scheduled to open by the end of 2018 in Rio de Janeiro. This corridor is expected to carry up to sixty thousand customers during peak hour, due to extensive use of express services, two lanes per direction, and larger buses, such as articulated and biarticulated buses.

This guide recommends that the existing transit ridership data be presented to stakeholders in transparent form, ideally on a map with link by link loads.

Figure 5.4. Major arterials are not the only options for BRT corridors. In Bogotá roadways in city center are used to give exclusive access for public transport and pedestrians. *Shreya Gadepalli.*

5.2 Transit System Speed and Delay Analysis

> *"You think that because you understand ONE you understand TWO, because one and one makes two. But you must understand AND."*
>
> — Sufi proverb

BRT infrastructure is only going to yield significant benefits if buses on the corridor are currently operating below their optimal speed. Therefore, the slower the existing bus or minibus speeds on an existing corridor, the greater the theoretical potential for BRT investments to improve the situation. For this reason, after looking at existing transit demand, it is a good idea to evaluate existing transit speeds, and to map these speeds in such a way that they are very clear.

Average bus speeds can be calculated either from transit agency data, or by frequently riding the bus routes in corridors being investigated and measuring bus speeds with a GPS. Below is a simple map of average peak hour bus speeds developed during an alternatives analysis for the proposed Tianjin BRT.

Figure 5.5. Quito, Ecuador have made narrow roadways in city center exclusive to public transport. *Lloyd Wright.*

If average bus speeds in a corridor are relatively high, BRT infrastructure is less likely to bring a significant improvement in bus speeds. If, on the other hand, speeds are very low, then BRT investments are more likely to bring about significant passenger time savings and operational benefits.

Gold Standard

Figure 5.9 is a graphic taken from an analysis of two parallel corridors in Chicago. It compares the existing running time on two proposed BRT corridors to what could be achieved on the corridor were "Gold Standard" BRT investments made.

Gold Standard BRT systems are primarily designed to reduce delay caused by boarding and alighting and general traffic congestion. If the cause of delay is congestion, dedicated lanes without other BRT infrastructure may be sufficient. If the primary cause of delay is from boarding and alighting, off-board fare collection and at-level boarding, without exclusive lanes, may be sufficient. Full BRT is most valuable where both types of delay are present.

Without knowing anything else about the BRT system design, it is generally safe to assume that Gold Standard BRT systems operating on urban arterials are likely to increase average speeds to as high as 29 kph, or in dense downtowns, as high as 20 kph. BRT speeds on highways could be significantly higher. More corridor-specific data about the existing causes of delay can yield far more refined estimates of the likely time savings benefits of BRT infrastructure.

Figure 5.6. Customer loads and boarding and alighting time for Nairobi, Kenya's A104 BRT Corridor. *ITDP.*

Figure 5.7. Bus flows of all routes in Guangzhou Avenue (being considered for BRT implementation) in Guangzhou, China. Peak points in the proposed north-south BRT corridor (in blue) have more than two hundred buses per hour in a single direction. Peak points in off-corridor locations, showing where the Guangzhou Avenue routes operate, feature more than 150 buses per hour in a single direction. *ITDP.*

Figure 5.8. Analysis of existing bus speeds for Tianjin, China, BRT. *ITDP.*

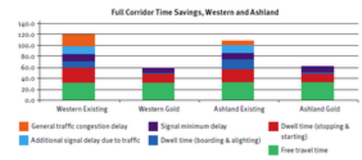

Figure 5.9. Causes of bus delay for two corridors in Chicago and how Gold Standard BRT can help reduce this delay. *ITDP.*

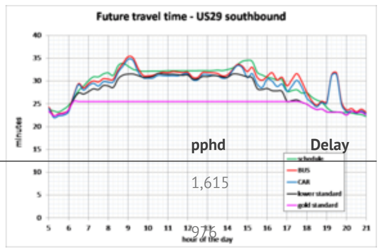

Figure 5.10. A graphical example of a possible BRT corridor in US29, in Montgomery County, Maryland, USA, and its existing speeds in relation to potential speeds. *ITDP.*

5.3 Corridor Prioritization Based on Existing Demand

> *"Many roads lead to the path, but basically there are only two: reason and practice."*
>
> — Bodhidharma, Buddhist monk, 6th century

Once both existing ridership and existing speed data have been mapped, the two datasets can be overlaid so that there is one map showing where high demand and low speeds overlap. This is a good indication of where BRT is likely to have the most impact.

From here, potential corridors should be delineated. Per the definition of a BRT corridor, a corridor must be at least 3 kilometers in length. It is rare that one single corridor will have uniform ridership and speeds along its full length. Therefore, corridors must be selected by choosing 3 kilometer or longer continuous segments of roadway with relatively consistent demand and speed values. This requires some judgment on the part of the planner, and ideally some knowledge of the city. It may make sense to draw corridors along existing bus routes, but it is not necessary since bus routes may enter and exit corridors, so BRT infrastructure might also be built along segments of routes.

Once corridors have been identified, they should be ranked from highest demand to lowest demand, with a minimum threshold that planners believe can still reasonably bring the corridor up to 1,000–1,200 pphpd in the first year of operation. Each corridor should be color-coded based on its average speed. Those corridors with unusually high speeds for the region should be screened out, as they are likely already functioning at a relatively high efficiency. Additionally, those corridors on which another public transport project is currently being planned should also be screened out.

Table 5.1. Rank order of Boston corridors from map in Figure 5.13. represents the least delay, moderate delay, and the most delay. The City Center to Government Center route currently does not exist, and thus the pphpd is not provided. Analysis done by ITDP.

Rank	Corridor	pphd	Delay
1a	Upgrade of existing Washington Silver Line	1,615	
1b	Extension Dudley Square to Mattapan	976	
1c	Extension City Center to Government Center		
2	Allston Union Square to Dudley Square	1,273	
3	Downtown Chelsea to Government Center	1,215	
4	Forest Hills to West Roxbury	1,077	
5	Harvard Square South to Newton Corner	998	
6	Forest Hills to Wolcott Square	799	

7 Allston Union Square to Longwood

8 Harvard Square to Watertown

In many parts of the world, demand far surpasses these minimums. In such cases, it is generally reasonable to select the top ten corridors based on demand, as these are the corridors on which BRT is likely to have the most impact. In fact, *The BRT Standard* (2014) awards maximum points for corridors that are located in the city's ten corridors with the highest demand.

If stop-by-stop boarding and alighting data is available, it is also a good idea to map boarding and alighting volumes along the corridors. The larger the concentration of boardings and alightings along a corridor, the greater the likelihood that a BRT will be beneficial. Boarding and alighting can be used as a third metric for determining which corridors BRT could provide the most benefits.

With the top corridors ranked based on existing ridership and speed, we can assume that if any of them are upgraded to BRT, the ridership will increase due to the higher speed and attractiveness of the BRT as compared to the current bus routes or other options. In the first year of operation, it is reasonable to expect an increase of 30 percent above existing ridership. Unless ample resources are available to build a model, looking at existing conditions only is generally a reasonable means of determining which corridors are best suited for BRT and what kinds of ridership to expect in the opening year.

If a good set of corridors already exists based on this methodology, it is generally enough to build a BRT network plan. But sometimes, for political reasons, other corridors without existing bus routes, or with existing bus routes but with low demand, are desirable for BRT. In these cases, a costlier and more resource-intensive study must be undertaken in order to estimate demand on such a corridor and to insert it into the rank order with the other corridors already prioritized.

5.4 Additional Corridors Based on Future Demand

"Prediction is difficult, especially about the future."

— Yogi Berra, former baseball player, 1925–2015

There are cases in which corridors without existing bus routes, or with existing bus routes with low demand, may still be good BRT corridors. There are four main reasons for this:

1. Route Shift: Some trips may shift from nearby public transit routes;
2. Mode Shift: Some customers may be new to public transport due to the dramatic service improvements that BRT can offer;
3. Land Use Changes: Land use may change, generating new trips altogether, or BRT can be used to help stimulate land use changes;
4. Downtown Infiltration: BRT may provide a new link into a city's downtown, where public or private buses were not previously permitted to go.

Transit ridership during the first year of operation, however, is difficult to predict with any accuracy. Hence, future projections of this type are subject to interpretation and manipulation. As such, it is wise not to put too much stock in any hard numbers with regard to projected future ridership. It is also a good idea to require that all assumptions used to predict future ridership be presented to stakeholders in their raw form rather than merely processing the data and burying it in a multi-criteria analysis. This might include:

- Service plan assumptions;
- Speeds on BRT links;
- Source of all origin-destination data;
- Land use change assumptions;
- Mode-specific constants;

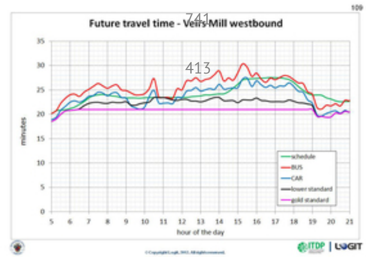

Figure 5.11. Another graphical example of a possible BRT corridor in the same area of previous image. Here (Veirs Mill Road), the potential time savings is much greater on US Route 29. *ITDP.*

Figure 5.12. Boston map of existing bus ridership and speeds. High ridership is depicted with thicker lines, while low speeds are depicted in red. *ITDP.*

Figure 5.13. After considering bus ridership, speeds, and city typology, the best potential corridors for BRT in Greater Boston are highlighted on the map. *ITDP.*

Figure 5.14. BRT bus flows and proposed BRT corridors in Vientiane, Laos. Peak bus flows will be around eighty buses per hour in a single direction, assuming fifty-customer maximum capacity buses are utilized. *ITDP.*

Figure 5.15. Boarding and alighting volumes at bus stops in Tianjin. *ITDP.*

- Transfer, walking, and waiting penalties.

Now we will delve into further detail about how best to estimate future ridership based on the three categories: route shift, mode shift, and land use changes.

5.4.1 Route Shift

Sometimes a new BRT is built that provides a new or faster public transport link for existing customers. This might be because the BRT offers faster services than parallel bus routes, or because it offers new routes that cover a shorter distance than the previous routes. Such new routes may even eliminate a previously necessary transfer. It is difficult to predict such route shifts without a model.

A public transport model gives us the ability to insert a new public transport link, perhaps at higher speeds than the existing links, and see how many customers make the switch. Unlike modal shift (see below), public transport customers have already made the decision to use public transport, and are therefore most likely to choose the corridor/service that provides the fastest trip, even if it is new.

Modeling route shifts requires a complete set of transit data about existing conditions, including existing ridership and speeds on all public transport routes. Ideally, there will also be an existing origin-destination matrix indicating the boarding and alighting stations of all public transport. If not, one should be created and include transfer data as well.

In order to ensure a fair comparison between corridors modeled from route shift and corridors selected from the demand analysis, the model should be run as if the BRT were opening today, without accounting for any future system growth. Once the model has been run, the maximum pphpd on the modeled corridor should be extracted from the results. Demand is usually highly elastic, so an increase in the price of the service may significantly reduce demand. This needs to be factored in when modeling demand from route shift, unless all these are consistent between the two services.

Because a BRT corridor is estimated to gain a significant percentage increase in ridership over existing conditions, one must decrease the maximum pphpd identified by the corresponding percentage, so that the corridor may be comparable to the other corridors selected in the existing conditions analysis.

5.4.2 Mode Shift

When a new high-quality public transport corridor is built, such as BRT, some people who currently drive may switch over to public transport. This might be because the BRT is faster or more convenient than driving, or because parking is difficult or expensive and the BRT represents a less costly option. Many cities, particularly in developed-world contexts, invest in transit precisely to lower auto use and fundamentally change travel patterns.

It is difficult to model modal shift. Often, it is based on a four-step model that begins with a household survey and a mode choice analysis. This can be quite complex and can hide many important assumptions. Indeed, many models that have predicted a high mode shift have been significantly overestimated.

A BRT corridor cannot be selected based primarily on the assumption that it will lure people out of their cars. This could take many years and could result in empty buses until this goal is realized. Instead, it is safer and more realistic to plan for corridors where existing demand and bus service already exist. This way, BRT corridors are selected where there is certain to be ridership and some modal shift is a good possibility.

International experience has shown a range of percentage increases above existing ridership due to modal shift. In Rio de Janeiro, 5 percent of the people surveyed for the TransOeste Impact Study said they had shifted from car use to the BRT in the system's first nine months of operation. Likewise, in Mexico City, 17 percent of Metrobús customers left their cars for BRT. According to Metrobús, that percentage translates to 122,000 fewer car trips every day.

However, because it is best to apply the mode shift increase to corridors with existing high demand, it is just as well to leave the corridors prioritized as is and, once built, make efforts to attract people to use the new system rather than cars.

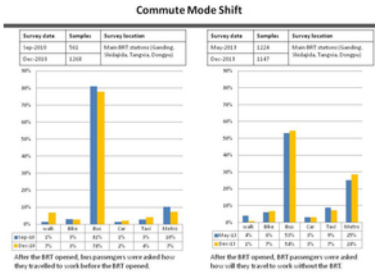

Figure 5.16. Mode-shift data from the Guangzhou BRT system. There was an increase in mode shift from cars to BRT between 2010 and 2013. *ITDP.*

5.4.3 Land Use Changes

There are two reasons why a BRT might be built where land use is changing. First, rapid urban revitalization in a certain area might not be reflected in the existing transit services and, if dense enough, is likely to need a high-capacity public transport link in order to discourage auto use from the start. Second, a growing number of cities, particularly in the United States, are looking to BRT as a tool to stimulate urban revitalization and transit-oriented land development. In either of these cases, it might be worth considering BRT in order to serve the newly developed land. First, we describe how to determine if these conditions are met, and second, we describe how to create a BRT corridor in order to serve these changes.

To determine where land is developing and no transit has yet been designed to serve the new development, one should look at net changes in housing and commercial units over the past ten years (Figure 5.18). This information can sometimes be collected from the census or from other sources. Another good source of data is to look at building permits issued but not constructed as a guide to where new development is likely to take place (Figure 5.19). Sometimes these can be collected from the planning department or the buildings department of the municipality. This data about recent existing trends in real estate development is likely to be continued to some extent over the next decade. This grounds future projections on land use changes in reasonably transparent empirical data.

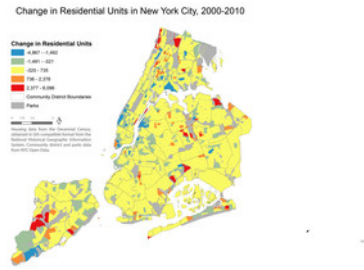

Figure 5.17. This map illustrates which neighborhoods in New York City have experienced the greatest change in the construction of housing units. *ITDP.*

In addition to using BRT to serve development that is already occurring, BRT is more and more commonly being used to help stimulate development in designated areas. A recent study conducted by ITDP analyzing transit corridors throughout North America found that if BRT is built in the right corridor and the government institutes policies that encourage development around that corridor, there is a strong chance that the land along the corridor will attract development. However, using BRT to drive development is not enough. BRT planning, when premised on development, must be directly linked to government development initiatives.

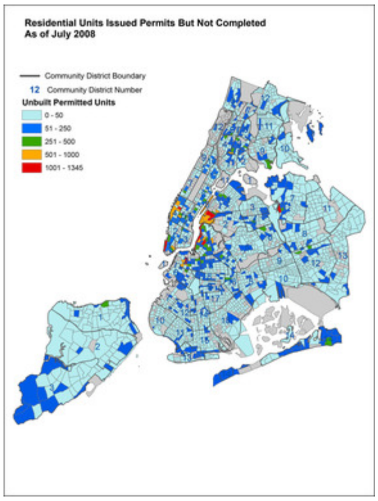

Figure 5.18. This map illustrates which neighborhoods in New York City have the greatest number of building permits issued but not completed. *New York City Department of Buildings.*

Often, local planning and urban development authorities have a fairly good sense of where they want to develop, what new development is likely, and where they have been approached by developers asking for zoning variances or other support from the municipality. Sometimes planning authorities have regulatory structures that guide new development in specific areas through spatial development plans, and they may have a good sense of the likely time frame for these developments. So if one of the purposes of BRT corridor selection is to simulate development, information regarding the government's development plans should be collected and the locations should be mapped.

There are integrated transportation and land use models available, some of them open source like Tranus, which provide more sophisticated modeling tools for predicting future land use changes and hence are able to provide more robust future demand projections than traditional four-step travel demand models. These models generally rely on census-tract-level changes in population and employment as a baseline, and then supplement their future demand projections with additional data sources. In our experience these models are quite difficult to use and require a significant amount of data that is difficult to collect. It is preferable that all of the basic

Figure 5.19. Areas in Greater Boston where the government is focusing its development efforts or has at least created area plans. *ITDP.*

information described above be presented to stakeholder groups in the form of a map to serve as a guide for the BRT corridor selection.

Once all of the information has been mapped and presented, planners must determine how areas of new development can be linked to BRT corridor selection. An underdeveloped area on its own, even if in the process of being developed, is unlikely to be able to support a BRT, particularly if the BRT serves only that area and does not connect with other sectors of the city. It is much better to link areas of new development to transit corridors with already high demand, as this is more likely to provide a useful connection to the people moving into or working in the new development areas. Additionally, in the years during which the development is occurring, the BRT corridor will still be relatively successful due to its serving areas of already high demand.

Ideally, a BRT corridor proposed to serve a new development will be close to existing high demand corridors, because the link between existing high demand and newly developing areas will be short so if buses are empty for a while, it will only be for a short link. Second, studies have found that the closer a new development area is to existing activity, the more likely it will be to develop.

5.4.4 Integrating the Downtown

Sometimes preexisting bus routes stop just short of a city's downtown. This is rarely due to low demand in the downtown. Instead, it is often simply government policy to keep buses out of the downtown core. In fact, most cities' downtowns are still where the majority of trips end in the morning and begin in the afternoon. It is almost always the case that providing a city's downtown with Gold Standard BRT will increase the demand on the BRT as a whole. It is possible to prove this with a demand model; however, it is generally not necessary to model such a situation since in nearly all cases, it turns out to be true.

If a city's downtown is so blighted that demand is unlikely to materialize in the near term, it is still generally worth serving the downtown with any BRT corridors that are planned to come near it, as it is almost always the case that downtowns revitalize more quickly than any other parts of a city. Additionally, a BRT that passes through the downtown can have positive development impacts along the rest of the corridor as well, since downtown access makes the entire corridor more attractive to developers. Cleveland, Ohio, USA's Silver Standard HealthLine is a great example of a BRT that was built directly into the downtown and, as a result, leveraged over US$5.8 billion in development throughout the corridor.

Many cities have multiple subcenters that serve as smaller downtowns. It is often the case that serving these subcenters with Gold Standard BRT can have nearly the same effect as bringing BRT directly into the city's main downtown.

Finally, the specific routing of BRT infrastructure through a city's downtown or an important subcenter, particularly if there are currently no bus routes to mimic, may be subject to a political negotiation, since downtown streets are often quite narrow. However, the BRT should ideally be routed through the densest part of downtown.

CORRIDOR	ENTERS INTO DOWNTOWN	TOD INVESTMENT (MILLIONS)
Portland MAX Blue Line	Yes	$6,600
Cleveland HealthLine	Yes	$5,800
Portland Streetcar	Yes	$4,500
Kansas City Main Street Metro Area Express (MAX)	Yes	$5,200
Seattle South Lake Union (SLU) Streetcar	Yes	$3,000
Phoenix Metro	Yes	$2,821
Denver Central Corridor	Yes	$2,550
Las Vegas Strip & Downtown Express (SDX)	Yes	$2,000
Boston Waterfront Silver Line	Yes	$1,000
Ottawa Transitway	Yes	$1,000
Pittsburgh Martin Luther King, Jr. East Busway	No	$903
Charlotte Lynx	Yes	$810
Boston Washington Street Silver Line	Yes	$650
Los Angeles Orange Line	No	$300
Denver Southwest Corridor	Yes	$160
Eugene Emerald Express Green Line (EmX)	Yes	$100
Pittsburgh South Busway	No	nominal
Ottawa O-Train	No	nominal
Pittsburgh West Busway	No	nominal
Pittsburgh "The T"	Yes	nominal
Las Vegas Metropolitan Area Express (MAX)	Yes	nominal

BRT Bus Rapid Transit BUS Bus SC Streetcar LRT Light Rail Transit

Figure 5.20. A public transport system that runs on dedicated lanes in a city's downtown is more likely to leverage TOD. *More Development for Your Transit Dollar: An Analysis of 21 North American Transit Corridors. 2013.*

5.5 Framework for Comparing Corridors

> *"The only relevant test of the validity of a hypothesis is comparison of prediction with experience."*
>
> — Milton Friedman, economist, 1912–2006

Making a good decision in a timely manner is not always facilitated by elaborate analysis. Often detailed economic, financial, social, and environmental impact analyses are too cumbersome and expensive to do. Picking the right corridor is as much a matter of common sense as extensive research. However, the data and mapping suggested above are reasonable analyses to perform at the corridor-selection stage, and should be sufficient to result in a set of corridors that make sense from a technical perspective.

Once a set of corridors has been selected on technical grounds, it is important that these create a BRT network. Otherwise, the corridor-selection process may still be open to political interference, and a corridor could be selected with no real technical basis. However, it may not be possible to build out every one of the selected corridors, nor must the corridors be implemented in the same order in which they were prioritized. Some additional work may be needed in order to account for factors that are more political in nature, as well as to build a more detailed cost-benefit analysis weighing one corridor against another. In this way, the selected corridors may be narrowed down to a smaller set and/or reprioritized into a network and phasing plan.

5.5.1 Corridor Right–of-Way and Lane Uses

There is rarely anything innate about the characteristics of a corridor that would make it impossible to build BRT. Successful BRTs have been built on corridors as wide as Nueve de Julio Avenue in Buenos Aires—which is allegedly the widest street in the world—and as narrow as the historic downtown of Quito, which, at times, is only three meters across. Almost any road that can accommodate a bus can accommodate BRT in some form. Nevertheless, one-way streets, narrow rights-of-way, and suburban land use patterns all present special challenges for BRT system design.

A visual corridor review should look primarily at the existing configuration of the road, the basic traffic mix, the available right-of-way, and the land uses along it. One can get a general sense of the corridor now with tools such as Google Earth and Google Street View, but there is no substitute for walking the corridor. If survey data is not available, a laser distance measurer or measuring wheel can be used to record the road right-of-way width throughout each potential corridor.

There are a variety of ways of presenting this information to stakeholders. Software programs such as Streetmix allow users to display road cross sections and replicate lane widths and rights-of-way on actual streets. Figure 5.20 shows a specific cross section using this software at a specific location along a proposed BRT corridor in Boston.

Figure 5.21. Right-of-way and lane widths created using Streetmix for a specific location along a proposed BRT corridor in Boston. *ITDP.*

The roadway width can also be graphically shown along the length of the corridor using a plot of width against corridor location.

In addition to noting physical dimensions along a roadway, an initial survey should also note other features, such as the configuration and condition of medians and the presence of trees, utility poles, public art, or other features that may be expensive or politically difficult to relocate. Are the pedestrian paths adequate for providing access to a public transport system, or do they likely require widening? Are there difficult intersections along the corridor, such as roundabouts with fountains or artwork, or cloverleaf highway-grade interchanges, or narrow flyovers and bridges? Are there locations with low-cost land uses, such as surface parking lots, that could be procured for station stops where the road may need to be widened? A BRT engineer will tend to look for things on a visual survey of the corridor to get a general sense of how expensive it is likely to be to build a good-quality BRT along it.

While there is no clear metric for prioritizing corridors based on right-of-way, lane uses, or other features, this information should be included in the BRT corridor-prioritization analysis and presented to the public in a transparent way. Generally, if the public and/or the government supports a proposed corridor despite narrow right-of-way or other related issues, it should be kept on the list.

Figure 5.22. BRT station rendering in a narrow right-of-way in Rue Setthathilath where a transit mall (BRT bus, bicycles, and pedestrians only) is proposed in Vientiane, Laos. *ITDP.*

5.5.2 Corridor Typology and Suitability for BRT

We define here five corridor types on which BRT projects are often considered. Generally, BRT only makes sense on the first three (Types I, II, and III) and is not recommended for the last two (Types IV and V). While some BRT elements could make sense for the latter types, this guide focuses only on true BRT systems, and so BRT is recommended only on Types I, II, and III.

- **Type I: Urban Corridor**. Urban corridors are typically arterials and secondary streets in dense urban environments with curbside activity, relatively short block lengths, and preexisting bus routes. Euclid Avenue outside of downtown Cleveland is an example of an urban arterial with a Silver Standard BRT. Other urban arterials include the Gold Standard BRT in Yichang, China completed in 2015; Geary Street in San Francisco, where a Silver Standard BRT is being planned; and many others. Most cities have at least a few urban arterial streets, and those streets are, by definition, well integrated into the urban context;
- **Type II: Downtown Corridor.** Downtown corridors are typically streets that go right through a city's downtown. Downtowns are still the center of activity in most cities. As cities look to re-urbanize and revitalize their downtown cores, public transport directly through the downtown is critical. Often, downtown streets are narrow and congested, with very high levels of curbside activity. Sometimes there are preexisting bus routes through downtown streets, and other times, bus routes stop on the edge of a city's downtown due to businesses and other powerful interests that fight to keep them out. Yet if there is any place where BRT could be successful, it is directly through a city's downtown. Mexico City, Mexico; Bogotá, Colombia; Johannesburg, South Africa; Dar es Salaam, Tanzania; and many other cities have built Silver and Gold Standard BRTs on very narrow downtown streets, providing a large boost to BRT ridership and revitalizing many dying central cities.

Because Type I corridors are the simplest to verify in terms of ridership, and Type II corridors, while sometimes less simple to verify, are often likely to have the highest ridership of any corridor in a city, Type I and II corridors should be prioritized in the corridor selection process;

- **Type III: Former Freight Rail Right-of-Way Corridor**. There are many corridors that were once dedicated for freight rail but which at some point were abandoned. These corridors often make attractive corridors for BRT, since they do not require reallocating road space. Both Pittsburgh, Pennsylvania, USA, and Los Angeles have built Bronze Standard BRTs on former freight rail right-of-way corridors. Yet former freight rail corridors do not often have preexisting bus services already operating on them, nor are they generally well integrated into the urban environment.

Type III corridors have potential, in some cases, to be successful BRT corridors. However, because ridership is less assured than with Types I and II and because they do not generally integrate as well into the urban environment, Type I and II corridors should be prioritized over Type II corridors.

- **Type IV: Suburban Arterial Corridor.** Many streets just outside of urban areas classify as suburban arterials. Suburban arterials are often higher speed, carry higher capacities than urban arterials, and have less curbside activity (parking, deliveries, etc.). This is because suburban arterials tend to be lined by surface parking lots and most deliveries and passenger drop-offs occur from these off-road parking lots. There are also generally lower pedestrian-crossing volumes at intersections to impede right turning movements. As a result, there is little curbside activity, so dedicating the busway to the center of the road is not particularly needed. Hence, other than traffic congestion, the type of bus delay that BRT is designed to reduce does not typically exist on suburban arterials. Additionally, the distributed nature of trip patterns in suburban contexts means that bus boarding and alighting volumes at stops along suburban arterials are typically low, so off-board fare collection has less utility. Therefore, while some bus treatments could make sense on a suburban arterial (e.g., signal priority, curbside bus lanes, etc.), BRT rarely does. BRT on suburban arterial corridors is generally not recommended.

However, there is one condition in which BRT might be considered on a suburban arterial: If there is a concerted effort by the government to urbanize a suburban arterial, and thus transform it into a Type I "Urban Arterial Corridor," BRT could make sense, provided the application meets the minimum pphpd requirements. In order for a city to demonstrate that a project is on an urbanizing suburban arterial, there must already be zoning changes in place that allow for a more urban form and the corridor must pass through at least one or two pockets of somewhat more urban character. Rockville Pike in Montgomery County, Maryland, USA, falls into this category. The proposed BRT project makes sense in light of the fact that the county has rezoned along Rockville Pike and has special zoning rules around high-capacity public transport stations. Further, and of particular importance, is the fact that the corridor connects to downtown Bethesda and downtown Rockville, both areas of a somewhat urban character. An urbanizing suburban corridor should at least connect to the more urban subcenters.

- **Type V: Highway Corridor.** Highways are often congested and in some cases, carry large volumes of bus customers. However, as on suburban arterials, the delay that BRT is designed to reduce does not typically exist on highways. And, unlike with suburban arterials, there is no possibility that a highway corridor will urbanize. A highway with transit needs is best served by express buses, operating in an HOV lane, which exit the highway to make stops. This is not BRT. Thus, if a Type V corridor has made it onto the list of possible corridors, it should be removed.

5.6 Corridor Length

"Time is the longest distance between two places."

— Tennessee Williams, dramatist, 1911–1983

The basis for the cost-benefit analysis of corridor length is typically the time savings generated by the exclusive busway. Once the exclusive busway no longer provides a net time savings benefit in comparison to the construction costs, then the point has been reached when the exclusive busway is no longer cost justifiable. As the number of customers falls with the distance from the city center, the total time savings benefit is reduced. Further, since congestion levels will also likely fall with distance from the city center, the travel-time advantage of an exclusive busway will likewise fall. Table 5.3 provides an example of a cost and benefit analysis plotted against a corridor's length.

Figure 5.23. The availability of land for terminal and depot space can be a consideration of the end point for a specific corridor. *TransMilenio SA.*

Of course, this time savings benefit will tend to increase as congestion worsens over time. Since a BRT system is likely to last a long time, it is standard practice to roughly estimate the likely congestion along the corridor in the next ten to twenty years rather than simply assuming that current congestion conditions will prevail long into the future.

Table 5.2. Cost-benefit analysis of corridor length

Corridor segment	Length of segment (km)	Demand along segment (x 1000)	Time savings (minutes)		Cost		Benefit	Benefit / cost ratio (B / C)
			Total	/ km	Total	/ km	/ km	
A	3	13	6	2.00	5	1.67	26.00	15.60
B	2	12	4	2.00	4	2.00	24.00	12.00
C	1.5	13	5	3.33	3	2.00	43.33	21.67
D	3	11	4	1.33	4	1.33	14.67	11.00
E	1.8	9	1.2	0.67	2	1.11	6.00	5.40
F	3.1	7.5	2.5	0.81	4	1.29	6.05	4.69
G	2.3	6	0.5	0.22	3	1.30	1.30	1.00
H	1.5	4.5	0.6	0.40	2	1.33	1.80	1.35
I	3.1	3	1	0.32	5	1.61	0.97	0.60
J	1.9	2.2	0.2	0.11	3	1.58	0.23	0.15

In the example given in Table 5.1, the corridor would end after segment "H" if the decision was based only on benefit to cost considerations. After segment "H," the benefit to cost ratio falls below a value of one, meaning that the costs of extending the exclusive busway corridor outweigh the time savings benefits.

5.6.1 Where to Build Infrastructure Versus Where to Run BRT Services

Modern thinking in BRT planning has evolved to separate BRT infrastructure from BRT services in such a way that BRT services may operate both on- and off-corridor in a way that optimizes customer benefits versus infrastructure cost. Therefore, in the sections above, "BRT corridor" refers directly to the infrastructure built on a segment of road, rather than to the services that are needed.

Once a corridor has been selected, it is important to make an informed judgment regarding where to design BRT infrastructure and for how long of a stretch. This is best done by graphing the demand distribution and speeds during the peak hour, and selecting the location with both the highest demand and lowest speeds. Per the definition of BRT, the selected corridor must be at least 3 kilometers.

Building BRT infrastructure on the segment of roadway along the corridor with the highest demand means that infrastructure investment will yield the greatest benefits. Oftentimes, however, the sections of a corridor with the highest demand are precisely the sections where politicians are less willing to propose BRT infrastructure, as those sections often face more constraints. As a result, BRT infrastructure often stops just before the segment where it is needed most. *The BRT Standard* (2014) awards maximum points to corridors that include the highest quality of BRT infrastructure on the highest demand segment. This often means extending the BRT directly into the city center. For other corridors that do not come near the city center, this may simply mean the area with higher demand than the rest of the city.

Once the location for BRT infrastructure has been selected, one must consider what to do beyond the infrastructure. Many cities propose lower-quality bus treatments beyond the infrastructure. Generally, however, it is preferable to allow BRT services to simply enter mixed traffic beyond the infrastructure. This sends a clear signal to the public that there is a difference between BRT and everything else, and leaves open the possibility of building out the rest of the corridor as full BRT at a later date. If lower-quality bus treatments are implemented beyond the BRT infrastructure, it is less likely that they will ever be upgraded to full BRT.

Finally, it is possible to design BRT services to extend beyond the BRT infrastructure into many parts of the city. This expands the catchment area of the BRT to many more beneficiaries than simply a service that directly matches the infrastructure. It also provides an opportunity to bring new BRT services to sections of the city where no bus services previously existed but where stakeholders wished to see a BRT corridor. That is, in some cases, during the corridor selection process, some selection of stakeholders may advocate for a corridor with no preexisting bus demand. It is unlikely that such a corridor will make it to the list of top corridors for BRT implementation. However, if the requested corridor is located near the corridor ultimately selected, it may be reasonable to run a service into that area to begin to grow demand for future BRT infrastructure in that location, as well as to demonstrate to stakeholders that such an area will be a beneficiary of BRT.

The next chapter covers how to develop and optimize a BRT service plan. But it is worth noting here that a BRT corridor with multiple services receives maximum points on *The BRT Standard* (2014).

5.7 Other Considerations in Corridor Selection

> *"Success is a journey, not a destination."*
>
> — Ben Sweetland, author

The above framework and analysis should be sufficient to determine both the corridors that should be developed for the whole BRT system and the corridor that will be chosen for the pilot phase. While this is often all that is needed to make a decision about the right corridor, below are other considerations that can be used to choose the corridor, including:

- Customer time savings;
- Impact on mixed-traffic lanes;
- Implementation costs;
- Detailed cost-benefit analysis;
- Political considerations, including social goals.

5.7.1 Customer Time Savings Benefits

As discussed above, main public transport service improvements result from reducing congestion and boarding and alighting delays, in addition to upgrading the overall transit experience. The worse the congestion and the larger the number of existing bus customers along the corridor, the more positive the impact of a BRT system. The economic impacts from these effects are typically calculated through time savings analysis. The analysis mentioned above should be sufficient to know where the most savings from delays will occur, but quantifying the economic impact may confirm the decision.

To calculate the time savings benefits to public transport customers, estimations on passenger numbers and vehicle speeds both before and after the new system are required. The average vehicle speeds will directly relate to the amount of travel time for a particular journey. Equation 5.1 provides a framework for calculating the customer time savings.

Eq. 5.1 Customer time savings

Where:

P = Number of passengers;

Tp = Present travel time;

Tf = Future travel time.

Because benefits will vary quite a lot not only between corridors but within corridors, it is necessary to add up the benefits for each link in the corridor. These benefits will also likely vary according to the time of day and the day of the week. A calculation of this type is most readily accomplished with the assistance of a traffic model. However, a simple spreadsheet analysis with inputted survey data can also suffice. The more complete time savings formula is given in Equation 5.2.

Eq. 5.2 Detailed time savings calculation

Where:

i = Link;

h = Period (morning peak, off peak, night, etc.);

Pih = Passenger flow on the link (passengers/hour);

Hh = duration of period h in hours

Tpih = present travel time on link I period h

Tfih = future travel time on link I period h

Pih*ΔHh produces the total number of passengers on a particular link during a particular period. This value, multiplied by the estimated time savings yields per link, produces the total number of hours saved by public transport customers. This value can then be multiplied by a monetary value of time, or it can be left in the form of hours saved.

The existing public transport vehicle speeds and customer counts should have been collected during the demand analysis work noted in Chapter 4: Demand Analysis. Likewise, the boarding and alighting surveys during this phase should have produced values for both peak and nonpeak periods.

Future average vehicle speeds and customer demand will depend on the system's design. Future customer volumes should be based on a combination of existing passenger volumes in conjunction with the size of any expected mode shifting.

5.7.2 Time Savings Benefits for General Traffic

Corridor selection may also depend on the impact BRT infrastructure will have on mixed traffic flow. Ideally, BRT will improve mixed traffic speeds by taking the buses out of the traffic lanes and reducing delay from buses pulling over and stopping for customers. However, this might not always be the case. There are select instances where BRT could make mixed traffic flow much worse, which may become a political problem. The three most important indicators of the likely impacts of BRT on mixed traffic are: the current traffic mix; the available right-of-way relative to the existing road; and the possible behavioral and travel changes of motorists once the new public transport system is in place.

Current Traffic Mix

Normally, for a BRT system to be considered an option, there is likely to be significant congestion on at least part of the corridor. As a general rule, the greater the current contribution of public transport vehicles to the current congestion problem, the greater will be the chance that a new BRT system will actually decongest the mixed traffic-lanes (Figures 5.25 and 5.26).

In countries with higher bus volumes, public transport vehicles frequently have a disproportionately higher impact on congestion relative to private vehicles. This impact occurs because the vehicles often stop and go at undesignated bus stops, and because the vehicles sometimes stop two and even three abreast to pick up customers. Bringing these public transport operators into a new BRT system, therefore, frequently offers the opportunity to decongest mixed traffic-lanes even if a full lane or

Figure 5.24. An exclusive busway on a road in Dallas, Texas, USA, will likely make congestion for mixed traffic worse. *Richard Stouffer (iStockphoto)*

Figure 5.25. An exclusive busway on the road in Bangladesh would likely make mixed traffic less congested because of the high number of buses in mixed traffic. *Karl Fjellstrom.*

two become exclusive to buses. In such cases, the new BRT system can easily produce a somewhat counterintuitive result; taking away road space and giving a priority lane to public transport can actually give motorists *more* space and produce *less* overall congestion.

The specific congestion impact of the BRT system will depend on which public transport vehicles are incorporated into the new BRT system and which are excluded. The more public transport trips that can be incorporated into the BRT system, the less adverse impact the remaining public transport trips will have on the mixed-traffic lanes.

Methodology for Estimating Impacts on Mixed Traffic

As a rough estimate, one can calculate the likely impact of a planned exclusive busway on mixed traffic in the following manner: The existing traffic flow at the most congested point of the road (based on traffic counts) should be converted to passenger car units (PCUs) for each available road lane. If the road lanes are not delineated, then this PCU conversion should be done for every three meters of road width.

Normally, lanes with a width of 3 to 3.5 meters can handle approximately 2,000 PCUs per hour. The more the PCUs over 2,000 per lane, the more congested the road will become.

This level of existing congestion should then be compared to the scenario with the BRT system in place. Some of the current public transport vehicles will be relocated onto the new BRT system, and others will remain in the mixed-traffic lanes. All the vehicles that will not be incorporated into the BRT system, including the buses not incorporated into the system then need to be converted into PCUs, and allocated to the remaining number of lanes (or three-meter road widths). Table 5.2 provides an example of this type of analysis.

Table 5.3. PCU calculation for BRT scenario

Vehicle type	Traffic volume	Average passengers per vehicle	Total passengers	PCU equivalent	PCU total
Cars	1,200	2.5	3,000	1	1,200
Taxis	500	1.2	600	1	500
Motorcycles	170	48	8,160	2	340
Remaining buses	300	1.5	450	0.25	75
Total	2,170	-	12,210	-	2,115

If the PCUs of the BRT scenario are higher than the PCUs of the pre-BRT scenario, then the new BRT system will tend to increase congestion of the mixed-traffic lanes. If it is lower, it will lead to lower congestion levels. Because the PCUs of buses are generally double that of private cars and taxis, and eight times as high as motorcycles, the more buses in the existing traffic stream that are relocated to the new BRT system, the greater the degree to which the remaining mixed-traffic lanes are decongested. A more detailed and accurate calculation of traffic congestion impacts can be obtained through a traffic software model.

Once the level of traffic is estimated for both the baseline case and the BRT case, then the amount of time savings for occupants of mixed-traffic lanes can be calculated. Box 5.1 provides an overview of the time savings calculation.

In practical terms, the changes to intersections along a BRT corridor far exceed the importance of lane allocations to general traffic between intersections, and can result in dramatic improvements for both BRT buses and mixed traffic despite any lane reductions due to BRT lane segregation and the extra space required at BRT stations.

Box 5.1. Calculating Time Savings for Vehicle Occupants in General Traffic

On some critical sections (i), present general traffic volume on peak periods (j) will exceed the road's capacity, by a certain amount: ΔSij. The total general traffic prejudice on that point "i" is then estimated by Equation 5.3.

Equation 5.3 Time savings for general traffic

Where: i = Point of evaluation where one of the following effects takes place:

- 1. The point is the bottleneck of the corridor
- 2. The point is not the bottleneck, but future capacity (after BRT) will fall below present peak volume

j = A specific peak hour. There are normally two peak periods, a morning peak and an evening peak. A velocity survey for cars will more accurately identify the peak periods.

TGCj = Total time savings for general traffic

ΔSj = the amount of change on capacity to the new scheme. This value will be negative value if there is a reduction in capacity; this value will be positive if there is an increase in capacity.

Tcongji = duration of the congestion period being considered. The peak period can be better estimated by traffic velocity surveys that show when travel times increase more drastically. Usual values are around 0.5 to 3 hours.

Ki = reflects a group of factors derived form network analysis and demand elasticity.

It should be noted that reductions of capacity on two successive nearby points are not independent, and the more congested point should usually be considered the important one.

5.7.3 Implementation Costs

In general, the more complicated the physical aspects of a corridor, the more costly the planning and construction will be. Any of the following infrastructure components along a proposed corridor can cause costs to escalate:

- Road widening;
- Use of median;
- Relocation of utilities;
- Underpass or tunnel;
- Flyover, overpass, or elevated segment;
- Bridges;
- Large roundabouts.

Road widening can be particularly costly, especially when any property acquisition is considered. These considerations may affect the decision of which corridor to implement when.

As Quito has demonstrated, in some cases, underpasses and complicated roundabouts can be handled without extravagant costs. By contrast, simply converting a mixed-traffic lane to a BRT runway without any of these complications can reduce both planning and infrastructure costs.

Several Chinese cities are contemplating placing BRT runways along ring roads. Much of the reasoning is related to the existing right-of-way space and the relative ease of construction. However, customer access to a ring road station (both in terms of horizontal and vertical distances travelled) can be difficult. Building these "easy" infrastructure projects may eventually undermine the BRT concept. A BRT system with few customers may seem to operate quite smoothly, but it will not be cost effective and is unlikely to move public opinion to support future expansion.

5.7.4 Calculating the Cost-Benefit Ratio

A cost-benefit analysis incorporating the benefits from time savings, fuel savings, and environmental improvements can do much to help shape the eventual decision. Quantifying these benefits will also improve the project's attractiveness to many financial institutions.

A cost-benefit analysis calculates the ratio of a project's benefits to its costs. The larger this ratio, the more attractive a project is likely to be to decision makers and financing organizations. Equation 5.4 provides the framework for calculating the cost-benefit ratio.

Equation 5.4 Cost-benefit ratio

Where:

BC = Total benefit-cost ratio

Btp = Time savings for public transport customers

Btm = Time savings for occupants of mixed-traffic vehicles

Bfp = Fuel savings to public transport vehicles

Bfm = Fuel savings to mixed-traffic vehicles

Be = Environmental benefits

Ci= Implementation cost.

Box 5.2 provides an example of a multi-criteria analysis using two of the factors presented in this section.

Box 5.2. Calculating the Benefit to Cost Ratio

As a simplified example of this calculation, the table below presents a hypothetical example of time savings benefits for BRT vehicles and mixed-traffic vehicles. The "weighting" factor indicates how much consideration is given to each stakeholder group (transit users and car users). In this first case, each group is given an equal weighting.

Table 5.4. Time savings benefits, Scenario 1

Corridor	Time savings benefits			Cost	Benefits to cost ratio
	BRT	Cars	Total		
Weighting	1	1			
A	50	-6	44	10	4.4
B	2	0	2	5	0.4

In the above scenario, corridor A attracts a high volume of ridership. The benefits awarded to transit users in this case will greatly exceed the costs to car users. Corridor B is a low-ridership area but with little congestion, and therefore no time impact on car users. In this case, the time benefit to public transport customers is quite small. From these two options, the benefit to cost ratio for corridor A is eleven times greater than the same ratio for corridor B. Thus, from a time savings perspective, corridor A would be the chosen corridor.

If political officials were concerned about reactions from car owners, then the weighting for this group might be increased to five. But as the table below indicates, even this amount of prioritization to car interests would not change the overall result.

Table 5.5. Time savings benefits, Scenario 2

Corridor	Time savings benefits			Cost	Benefits to cost ratio
	BRT	Cars	Total		
Weighting	1	5			
A	50	-6	20	10	2

B	2	0	2	5	0.4

However, if officials were particularly worried about car owner reactions, and therefore gave a priority weighting of ten to private vehicles, then the result would change.

Table 5.6. Time savings benefits, Scenario 3

Corridor	Time savings benefits			Cost	Benefits to cost ratio
	BRT	Cars	Total		
Weighting	1	10			
A	50	-6	-10	10	-1
B	2	0	2	5	0.4

In this scenario, corridor A would be a less desirable choice than corridor B. However, with the low benefit ratio for public transport customers, corridor B would risk doing little to promote the future prospects of BRT development in the city.

An expanded benefits table could be constructed to also factor in impacts from fuel savings and environmental improvements.

5.7.5 Political Considerations

Capricious decision-making not grounded in analysis of actual travel demand can result in costly mistakes that do little to support a quality service for the customer (e.g., Lima's Tren Eléctrico). At the same time, political considerations can be quite appropriate in augmenting technical data. In fact, democratically elected officials have a responsibility to utilize their judgments in making determinations between different sets of costs and benefits. Some of the key instances requiring political inputs include:

- Preference to place initial corridors in a high-visibility location in order to promote the BRT concept more widely;
- Preference to locate corridors initially in low-income communities in order to promote greater social equity;
- Avoidance of corridors that may conflict with other infrastructure plans or with other governmental entities;
- Avoidance of corridors requiring extensive reorganization of many existing formal and informal public transport operators.

A purely technical analysis of the corridor attributes can miss some of the more subtle political considerations that may greatly affect the project's viability.

Frequently, the most difficult problem is that the corridors with the highest existing public transport volumes have already been included in a master plan for a future metro project. Decision makers are reluctant to plan a BRT on a future metro corridor for fear of eliminating the possibility of national government funds for a metro. In such cases, it may be politically expedient to propose putting BRT in the corridor as a temporary measure that can be upgraded at a later date. While this rationale was utilized successfully with TransJakarta Corridor I, it is currently being dismantled, as construction of the metro has commenced. This reinforces the notion that BRT is a second-class option for rail and undermines the legitimacy of BRT as a high-quality public transport system, and should be undertaken with care.

Political inputs can be particularly appropriate when cultural or social issues are at stake. In Hyderabad, India, the presence of a Muslim graveyard on both sides of the road creates a bottleneck on the main highway bisecting the city from the northwest to the southeast. An engineering solution may call for expropriating parts of the graveyard for road widening. But for a Hindu-dominated government to relocate this graveyard would likely be both politically and socially unsound. Thus, reasoned political judgment may be needed to curtail any discussion of road widening.

It may also be advisable in Phase I not to disrupt too many existing public transport routes that are not going to be incorporated into the new system. Negotiations with existing public transport operators are a delicate part of BRT planning, and it is generally advisable not to take on the entire private-sector transit industry at once. Corridors with a large number of existing separate bus operators will make the negotiations for reforming the system a lot more complex than corridors where there are only a small number of operators. This consideration was a determining factor with the Silver Standard Insurgentes BRT Corridor in Mexico City, and is also a factor in the planning of the Dar es Salaam system.

Social considerations may be a leading determinant in corridor decision-making. Public transport systems perform many key social functions in a city and have often played a central role in regeneration efforts. Political leaders and project developers may thus seek to target areas that would most benefit from a public transport investment.

Focusing the initial phase in a low-income community can produce several economic and social-equity benefits. The new public transport system will connect these residents to jobs and public services in the city's central areas. The system itself will also likely produce both direct and indirect employment opportunities for the community. Recent studies from Bogotá indicate that the significant reductions in travel costs resulting from TransMilenio have greatly expanded the potential job market for lower-income residents, increasing employment and wages among lower income groups.

A new public transport system can also do much to attract investment to lower-income areas. Additionally, the presence of the system can instill a sense of pride and community in areas that previously felt abandoned and ignored. For these reasons, Bogotá purposefully located its initial BRT corridor in between the central area and the lower-income south side of the city.

In both Guangzhou and Lanzhou, China, BRT systems appeared to lead to significant increases in civic pride in lower-income areas served by the BRT corridor. In Guangzhou those agreeing that, "I am proud of Guangzhou" increased among customers in the BRT corridor from 40 percent before the BRT to 73 percent after the BRT. Among car drivers, the figure was unchanged, and in the control survey in a different corridor, civic pride among bus passengers declined over the same period. The Lanzhou BRT, which opened in January 2013, also spurred large increases in civic pride, with those agreeing "I am proud of Lanzhou" increasing among customers in the BRT corridor from 40 percent before the BRT to 70 percent after the BRT. Pedestrians, cyclists, and motorists saw a similar increase of more than 30 percent, while in the control corridor there was no significant change.

Access to BRT can also increase land values, which can be a double-edged sword. Recent studies indicate that TransMilenio led to significant increases in property values in areas served by a TransMilenio feeder bus. For low-income families without land tenure, the benefits of lower transportation costs may be lost to higher rents. It is therefore a good idea to prioritize efforts to give low-income families land tenure in planned BRT corridors so that the resulting property value increases can be captured by the families instead of by land speculators.

Figure 5.26. Bogotá's TransMilenio system has successfully attracted users from a wide spectrum of society. *Lloyd Wright.*

At the same time, there are also social and environmental reasons for including middle- and upper-income communities in a project's early phases. While Bogotá did target the lower-income areas south of the city, Mayor Enrique Peñalosa also intentionally included a corridor extension into the more affluent north of the city. The wealthier areas of a city are obviously the locations of higher vehicle ownership. Thus, from the standpoint of shifting car users to public transport, there is greater emissions and congestion reduction potential in targeting car-owning households.

Further, the mayor also saw significant social benefits from encouraging greater interactions between economic classes. Peñalosa has noted that: "A public transport system may be the only place that the rich and the poor interact with one another." In terms of propagating understanding and awareness among social groups, a high-quality public transport system can thus be a potential social unifier within a city. Having the new system also serve higher-income groups also helps encourage political buy-in to the system by influential families. Finally, in places like Cape Town, South Africa, running the Bronze Standard MyCiTi BRT into middle-income neighborhoods demonstrated that public transport is not just for the poor and garnered more support from rich and poor alike in the rollout of future phases.

Social-equity issues may also be central to loan prerequisites from major international financing organizations. Most development institutions, such as the Asian Development Bank, justify investments in terms of poverty alleviation. Thus, ensuring that a reasonable number of BRT customers are below median income is important to link the system to broader goals of poverty alleviation.

6. Service Planning

> *"Always design a thing by considering it in its next larger context—a chair in a room, a room in a house, a house in an environment, an environment in a city plan."*
>
> — Eliel Saarinen, architect, 1873–1950

Once the corridor is selected as proposed in the previous chapter, BRT system design starts by characterizing the specific services that should operate inside any planned new BRT infrastructure. The final specification will be the operational schedule, including vehicle requirements.

A basic service plan should be developed before *any* infrastructure design is done, and certainly before it is finalized. The BRT services should serve as many trips as possible (from their origin at the household to their destination) at the highest speed with a minimum of transfers. The infrastructure should then be tailored to that service plan in a way that minimizes delay for as many customers as possible.

A common mistake in BRT planning is to design BRT infrastructure without having made even basic decisions about what sort of BRT services should use the infrastructure. While political or financial constraints may make it impossible to build the optimal physical design, infrastructure design should accommodate an optimal service plan to the greatest extent possible. Once key physical design decisions have been made, however, it is generally necessary to further modify the service plan given the limitations of the final physical design, in an iterative process.

The "service planning" part of this process is normally about deciding—under assumptions about infrastructure and on a route-by-route basis—which of the existing public transport services on or near the corridor will be included in the new BRT services as they exist, which to modify, which routes to add, which to leave out, and which if any to cancel.

This chapter provides guidance for making these basic BRT service decisions; the introductory section presents an approach to the iterative process and the reasoning behind it; the second section details how to describe the status quo of the existing public transport system properly, which becomes the basis of clearly defining customers' service needs. The later sections, after introducing basic service planning concepts, provide specific tools for each decision step required to transform existing public transport services into a planned BRT corridor with BRT services.

The topics discussed in this chapter are:

- Introduction;
- Basic Data Collection;
- Basic Service Planning Concepts;
- Optimizing Vehicle Size and Fleet Size;
- Determining Which Routes to Include Inside BRT Infrastructure;
- Direct Services, Trunk-and-Feeder Services, or Hybrids;
- Deciding on Stop Elimination and Express Services;
- Creating New Routes and Combining Old Routes;
- Pulling Services onto a BRT Trunk Corridor from a Parallel Corridor.

6.1 Introduction

> *"Sometimes we stare so long at a door that is closing that we see too late the one that is open."*
>
> — Alexander Graham Bell, inventor, 1847–1922

As BRT systems are generally built on busy corridors where there are already many bus or minibus services operating, BRT service planning should start with a detailed understanding of the existing public transport services on the corridor. Sometimes these existing services are already well designed to meet the travel needs of most customers and there may be only minor changes needed to existing bus services to take advantage of the higher speeds along the BRT corridor. At other times the public transport services are poorly matched with the travel needs of customers, and a BRT project creates an opportunity to improve on any preexisting service plan. Modifying these services as part of the BRT project can result in significant benefits to customers.

In order to determine whether existing services are already well designed to serve customer needs, or whether significant improvements could be made, BRT service planning should start with a careful evaluation and understanding of all the bus and minibus services currently using the corridor. The Basic Data Collection section of this chapter outlines how information should be processed and displayed in order to make this clear to both the system planners and the general public.

In most cases, there are significant efficiencies to be gained by optimizing services as part of a BRT project. The following would be indications that the existing services are poorly designed:

- Large numbers of buses running partially empty for all or part of their route;
- Significant overcrowding on buses on all or part of a route;
- Significant overcrowding at some stations;
- Large numbers of customers transferring at locations that are not their final destination;
- Large numbers of people walking or taking shared taxis from an area currently underserved by public transport;
- Large numbers of buses stopping where few customers get on or off.

The construction of specialized BRT infrastructure along a corridor will introduce three changes to existing public transport operations that will affect the optimization of services:

- Speeds within the BRT infrastructure along the trunk corridor should increase significantly in comparison to speeds outside the BRT infrastructure and on parallel corridors;
- The new BRT trunk corridor may require vehicles to operate most efficiently at the greatest speed;
- Vehicles will need to be able to enter and exit specialized BRT infrastructure, which is often in the central median of the roadway.

Chapter 4 (Demand Analysis) describes the process used to estimate the baseline public transport demand on the system, and how to model the demand of a proposed service plan under a given infrastructure. So we have at our disposal tools to evaluate future situations. However, that chapter gives no guidance as to how to decide which service scenarios to model. This chapter provides more guidance on how to decide what sort of services should be proposed and modeled.

If a public transport system demand model has already been created (as proposed in Chapter 4: Demand Analysis), it can be extremely useful in performing the necessary route-by-route analysis and testing the benefits of various service planning alternatives. Running alternative service plan scenarios in the demand model is cumbersome, and creating too many scenarios is very confusing for the public and decision makers alike, so this chapter attempts to help craft better service plan scenarios that can later be tested in the model.

The construction of alternative service plan scenarios is generally done incrementally by first making broad assumptions about the best solution. For this chapter, it will be assumed that the selected corridor has enough demand travelling at slow enough existing speeds that BRT infrastructure is justified. As such, it is reasonable to assume that when planning the services, the bus speeds on the BRT corridor would be BRT speeds, either 20 kph for a standard corridor with stations about 450 meters apart, or the speed of an existing service on the same itinerary late at night or "off-off peak." Further detailing of the infrastructure can thus be left aside while we consider alternative service planning scenarios. Once basic service planning decisions have been made, Chapter 7: Capacity and Speed provides the tools to refine infrastructure decisions in light of these service planning decisions.

6.2 Basic Data Collection

> *"It is a capital mistake to theorise before one has data. Insensibly one begins to twist facts to suit theories, instead of theories to suit facts."*
>
> — Sir Arthur Conan Doyle, writer and physician, 1859–1930

In order to propose an optimal service plan, its costs and benefits must be known, and understanding customers' needs is essential for achieving that. The current state of the public transport system may not exactly show all user demands, but it will certainly point in that direction more reliably than alternatives; it is composed of very objective and comprehensive information, which is cheap to collect in comparison with alternatives and overall project costs.

While existing public transport operations are sometimes poorly aligned with public transport customer needs for a variety of reasons, in most cities economic forces tend to push public transport services close to consumer needs. In addition, customers are used to the services as they currently exist—and resist change. Service plans should be developed conservatively, moving away from existing services only when compelling data indicates that a change would improve services.

Ideally, the data collected should be enough to understand all existing services, the demand throughout the day, and the full trip origin and destination for every public transport customer in the corridor influence area, or at least the time and location of where customers entered the existing public transport system and where they exited.

Normally, this does not require having all the data about every trip, but rather having a sample of data large enough to infer the behavior of the whole. Even where all disaggregated trip data is available, as well as a computer program able to process it trip by trip (to date, no current demand modeling software has such capabilities), a systematic aggregation is still necessary so that the results can be analyzed by humans.

The common way of doing this is to provide customer demand information aggregated per hour of the day in a visual format. It is always best to have data for both peak and off-peak periods. For the analysis in this chapter, much of the services and engineering will be designed around the peak hour, so an estimated peak hour demand is needed. If the frequency is very low, it may be necessary to aggregate by peak period, as in morning peak, midday off peak, afternoon peak, and so forth, and then infer the average peak hour demand from the peak period, in order to avoid data distortions. For instance, in the United States, a bus route might have only three trips between seven and eight, and only two between eight and nine, because one of the trips falls at 7:59 and one falls at 9:01, creating a false impression that demand is far more irregular than it is. In general, however, the data needs to be put in a "peak" hour format, as this is used to make key engineering decisions. Business planning decisions must also be informed by the relationship between the peak hour and the off-peak periods, as this relationship can make (or break) the financial sustainability of the project.

For service planning, the following data is needed:

- The itinerary of every route,
- The number of departures per hour;
- The average travel time between stops;
- The number of customers boarding and alighting at each stop;
- The number of customers transferred from each route to every other route.

Initially, it is only relevant that this data is processed for typical days, but when the project moves forward, service plans for Saturdays and Sundays and seasonal variations (school holidays) will be required for a complete evaluation. Additional trip data, as described below, may already have been collected using the methods described in Chapter 4: Demand Analysis, and repeated here, focusing on the processing needs for the service plan design.

6.2.1 Itineraries and Average Travel Time between Stops

For the process of corridor selection, all of the existing public transport routes using the planned BRT corridor should have been mapped into a GIS program (or a GIS interface of a demand modeling tool like TransCAD or Emme).

If this information is not already available, or badly coded, it will be necessary to have surveyors ride each bus with a GPS and record the coordinates of each bus stop and each bus route. This is not expensive or difficult. Even if this data has already been collected by someone else, it may be out of date, so it is a good idea to check the data by randomly sampling the key routes with a GPS to make sure it is accurate. Many software applications (apps) for smartphones can collect this data.

Average speeds from bus stop to bus stop should be surveyed during the peak hour and off-peak period. For a given distance, a graphic such as the one below can be generated to represent the speed over the course of a day. Data needs to be collected over multiple days to generate a reliable average speed.

In a growing number of cities, the bus routes have already been input into an open standard format like General Transit Feed Specification (GTFS) that allows people to manipulate the data in multiple applications. Usually this data is used for customer information dissemination (its name was originally Google Transit Feed Specification), but these same data sets can be used for service planning. GTFS data may be good enough to give coordinates for mapping the existing public transport system, or it may have a lot of inaccuracies that need to be cleaned up. The route needs to be mapped in both directions, as buses may not take the same route going in different directions and bus stops have different positions.

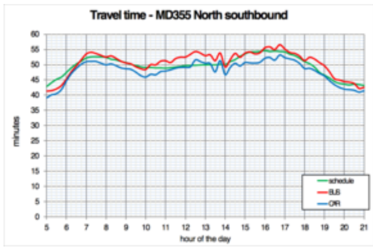

Figure 6.1. Travel times by mode for Montgomery County, Maryland, USA, on the bus route MD 355. The red line represents observed actual bus times, the green line represents scheduled bus times, and the blue line represents the travel time of a car moving on the same route as the bus. *Arthur Szász.*

6.2.2 Number of Customers Boarding and Alighting at Each Stop

The number of existing bus or minibus customers that are currently boarding and alighting on all of the bus routes that use the BRT corridor at each station needs to be collected and mapped. This is usually done by a survey team. Typically, along the planned BRT trunk corridor, if the stations are clearly marked and used, the boarding and alighting counts can be conducted at the stations. For the parts of bus routes that extend beyond the trunk corridor, boarding and alighting counts are generally conducted on board. If the buses or minibuses do not stop in consistent locations, the boarding and alighting numbers along a link need to be collated and assigned to a reasonable location or segment approximating most boardings and alightings, or a location where a new BRT station is being considered could also be used. Boardings and alightings are typically known within a segment, but not at an exact location.

Sometimes boarding and alighting numbers can be collected from Automated Passenger Counter (APC) systems if the locale has this technology. APC data can sometimes give very detailed and accurate numbers of boarding and alighting customers per bus route, but frequently they are coded by time of day, and the station location is not fully clear, so a correlation between APC and existing stops needs to be determined.

With this data, a map such as the shown in figure 6.2 should be generated:

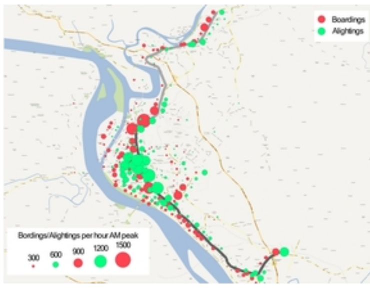

Figure 6.2. This figure shows in black the proposed BRT corridor in Yichang, China, and in green and red the estimated peak-hour boardings and alightings at all the stations on routes that are using the BRT trunk corridor. The number of existing boarding and alighting customers at each existing station will give a good preliminary indication of which stations are more important than others. *ITDP.*

This data can already be used to identify some stations that could possibly be eliminated in the new BRT service, or stations that might become express stops. In the United States, there has been a tendency over the years to accommodate citizens' demands for adding additional stations to the point where there are stations every 200 meters or less. If a stop has very few customers boarding or alighting, extra delay is being imposed on all the customers on board the bus to accommodate only a handful of people. *The BRT Standard* imposes a deduction of 2 points for station stops closer together than 200 meters. In some of the high-demand BRT systems in Asia and Latin America, stations are sometimes 200 meters long. In addition, this data is used to identify locations where off-board fare collection may be the most important.

Further, it is used to identify important transfer nodes. Where large boarding and alighting volumes are observed in locations with perpendicular public transport routes and no other clear destinations, it is likely that many of the customers are transferring. Identifying these transfer points is important to service planning, and additional surveys will need to be conducted at these transfer points as discussed in the next subsection.

6.2.3 Number of Customers Transferring between Routes

The boarding and alighting data can be used to either construct and/or calibrate a public transport trip origin-destination (OD) matrix. This public transport OD matrix reveals where public transport customers want to go, regardless of where the current bus or minibus routes go. It can be developed in a number of ways depending on the sort of data available.

For a single corridor, when there is no other data, modelers typically use the same boarding and alighting counts done above to first create a "stop-to-stop" OD matrix for routes serving the selected BRT trunk corridor. This is generally done by a Fratar distribution model. This mathematical method makes assumptions about where people are getting on and off public transport vehicles based on uniform probability. This data will generally reliably re-create where customers are starting and stopping their journeys along a single public transport route, but it misses where customers may be transferring to other routes.

In order to transform the stop-to-stop OD matrix into an OD matrix for full trips along the pilot BRT corridor, transfer surveys that identify not only the number of people transferring but also their final destinations need to be conducted where large volumes of customers board and alight or at locations that intersect other public transport routes. All major likely transfer points should be surveyed. Many systems, however, have large numbers of transfers distributed across the entire corridor and not necessarily concentrated at particular stops, so it is harder to create a full public transport OD matrix from this methodology alone.

The transfer survey should interview a statistically significant sample of the boarding and alighting customers at each stop and ask them their trip origin, destination, and the public transport route they used to make the trip. Once this data is collected, the stop-to-stop OD matrix should be modified based on the transfer survey data, to link the appropriate proportion of stop-to-stop trips based on the transfer survey results.

Figure 6.3. Location of transfer surveys done for Yichang BRT modeling. Image *ITDP.*

In the developed world, there is usually more data available than can be easily processed. For instance, in the United States, a growing number of cities are creating public transport OD matrices from new ticketing system information. A growing number of public transport ticketing systems can track by ticket ID number where a customer enters the system (where he or she swipes at a payment site). By noting where he or she enters the system next, usually in the evening from his or her destination or at some transfer point, one can create a matrix of trip origins and destinations for virtually all public transport customers. All of this is used to generate a detailed customer "origin and destination matrix."

After this is done, there is sufficient data in the demand model to test alternative service plan scenarios. If put into a public transport demand model like TransCAD or Emme, more refined alternative service planning options can be developed and tested.

6.2.4 Data Processing

For each existing bus or minibus route along the selected trunk corridor, as stated above, data of existing operations needs to be collected for the full length of daily operations. Then, the following information can be generated for assisting the service plan:

- Total route distance;
- Route travel time: total, disaggregated by section and hour of day per section;
- Stop-by-stop boarding and alighting customers;
- Vehicle loads at each link (between each station);
- Overall public transport vehicle and occupancy per section;
- Overall public transport vehicle frequencies.

From this data, the critical link and load of the corridor can be identified, also known as the maximum load on the critical link (MaxLoad). At this location, it is important to have full-day public transport vehicle and occupancy counts with consistent data.

From the full-day counts at the critical link, the degree to which the demand has peaked on the corridor can be calculated. This is needed in order to calculate the required fleet under different scenarios and to convert peak hour ridership numbers to daily numbers. The total route distance and link-by-link peak hour speed are needed to calculate the route-by-route full-circuit total cycle time (TC).

Though not completely necessary at this stage, it will also be useful to know:

- The existing fleet size;
- The total customers per line per day and per peak hour (to calculate the renovation rate [Ren]);
- The total vehicle distance operated on the route.

It will also be necessary to calculate:

- The total amount of the route that overlaps the corridor;
- The total cycle time that occurs on the planned corridor and off the planned corridor.

This information gives us the preliminary tools to begin a service planning analysis.

As an example, Figure 6.4 shows a corridor identified as a future BRT corridor in Montgomery County, Maryland, USA, to which the involved routes are shown in Figure 6.5. The Table 6.1 presents the total amount of the route that overlaps the corridor, and the part of total cycle time that occurs on and off the planned corridor.

Figure 6.6 shows travel time differences with the BRT speeds (the pink line) and with the current speeds (red line) and the benefit per trip in minutes (the difference between the lines) for the route to be incorporated into the BRT corridor in each period of the day. Off-peak benefits will be smaller. The potential benefits of implementing each alternative are calculated in table in figure 6.6 for the proposed preliminary service plan by multiplying the number of customers for each trip throughout the day by the estimated travel time saved.

Figure 6.4. Planned BRT corridor in Montgomery County, Maryland, USA. *ITDP and Logit*

Figure 6.5. Map of proposed BRT services for a planned corridor in Montgomery County, Maryland, USA. *ITDP and Logit*

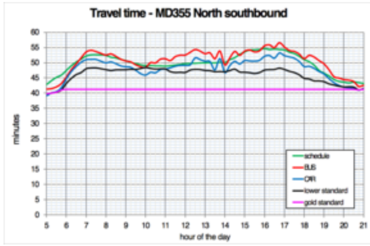

Figure 6.6. Travel times by mode for Montgomery County, Maryland, USA, on MD 355 along with an estimated BRT travel time. *Logit*

Table 6.1. Existing bus routes using the Route 355 proposed BRT corridor, proposed changes for two scenarios and time savings for Montgomery County, Maryland, USA.

line	# of daily trips	fleet	ALL LINE		IN CORRIDOR		SCENARIO A			SCENARIO B		
			Total Pax	Vehicle miles	Route extension	Passenger time	change	operation in corridor	procurement # of buses	change	operation in corridor	procurement # of buses
026R	89	8	3.328	1.382	4%	5%	no change	(express)		no change	(express)	
030R	59	4	640	405	25%	36%	no change	(express)		detour off	(express)	
033R	32	3	353	224	5%	9%	no change	(express)		no change	(express)	
034R	93	7	2.721	819	23%	27%	no change	(express)		no change	(express)	
037R	27	3	224	244	5%	6%	no change	(express)		no change	(express)	
038R	69	5	1.385	923	8%	15%	no change	(express)		no change	(express)	
046R	126	8	4.023	1.200	100%	100%	trunk	left door	6	trunk	left door	6
055R	134	11	7.579	2.140	89%	99%	trunk	left door	9	trunk	left door	9
059R	98	7	3.859	1.247	35%	39%	no change	both sides	7	no change	(express)	
067R	12	1	141	120	12%	12%	detour off	-		detour off	-	
070R	55	7	721	1.070	12%	25%	detour off	(express)		detour off	(express)	
075R	56	2	392	518	11%	17%	no change	(express)		no change	(express)	
081R	31	2	217	184	22%	37%	no change	(express)		no change	(express)	
083R	86	4	673	641	7%	4%	no change	(express)		no change	(express)	
0C8W	64	6	2.200	1.147	3%	1%	no change	(express)		no change	(express)	
0J1W	30	3	341	136	8%	13%	no change	(express)		no change	(express)	
0J2W	140	9	4.829	1.761	20%	35%	detour off	(express)		detour off	(express)	
0J3W	25	4	711	277	17%	33%	detour off	(express)		detour off	(express)	
0J5W	20	2	303	226	22%	24%	no change	both sides	2	no change	(express)	2
0J7W	11	2	110	172	17%	32%	detour off	(express)		detour off	(express)	
0J9W	22	3	357	363	19%	26%	no change	(express)		no change	(express)	
0Q1W	9	-	400	120	21%	13%	trunk	both sides	7	trunk/feeder (feeder=Q4)	left door	2 (6 became feeder)
0Q2W	34	-	1.666	445	21%	9%	trunk					
0Q5W	5	-	303	49	30%	25%	trunk					
0Q6W	75	8	2.416	812	37%	31%	trunk					
						TIME SAVINGS passenger hours per day	863			668		

In Table 6.1, which was generated for Montgomery County using the GTFS and APC data corresponding to the routes in Figure 6.5, route extension is the percentage of the bus route that overlaps with the proposed BRT corridor, and passenger time is the percentage of the customer's time that is the spent on that section of the bus route that overlaps with the proposed BRT corridor. While these two indicators essentially measure the same thing, the comparison between the two allows for identification of congestion and thus where BRT would significantly improve travel times. If the customer time in the corridor (last column marked "passenger time") is higher than the percentage of full bus route length that overlaps with the BRT corridor (second to last column named "route extension"), this indicates that the corridor is where most of the congestion is, which suggests BRT should help significantly improve travel times.

6.3 Basic Service Planning Concepts

> *"When I was young, I had to learn the fundamentals of basketball. You can have all the physical ability in the world, but you still have to know the fundamentals."*
>
> — Michael Jordan, former professional basketball player, 1963–

6.3.1 BRT Stations and Saturation

With rail systems, the constraint on capacity tends to be the frequency that the signaling system can handle. Rail system designers thus frequently try to add longer and longer trains, but on city streets eventually this runs up against block lengths. In BRT systems, by contrast, the constraint on capacity is the BRT station. Vehicles can platoon, in which many can follow very closely, one behind the next, with very high frequencies. A traffic signal can handle far more vehicles passing through it over the course of an hour than a bus stop can process. As a result, for BRT, the station saturation problem is the critical issue that needs to be solved to maintain system speeds—not intersections or headways, which can be defined as the time between two vehicles offering a service, conveying exactly the same information as frequency.

Thus understanding the saturation level of a station is a basic starting point in achieving high capacities and high speeds (covered in the next chapter), and if there is a risk of station saturation it also becomes a primary concern of service planning (covered in this chapter). Saturation level of a station refers to the percentage of time that a vehicle stopping bay is occupied. The term *saturation* is also used to characterize a roadway, and in particular, the degree to which traffic has reached the design capacity of the road.

When engineers talk about the capacity of a road or a BRT system, they will give a capacity for an acceptable level of service, rather than for the maximum number of vehicles or customers that could pass through a road or a system. After a certain point, the lane or BRT system becomes congested. With congestion, the total flow of vehicles may not change (usually it increases at first and later decreases), but the vehicles are going slower and slower.

Saturation, of course, changes as the demand (arrival of vehicles) is not perfectly regular; so when we talk about saturation we are assuming a permanent flow subject to the irregularity normally observed in a roadway or in a busway. The peak hour is an appropriate measure of saturation for dimensioning a system.

Exactly because of this irregularity, a level of saturation of (x=) 0.85 is commonly considered acceptable for mixed traffic. Below a saturation level of 0.85, increases in traffic will have only a minimal impact on average speeds, and the level of service is acceptable. Once saturation levels exceed 0.85, there is a dramatic drop in speeds.

However, with BRT stations, there is no clear breaking point. The queues and delays at bus stations occur at small amounts even at low saturation levels, and these delays simply increase with saturation. In the case of a bus station, saturation is defined as the percentage of time that the station is occupied by vehicles boarding and alighting customers.

In general, stations should be planned at less than 40 percent saturation, or else the risk of congestion increases significantly. The impact of stopping bay saturation on speed is shown in Figure 6.7.

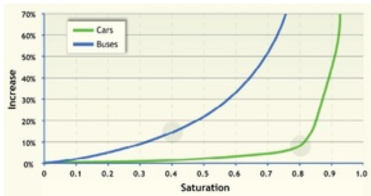

Figure 6.7. Relationship between travel time and saturation levels. *Steer Davies Gleave.*

Rather than a clear point at which the system collapses, station saturation tends to lead to a gradual deterioration of service quality. For this reason, the optimum level of station saturation is not clear. Some studies argue that the optimum should be around 0.30, but saturation levels as high as 0.60 can be tolerated in specific locations if this condition is not general throughout a BRT corridor. However, for saturation levels above 0.60, the system can be deemed unstable, and risk of severe congestion and system breakdown is considerable.

A low saturation level, or a high level of service, means that there is a low likelihood of vehicles waiting in a queue at a BRT stop. A high saturation level means that there will likely be long queues at stopping bays. For saturation levels over one ($x > 1$), the station will certainly have queues increasing to the point where the system does not move until long after the peak is over.

6.3.2 Sub-Stops and Docking Bays

A docking bay is the designated area in a BRT station where a vehicle will stop and align itself to the boarding platform. Docking bays are typically aligned quite close together, so close in fact that one vehicle does not have the space to pull around and pass another vehicle stopped in front of it at another docking bay.

Sub-stops, by contrast, are the stopping areas where one or more docking bays may be located. A station may be composed of more than one sub-stop. The critical thing about a sub-stop is that it be far enough away from the next sub-stop that any vehicle pulled up to a docking bay in the sub-stop in front of it has enough space to pull around and pass the other vehicle. This requires that one BRT vehicle be able to pass another BRT vehicle at the sub-stop, which necessitates a passing lane. Because sub-stops and passing lanes are extremely critical to avoiding station saturation and hence reaching higher speeds and capacities, and making express and limited stop services viable, they are both given points in *The BRT Standard*.

In the first BRT systems, each station had only one docking bay and one sub-stop. A key innovation of Bogotá's TransMilenio system was that more capacity and speed could be obtained, if, at each station, instead of having just one sub-stop with one docking bay, each station might have two or more sub-stops, and each sub-stop might have one or two docking bays. In Figure 6.8 the TransMilenio stop has two sub-stops, one with one docking bay and one with two docking bays.

By adding more sub-stops and docking bays (the sub-stops are far more important than the number of docking bays), the saturation level of each sub-stop can be kept to a maximum value of 0.40 until very high levels of demand are reached. TransMilenio strives to keep the maximum variation in the saturation value at no more than 0.10 between sub-stops at the same station, so the values should not vary from a range of 0.35 to 0.45.

Figure 6.8. The use of multiple sub-stops and docking bays with passing lanes in Bogotá helps minimize vehicle congestion. *Oscar Díaz and Por el País que Queremos (PPQ).*

6.3.3 Direct Services

Direct services, sometimes called "trunk extensions" or "complementary" routes, are new BRT services that operate both in mixed traffic and inside dedicated BRT infrastructure on trunk routes. Usually, they follow former bus or minibus routes that have been converted into BRT services.

When designing BRT services, the easiest thing to do is to simply convert existing public transport routes into identical new BRT routes, and allow whatever portion of the existing route that does not overlap with planned BRT infrastructure to simply operate in mixed traffic. One of the main advantages of BRT over rail-based modes is that buses, unlike rails, can easily leave the trunk infrastructure and operate on any normal road.

If a city has already done a good job designing its bus services, and the routes are well correlated to trip origins and destinations, it may be a good idea to leave several or most of them more or less where they are. Riders are already familiar with these routes, and a conservative approach to BRT service planning will minimize the likelihood of major mistakes or public confusion when the new system opens. Because such routes need to operate both in mixed traffic and along specialized BRT trunk infrastructure, the buses and the fare collection system need to be able to operate in both environments. Generally, this will require the procurement of a fleet compatible with the new BRT infrastructure and mixed traffic operation. Developing BRT vehicle technical specifications that allow for both BRT trunk and mixed traffic operation (see Figure 6.9) significantly improves the flexibility of the system. If the system has central median platforms on the BRT trunk corridor, vehicles will need to have doors on both sides. Direct service systems increasingly use low-floor buses to ease boarding and alighting off the trunk corridor. Direct service operations with flexible vehicles also make it easier to expand BRT trunk infrastructure onto other linked corridors without major disruptions in service or new fleet procurement. Direct services within a closed system can employ off-board fare collection at BRT stations, but need to have an on-board or proof-of-payment fare collection system when using regular bus stops outside the BRT corridor. With proof-of-payment systems, inspectors will be needed, and there is risk of fare evasion.

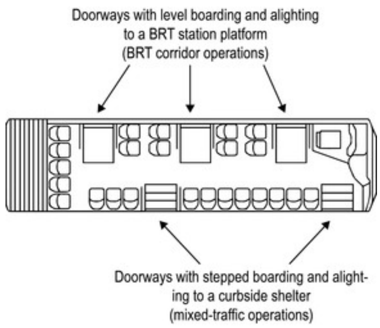

Figure 6.9. Two-sided doorway configuration for a direct-service system where the bus operates both in the BRT corridor and outside the corridor in mixed traffic. *ITDP.*

Until 2010, the only direct-service BRT reaching Silver or Gold Standard was the Brisbane Busway (Australia). Many of the Bronze-rated BRT systems with direct services lacked basic administrative controls over access to the trunk BRT infrastructure, with lower quality vehicle infrastructure improvements, and these systems frequently encountered station saturation problems. Problems of station saturation are not caused by direct services, but rather by a misalignment between the service plan and the infrastructure design that could happen regardless of service type. Since 2010, several systems have opened (Guangzhou, China; Cali, Colombia; Johannesburg, South Africa) that feature Gold- or Silver-Standard BRT infrastructure and direct services. These systems all offer services that operate both on Gold- or Silver-Standard BRT trunk infrastructure and continue beyond the trunk into mixed traffic.

Figure 6.10. Complementary service in Cali. *Karl Fjellstrom.*

Figure 6.11. Complementary service in Johannesburg. *Yoga Adiwinarto.*

Figure 6.12. Complementary services in Guangzhou. *Far East BRT.*

Guangzhou's BRT proved that direct services in a closed system with Gold Standard BRT infrastructure and properly sized stations can reach very high capacity and speed with high customer service levels. Guangzhou's peak-hour, single-direction passenger flows, at over 27,000 passengers per hour per direction (PPHPD), are double all but the best trunk-and-feeder BRT systems in the world.

Figure 6.13 provides a map of the services for the Guangzhou BRT system. The BRT routes illustrated in Figure 6.13 are allowed to operate along the BRT trunk corridor. The physically segregated busways and prepaid boarding stations were built along the trunk corridor illustrated in this figure, which also shows the bike-sharing stations implemented along the BRT corridor. Although the trunk corridor is only 23 kilometers long, BRT service coverage extends to 273 kilometers of roadways in the city.

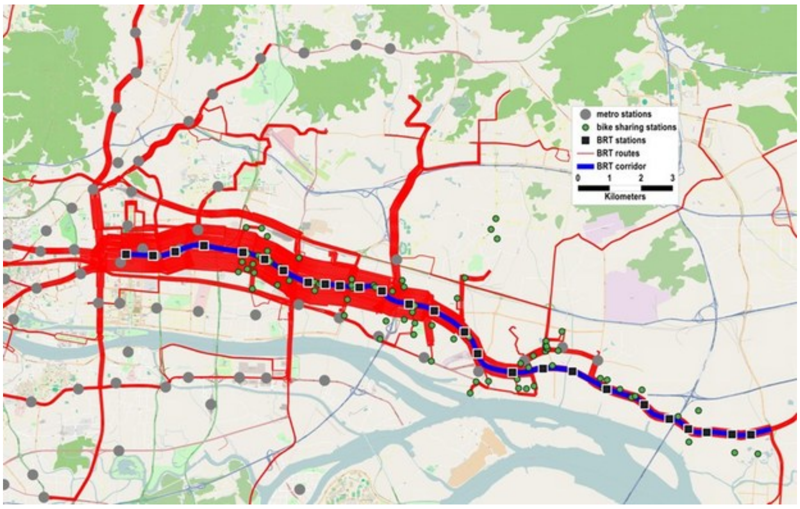

Figure 6.13. Vehicles operating on the BRT system in Guangzhou move directly from an exclusive busway to feeder routes, and thus greatly reduce the need for transfers. This image also shows bike-sharing stations implemented along the BRT corridor, and the city's metro stations. Image *ITDP.*

6.3.4 Trunk-and-Feeder Services

Until recently, the most famous BRT systems operated "trunk-and-feeder" or "trunk-only" services. In some cases, a new BRT service will run only up and down the BRT trunk infrastructure. This would be called a "trunk-only" service. Trunk-only services can either allow the previous routes to continue to operate in mixed-traffic lanes parallel to the BRT corridor, and then continue as the route extends past, or they can be rerouted off the corridor, or they can be eliminated and force their former customers to transfer to the new BRT. The approach of allowing former bus routes to continue in mixed traffic is what occurred in Jakarta, Indonesia, and in many Chinese systems. It has the advantage that it does not force customers to transfer against their will. These systems have the disadvantage that the ridership of the BRT system tends to be lower, undermining returns to scale in the BRT system operation. Also, as it leaves many bus routes in the mixed traffic lanes, this approach also tends to degrade the level of service in the mixed traffic lanes, resulting in lowered mixed traffic speeds due to increased congestion.

Initially, trunk-and-feeder service design was the result of BRT system developers copying the service characteristics of rail systems without considering direct service alternatives that were possible with BRT. Often, designers of "trunk-only" services think that informal operators will automatically provide feeder services to the trunk routes. In some cases, where enforcement and regulation of informal operators is reasonably effective, this can bring some customers to the trunk system, though it normally forces customers to pay twice, and does little to improve the quality of the trip still being performed by the informal part of the service. More typically, however, informal operators will refuse to stop at trunk stations in an effort to retain their customers for the longer haul trip, draining the BRT system of ridership and revenue, and congesting parallel mixed-traffic lanes.

TransJakarta remained for many years a "trunk" system without a "feeder." As a result, despite being one of the longest BRT systems in the world at over 172 kilometers, in early 2012 it carried only 350,000 customers per day and about 4,000 customers per hour per direction at peak times. Roughly two-thirds of all public transport customers using the TransJakarta corridors continued to use their former bus routes and operate in very congested mixed traffic conditions. While some operational improvements have been made, and a few new direct services have been added, the system has yet to fully optimize its services and operates at a loss.

Mexico City also operates a trunk-only system. Rather than allowing former bus routes to operate in parallel, it cancelled them, reducing mixed traffic congestion and pushing up ridership on Metrobús. The new routing did not cause that many new forced transfers, because most of the former bus routes were already organized to operate on corridors in a manner that was not fully consistent with demand pattern. As the Mexico City system expanded, inter-corridor routes were added, and the system began to serve more customers, while reducing unnecessary transfers and station saturation.

Systems such as Bogotá's TransMilenio, Curitiba's system, Rio's TransOeste/TransCarioca/TransOlímpica, Lima's Metropolitano, and others provide fully integrated feeder bus services that connect to the trunk services in formal transfer terminals, offering a better quality and more comprehensive door-to-door service than the trunk-only services. In this case, a former bus route that overlaps the trunk BRT corridor for only part of its route is split into two services: a trunk service operating only inside the BRT system, and a feeder route that operates in mixed traffic.

In the best systems, the BRT system operator operates both trunk services and feeder services under professional quality of service contracts with private vehicle operating companies. Such feeder services are not operated by informal operators, but by modern companies, and they form an integral part of the BRT system, with consistent branding, fare systems, information technology, and other BRT amenities. In some cases, especially in higher-income countries, a public transport authority is likely to operate both a BRT trunk service with special vehicles and branding, and a feeder service using normal buses in mixed-traffic lanes that are unlikely to be identified as part of the BRT system.

Figure 6.14. A Kopaja bus provides direct services in the TransJakarta BRT infrastructure. These buses run in mixed traffic and then enter the BRT corridor for part of their journey, but they are not officially part of the BRT system and have their own fare structure. *Aimee Gauthier.*

Figure 6.15. A Mio BRT vehicle in Cali operates off-corridor to provide direct services to some destinations. *Luc Nadal.*

Figure 6.16. New TransJakarta direct service. *Karl Fjellstrom.*

Figure 6.17. Many Chinese BRT systems operate trunk-only services, where the majority of the ridership remains on parallel traditional bus services operating in mixed-traffic conditions. Beijing's BRT features many more customers and vehicles in the mixed-traffic lane adjacent to the BRT than are included in the BRT roadways. *Karl Fjellstrom, Far East BRT.*

6.3.5 Services That Skip Stops: Limited, Express, Early Return, and Deadheading

The most basic type of public transport service along a corridor is typically known as "local service." This term refers to a service where stops are made at each station along a route. Thus, while local services provide the most complete route coverage along a corridor, such services also result in the longest travel times and the slowest speeds.

Each stop a vehicle makes adds some delay. One of the easiest ways to increase vehicle speeds is to add services that skip stations. Services that skip a few stations at regular intervals are usually called "limited stop services." Services that skip many stations are generally called "express services." One of the main advantages of BRT is that it is relatively simple and inexpensive to allow one vehicle to pass another by simply having passing lanes at station stops.

Single-track metro and light rail transit (LRT) systems and simple, single-lane BRT systems like TransJakarta and RIT Curitiba (except for the new Linea Verde), which do not have passing lanes, have few options but to operate only local services. There are no provisions within the infrastructure of these systems for vehicles to pass one another. Allowing passing in the infrastructure design can provide more service options and is a main reason why *The BRT Standard* weighs heavily the inclusion of passing lanes in the design.

Many of the examples in this chapter assume that it is possible to build physical infrastructure that can accommodate the passing of one service by another, generally through the inclusion of passing lanes inside the BRT infrastructure. The best solution is to simply provide enough space for passing lanes at station stops. The space is not needed along the entire corridor, only at stations that can be set back from the intersection to avoid compromising intersection capacity. When right-of-way for passing lanes is simply unattainable, figuring out how to accommodate passing to allow longer distance limited and express vehicles to pass local BRT services and still use the dedicated BRT infrastructure is a challenge. A variety of alternatives have been discussed, though with fairly limited application to date. Most of these techniques only work up to a certain maximum frequency.

If the barrier between the busway and the mixed-traffic lanes is not rigid and can be easily permeated, it is possible for express and limited buses to simply pass

Figure 6.18. Passing lanes at stations, like these in Bogotá, allow for the provision of express and limited stop services. *Karl Fjellstrom.*

Figure 6.19. Passing lanes prevent queue formation at stations in São Paulo, deliver significant travel time savings to customers. *Karl Fjellstrom, ITDP China.*

each other in the mixed-traffic lanes. This is often done in bus system improvements like Select Bus Service in New York, but so far there are no examples of this in full BRT systems. Its effectiveness depends on the degree of mixed traffic congestion at the critical points where the buses need to pass one another.

Another technique is to time services so that limited stop or express services only catch up with the local services at the terminal point of a route, or at select stations where passing lanes are available. Such services, called "catch up" services, are more commonly seen in rail systems. Thus, an express service may begin ten minutes behind a local service, and this starting-time difference ensures that the express service does not overtake the local service. Such an approach may be applicable to BRT for relatively short corridors with relatively long headways (e.g., ten minutes), but to date there is limited experience, and its application has been limited to express-service demands only.

Some cities have considered adding a pull-by bay in front of stations, where a local BRT vehicle can pull aside and let an express bus pass. This solution has the benefit of only requiring right-of-way where it is least needed for other purposes, such as BRT stations or turning lanes. Some preliminary analysis indicated that pull-by bays at some stations might be feasible in systems with headways greater than about five minutes, but there remains limited real-world experience with their application.

If the BRT infrastructure does not include passing lanes at station stops, it may be advisable to leave express services in mixed traffic lanes. Curitiba's RIT system, for instance, excluded longer-distance express buses from BRT services due to the lack of passing lanes. This was a second-best solution, the benefits of which degraded as traffic congestion increased in the mixed-traffic lanes. One of the main innovations of Bogotá's TransMilenio was to introduce express, limited, and local services, all inside the BRT infrastructure.

Sometimes the overabundance of stops is mitigated by stop-on-demand. Stop-on-demand does not work well during peak hours, however, as there is usually demand for all of the stops. It is also virtually incompatible with BRT services. Since stop-on-demand offers limited benefits during the critical peak period, and does not integrate well with BRT, it is generally not used in BRT services and hence is not further considered here.

In many developing-nation cities, public transport services operate on a hail-and-ride basis. Even in cities in the United States, minibus services effectively stop wherever hailed by a customer, whether at a bus shelter or not. This has the advantage of minimizing walking times. Hail-and-ride vehicles may also offer a variety of service options and very high frequency. Hail-and-ride services are not compatible with operations inside a BRT system, though it is possible to allow hail-and-ride services to continue to operate in mixed-traffic lanes and to continue to provide services to locations where stops have been removed. Hail-and-ride is also not further considered herein.

"Early return" services are another form of service that eliminates stops, in this case from the extreme ends of the route. Typically, the highest-demand segment of a route is in the city center, so early return services only operate the service on the highest demand part of the BRT corridor, allowing other services to operate on the full length of the corridor. With a limited fleet of vehicles, these early return services will significantly reduce operating costs for the system operator, while reducing the fleet size, but the demand profile needs to allow this type of service.

"Deadheading" is when buses are run without stopping for customers in the nonpeak direction. Because demand frequently varies in the two directions of a BRT service, the optimal frequency is likely to differ for the two directions. Full optimization of services therefore requires the programming of services separately for the two directions. TransMilenio, in fact, coded the different directions with different route numbers, and these routes had different stopping patterns optimized to the specific peak and contra-peak demand patterns. It is often more efficient to run some of the buses in the contra-peak flow direction to skip more stops or to not stop at all, allowing the bus to return more quickly to the peak flow direction. This is known as deadheading.

6.3.6 Speed, Travel Time, and Distance Relationships

Frequently, a BRT route's length and travel time will be known, but not the average speed, or the average speed and time but not the distance. These are the basic relationships:

$$\text{average speed} = \frac{\text{travel distance}}{\text{travel time}} \Leftrightarrow \text{travel time} = \frac{\text{travel distance}}{\text{average speed}} \Leftrightarrow \text{travel distance} = \text{travel time} * \text{average speed}$$

Box 6.1. Reminder for time units conversion

1 hour = 60 minutes = 3,600 seconds;

1 day = 24 hours = 1,440 minutes = 86,400 seconds

Most commonly, one calculates the length of a proposed or existing route (usually the transit authority knows the route length, or it can be taken from GTFS, or calculated using GPS on board the bus), and usually a speed survey is conducted so that several peak hour trips can be timed and the average taken, so one can calculate existing bus speeds by using the above formula.

If a trip takes one hour, and the distance is 20 kilometers, the speed is 20 kph. As the best BRT systems in urban conditions tend to move about 20 kph for a single track BRT and up to 30 kph for a BRT with passing lanes and sub-stops, if existing bus speeds are well below 20 kph, we know there is a reasonable likelihood of improving the speed on the route.

6.3.7 Peak Hour, Peak Hour Ridership, Peak Hour Travel Time, Peak Hour Speed

Most service planning decisions require a calculation of the peak hour, or the hour of the day when there are the most public transport customers using the system on a particular route. It is also often important to estimate the speed on the route.

How the peak hour is determined depends on what data is most readily available. In the United States, where it is fairly common to have transit agency data with boarding, alighting, and time at each bus stop (or at least each link), a chart like Table 6.2 can be created. It will show the total 6:00 a.m. departure for Route "A," the 6:15 a.m. departure, and so on. The total boardings per vehicle are then calculated for each departing vehicle on Route A, and the total travel time for each Route A departure.

Table 6.2. Route A: Boarding, Alighting, and Loads

	6:00 a.m. Departure				**6:15 a.m. Departure**				**6:30 a.m. Departure**				**6:45 a.m. Departure**			
	Boarding	Alighting	Load	Time	Boarding	Alighting	Load	Time	Boarding	Alighting	Load	Time	Boarding	Alighting	Load	Time
Station				6:00				6:15				6:30				6:45
1st	1	0	1	6:10	1	0	1	6:25	1	0	1	6:40	2	0	2	6:55
10th	1	0	2	6:20	1	0	3	6:36	2	1	2	6:51	2	1	3	7:05
20th	2	1	3	6:30	3	1	5	6:47	3	2	3	7:02	3	2	4	7:15
30th	2	2	3	6:40	3	2	6	6:57	4	2	5	7:13	4	2	6	7:25
40th	3	3	3	6:50	4	3	7	7:08	4	3	6	7:24	5	4	7	7:35

50th	3	3	3	7:01	4	4	7	7:19	5	5	6	7:35	5	5	7	7:45
60th	3	3	3	7:11	3	4	6	7:30	3	4	5	7:46	4	5	6	7:55
70th	2	2	3	7:21	2	3	5	7:40	2	4	3	7:57	2	4	4	8:05
80th	1	2	2	7:31	1	3	3	7:51	2	3	2	8:08	2	3	3	8:15
90th	0	1	1	7:41	0	2	1	8:02	1	2	1	8:19	1	2	2	8:25
100th	0	1	0	7:52	0	1	0	8:13	0	1	0	8:30	0	2	0	8:35
Total	18	18		1:52	23	23		1:58	27	27		2:00	30	30		1:50

The salient information per route (total boardings and total trip time) for all peak period departures can then be created as shown in next table

Table 6.3. Example of Average Peak Hour Riders and Times

Time	Travel Time	Customers
5:00 a.m.	1:32	10
5:30 a.m.	1:37	12
6:00 a.m.	1:52	18
6:15 a.m.	*1:58*	*23*
6:30 a.m.	*2:00*	*27*
6:45 a.m.	*1:50*	*30*
7:00 a.m.	*1:50*	*20*
7:30 a.m.	1:40	19
8:30 a.m.	1:35	20
9:00 a.m.	1:35	17

In Table 6.3, the peak hour for Route "A" is from 6:15 a.m. to 7:14 a.m. It is during this hour that total boardings of all Route A trips reach their maximum.

Alternatively, if this data is not available, the peak hour can be calculated from frequency and occupancy counts for each bus route. In this case, a surveyor would stand at the critical link (highest demand section of the route) and count the number of Route "A" buses and estimate their occupancy. The hour with the maximum frequency and highest occupancy is roughly the peak hour.

In the example above, the peak hour headway is fifteen minutes and peak-hour frequency is four minutes. The average peak hour demand per bus is twenty-five, or a hundred per hour, and the average travel time is 1:55. When inputting this data into a model (for calculating costs, benefits, stations, bus sizes, fleets, travel times, or simulating the network), one generally converts the above messy data into a constant flow that represents average peak hour conditions.

Table 6.4. Example of Average Peak Hour Riders and Times

Time	Travel Time	Travel Distance(km)	Speed(kph)	Customers
5:00 a.m.	1:55	20	10.4	25
5:30 a.m.	1:55	20	10.4	25
6:00 a.m.	1:55	20	10.4	25
6:15 a.m.	1:55	20	10.4	25
6:30 a.m.	1:55	20	10.4	25
6:45 a.m.	1:55	20	10.4	25

7:00 a.m.	1:55	20	10.4	25
7:15 a.m.	1:55	20	10.4	25
7:30 a.m.	1:55	20	10.4	25
7:45 a.m.	1:55	20	10.4	25

It is these averages that will tend to be used in a traffic model. The existing speed of the bus route should be used to code the link speed for the existing public transport route.

6.3.8 Public Transport Loads: Load, Critical Link, Maximum Hourly Load on the Critical Link (MaxLoad), Passengers per Hour per Direction (PPHPD), and Load Factor

The "load" of a given segment (or link) of a system is the total number of customers that travel through that segment within a given time period, usually an hour; if no other qualification is made it refers to "passengers per hour across the given segment"; this, like other measures presented, changes throughout the day (and from one day to the next), but for the service planning exercises presented in this chapter, if nothing else is said, the load of a segment refers to the peak hour load.

Table 6.5. Table 6.5 Load Example at a Corridor

	Route A Northbound peakhour			**Route B Northbound peakhour**			**Combined Northbound peakhour**		
Station	Boarding	Alighting	Load	Boarding	Alighting	Load	Boarding	Alighting	Load
Main St	5	0	5	3	0	3	8	0	8
1st	5	0	10	3	0	6	8	0	16
10th	5	0	15	3	0	9	8	0	24
20th	6	5	16	5	3	11	11	8	27
30th	7	5	18	5	3	13	12	8	31
40th	8	9	17	5	5	13	13	14	30
50th	9	8	18	5	5	13	14	13	31
60th	5	7	16	8	5	16	13	12	32
70th	5	6	15	8	5	19	13	11	34
80th	0	5	10	3	8	14	3	13	24
90th	0	5	5	0	8	6	0	13	11
100th	0	5	0	0	6	0	0	11	0
Total	55	55		48	48		103	103	

Once the peak hour load has been calculated (as in Section 6.3.6), the consolidated boardings, alightings, and loads at each stop on the planned BRT corridor can be calculated by simply adding up the hourly boardings and alightings of all the routes that will use the new BRT corridor, as illustrated above. In Table 6.5, the maximum load is thirty-four and it occurs after the bus departs the 70th Street Station until it reaches the 80th Street Station. The link between 70th Street and 80th Street is carrying the heaviest load of customers, and as such is called the "Critical Link." The load on this link (thirty-four in Table 6.5) is known as the "maximum load on the critical link."

Note that this is usually only for one direction of travel. To avoid confusion due to the fact that a segment normally has two directions, it is common for the unit

PPHPD to be used for the expression of loads. It is an abbreviation for "passengers per hour per direction" and it means "passengers per hour in one direction." PPHPD (or even *pphpd*) is used here with this intended meaning.

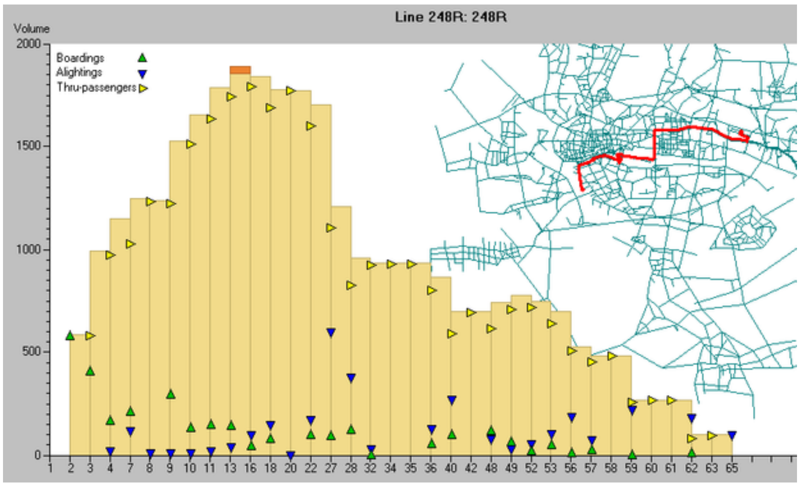

Figure 6.20. Output of a boarding and alighting survey for bus route 248R in Guangzhou, China, during the peak hour. The "Critical Link" is between Stop 13 and Stop 16. Graph *ITDP.*

Figure 6.20 illustrates the same idea graphically. The link between Stop 13 and Stop 16 carries the heaviest load, so it is the critical link, and the maximum load on this critical link is about 1,800 passengers per hour per direction (or PPHPD). The maximum load on the critical link is of primary interest to BRT system planners, as it is used for making many crucial design and service planning decisions. The duration of one hour is considered the appropriate measure of peak duration (shorter measurements have considerable oscillation). In the formulas that follow, this peak load is called the "maximum hourly load on the critical link" (MaxLoad). Identifying this location and this load is paramount in any service planning exercise as it is the load at this point that will determine the fleet needed and the appropriate vehicle size. The expressions *corridor maximum load* and eventually *system maximum load* also refer to this measurement.

The "load factor" is the percentage of a vehicle's total capacity that is actually occupied. For example, if a vehicle has a maximum capacity of 160 customers and 128 customers in a segment of a trip, then the load factor is 80 percent (128 divided by 160) on that given segment. The total load factor of the system would account for the average load for all services throughout the system (this average could be weighted by segment extension or time vehicles need to cross it), and it is used to show the efficiency with which the system's vehicles are used. When the term *load factor* is used without further qualification, it refers to the *design load factor*—that is, the planned average load factor to happen on the busiest segment of the service, or the critical link, when the system is implemented as discussed in the following paragraphs.

The actual load factors of any BRT system are determined by the frequency of the vehicles, the capacity of the vehicles, and the demand. In a service plan, the load factor is easily altered by changing the frequency of the services, changing the vehicle size, or changing the routes of competing services. Designing services using a lower load factor than the real capacity of the vehicle is recommended.

While systems with high load factors tend to be more profitable, generally it is not advisable to plan to operate at a load factor of 100 percent. If designing for 100 percent load, 50 percent or more of the vehicles will be overcrowded, because the distribution of customers will never be uniform from vehicle to vehicle, but will likely be some variation within 10 to 20 percent of the design load factor. Even if the vehicles were at capacity and not overcrowded, the conditions in the vehicle will be uncomfortable to customers, as well as create negative consequences for operations. At 100 percent capacity, small system delays or inefficiencies, especially with boarding and alighting, can lead to severe overcrowding conditions.

The desired load factor may vary between peak and nonpeak periods. In Bogotá's TransMilenio system, typical load factors are 80 percent for peak periods and 70 percent for nonpeak periods. However, as ridership levels increase in Bogotá, overcrowding becomes an increasing concern.

The load factor is unlikely to be uniform for the entirety of a route. Designing services that maintain high load factors for as much of the route as possible will tend to improve system performance and efficiency, including its financial performance.

A system's capacity is considered to be met when the load factor reaches 100 percent at the maximum load on the critical link. Systems can also sometimes operate at a load factor exceeding 100 percent, but not by much, and such a system would be considered to be operating at "above capacity." BRT system capacity is generally measured by the peak PPHPD. This measurement would be taken at the point of the maximum load on the critical link.

TransMilenio has a capacity of about 36,000 PPHPD based on its service plan, but its peak PPHPD has been counted as over 40,000. Such a level implies that customers are more closely packed than the maximum recommended levels. This situation is sometimes known as the "crush capacity." While such extreme capacities can be expected in some unusual circumstances (e.g., immediately after special events such as sporting events or concerts), it is not desirable to regularly overcrowd vehicles.

6.3.9 Service Frequency and Headways

The service frequency refers to the number of times a specific service is offered during a given time interval. Normally, frequency is expressed per hour, but service frequencies can also be expressed for any time interval, such as: "ten trips per day" or "twenty trips per three-hour peak period," or even "a quarter of a trip per minute." As with everything else in BRT service planning, frequency of service (existing or planned) changes throughout the day, but the sizing of the system should be based on the frequency during the peak hour. So, if no further mention is made, frequency means "the number of services provided in one hour, during the peak."

The time between two vehicles offering a service, which conveys exactly the same information as frequency, is known as the "headway." Headways can be expressed as, for example: "one trip every two hours" or as "one trip every ninety minutes" or "one trip every thirty seconds." The characteristic of headway measuring is that time is referenced to *one bus trip*.

Based on the concept definitions, the below equations are always true (mathematical identities).

Eq. 6.1:

$$\mathrm{Freq} = \frac{1}{\mathrm{hdwy}} \Leftrightarrow \mathrm{hdwy} = \frac{1}{\mathrm{Freq}}$$

Where:

- Freq: Service frequency; that is number of times a specific service is offered during a given time interval;
- hdwy: Service headway, that is time between two vehicles offering a service.

The service headway is the inverse of the frequency, but beware of units used for each one; for example: four buses per hour implies a headway of ¼ of hour, i.e., a headway of fifteen minutes. So the service headway in minutes is calculated as sixty divided by the frequency in hours and the frequency (in hours) is calculated as sixty divided by the headway in minutes.

The "minimum frequency" is the frequency that is needed to provide enough capacity to satisfy the existing demand without the average peak hour bus having a load factor above a policy-determined norm, usually 85 percent.

When planning services, if the vehicle size has already been determined, and an acceptable maximum load factor has been determined (normally 85 percent), then the minimum frequency can be determined based on the following formula:

Eq. 6.2:

$$\text{Freq} = \frac{\text{MaxLoad}}{V_{\text{Size}} * \text{LoadFactor}}$$

Where:

- Freq: Service frequency; the number of times a specific service is offered during a given time interval;
- MaxLoad: Maximum hourly load on the critical link;
- V_{Size}: Vehicle capacity;
- LoadFactor: Percentage of a vehicle's total capacity that is actually occupied.

For example, if the bus specification has already been determined to have a capacity of 150 customers per vehicle, and the maximum hourly load on the critical link is 3,000, and the maximum acceptable load factor is 85 percent, or if:

MaxLoad $= 2550$;

$$\text{V}_{\text{Size}} = 150;$$

$$\text{LoadFactor} = 85\%$$

Then:

$$F = \frac{2550}{150 \times 0.85} = 20$$

And if $F = 20$, then the headway is $\frac{60(\text{minutes})}{20} = 3(\text{minutes})$

In general, it is desirable to provide frequent services in order to reduce customer waiting times. At headways of ten minutes or longer, customers will no longer have confidence that they can just show up at the station at any time and a bus will come in a reasonable period of time. With headways longer than 10 minutes, customers tend to view the system as a timetable service, which leads to loss of ridership. In Mexibus corridor III, illegal services operating parallel to the corridor serve most of the demand in off-peak hours.

Figure 6.21. The perception of a relatively empty busway next to heavily congested mixed-traffic lanes, as seen in this image of Guangzhou can create political pressures. Images *ITDP.*

In low demand systems where authorities want to promote increased public transport ridership, they sometimes set frequency based on a policy decision rather than on the minimum frequency. As very low demand routes are quite common in the developed world, it is often the case that frequency is set as a matter of policy rather than as a function of capacity. Services operating at frequencies higher than can be justified by the demand, however, are likely to contribute to operating deficits.

Figure 6.22. Despite carrying far more passengers per lane than a car lane, this busway, in Jakarta, can also be perceived as empty. *ITDP.*

On a BRT system, a corridor with relatively high frequency should have been chosen, so the chances are that frequencies will rarely drop below six in any case. But what appears as high frequency in mixed traffic appears as low frequency on a busway. A five-minute frequency in mixed traffic is very high; on a busway, it is comparatively low. A busway with a headway of five minutes will appear empty most of the time to motorists sitting in traffic congestion. The lower the frequency, the greater the likelihood that motorists will complain that the road is being underutilized. Such complaints can ultimately undermine political support for future busways. In Quito, pressure from motorist organizations led the national police to open up exclusive busway corridors to mixed traffic for a period of time in 2006. This was also the case in León, Mexico in 2008. This conversion occurred despite the fact that each busway lane was moving three to four times the volume of customers as a mixed traffic lane. Nevertheless, the perception of an empty busway next to heavily congested mixed-traffic lanes can create political difficulties. A similar political battle has been fought over the BRT corridor in Indore, India.

On the other hand, if headways are very low, and frequency is very high, congestion at the station and service irregularity become a risk. Figure 6.23 illustrates the relationship between service frequency and congestion.

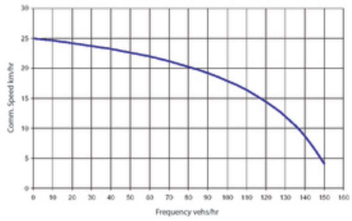

Figure 6.23. Service frequency and the potential impact on vehicle speed at a station with no passing lanes. Graph *Steer Davies Gleave.*

Service irregularity (bus bunching) is an even greater risk with higher frequency. For these reasons, it is usually advisable to split a service into two distinct services (for example, one limited and one express) if the frequency rises above 30 vehicles per hour.

6.3.10 Dwell Time

One of the main aims of BRT system design and service planning is to reduce the delay caused by vehicles slowing down to stop at stations, allowing the customers to board and alight, and then to accelerate to a free-flow speed. The entirety of this delay is known as "total dwell time," or Td, in this chapter's equations.

The dwell time consists of two separate types of delay: "fixed dwell time" (T_0) and "variable dwell time." In BRT system planning, it is critical to keep these two causes of delay distinct, because different decisions will affect different types of dwell time. Fixed dwell time, also called "dead time," is the time consumed by a vehicle slowing down on approaching a station, opening its doors (and after a variable dwell time for boarding and alighting), closing its doors, and then regaining free-flow speed. This delay is called fixed dwell time because it does not vary with the number of customers boarding and alighting at each stop, and it does not vary much between stops in a system. The only way to reduce fixed dwell time is to remove stopping at particular stations in the service design, by offering express or limited stop services or eliminating the stop from the system.

In some countries, it is more typical to model fixed dwell time as only the time at the station when a bus is opening and closing its doors, and the time consumed accelerating and decelerating on the approach to the stop is modeled as a reduction in the link speed between station stops. It is important to keep in mind that this guide, when it talks of fixed dwell time, refers to both.

Variable dwell time consists of customer boarding time (T_b) and alighting time (T_a). Because it varies with the number of customers boarding and alighting at a given station, it is called "variable dwell time," ($T_b + T_a$ or $max(T_a, T_b)$ depending on the vehicle/system configuration).

Many key elements of BRT that are recognized by *The BRT Standard* are measures that will tend to reduce variable dwell time, such as:

- Number of vehicle doorways;
- Width of vehicle doorways;
- Level boarding;
- Fare collection outside the vehicle.

BRT systems are able to operate metro-like service in large part due to the ability to reduce dwell time per customer from an average of five or six seconds per passenger for a typical bus service to only 0.3 seconds per customer on a Gold Standard BRT.

6.3.11 Renovation Factor

The renovation factor (Ren) is total demand of a bus route divided by the load on the critical link of that route (note that operators customarily use the vehicle capacity instead of load on the critical link). It is the multiplier used to convert the number of customers that one would observe travelling on a route at the critical link (for example, in a vehicle occupancy survey) into the total number of customers on the route. Higher renovation factors are seen when there are many short trips along the line; corridors with very high renovation factor rates are more profitable because the same number of total paying customers is handled with fewer vehicles. For example, the Insurgentes corridor in Mexico City has a recorded renovation factor of five, which means that there are five times more people getting on and off the vehicle as there are people on the vehicle at the most loaded time.

Corridors with very high renovation factors meet higher demand more easily than corridors with low renovation factors, simply because more people are getting on and off vehicles along the corridor after shorter rides, so more people can be served.

Eq. 6.3:

$$\text{Ren}_{\text{route}} = \frac{D_{\text{route}}}{\text{MaxLoad}_{\text{route}}}$$

Where:

- $\text{Ren}_{\text{route}}$: Renovation factor of a route;
- D_{route}: Route demand (in passengers);
- $\text{MaxLoad}_{\text{route}}$: Route demand on the critical link.

6.3.12 Irregularity Index (Irr)

The irregularity index is a number that expresses the reliability of actual headways against scheduled headways. An irregularity index of one means that the vehicles are arriving at completely random times, and an irregularity index of zero means that vehicles are arriving precisely when they are scheduled. It is measured as:

Eq. 6.4:

$$\text{Irr} = \frac{\text{Variance of the headway}}{\text{Scheduled headway}^2}$$

Where:

- Irr: Irregularity index, the measure of the variance between the actual headways and the scheduled headways;
- Variance of the headway: Amount that the headways are spread out;
- Scheduled$_{textheadway}$: Average waiting time between vehicles.

Variance of the headway is statistically defined as the expected value of the squared deviation from the mean headway. When calculating it from a sample it would be equal to the sum of the square of the differences between each observed headway and the average headway divided by the number of observations minus one, given by:

Eq. 6.5:

$$V_{\text{hdwy}} = \frac{\sum_{i=1}^{N_{\text{obs}}} (\text{hdwy}_i - \text{hdwy}_{\text{average}})^2}{N_{\text{obs}} - 1}$$

Where:

- V_{hdwy}: Variance of the headway, expected value of the squared deviation from the mean headway;
- N_{obs}: Number of observed headways;
- hdwy_i: Observed headway for "i";
- $\text{hdwy}_{\text{average}}$: Average headway, average waiting time between vehicles = scheduled headway.

The average headway will generally be equal to the scheduled headway, unless fewer trips than scheduled regularly occur. Consider the extreme case where we should have one bus every twenty minutes every hour during ten hours, which would be thirty buses throughout the day (or three buses per hour for ten hours), and imagine that the first bus was on time and the other twenty-nine arrive one after another in the last half hour of the tenth hour. The headway of the first bus would be 571 minutes and the other 29 would be 1 minute, so on average the headway would still be 20 minutes per bus (600 minutes divided by 30 buses). Without an operational control system, empirical observation indicates that under many conditions, the irregularity index is around 0.3.

6.3.13 Cycle Time-Related Concepts: Cycle Time (TC) and Maximum Demand Load per Cycle Time (MaxLoadperCycle)

Assuming that a vehicle will keep repeating a service (in both directions, or as a circular route), cycle time is the amount of time that it takes for a bus to travel the entire length of its route, in both directions, and be ready to begin a second circuit, including any time waiting and reversing direction at the end points. It is extremely important to know the cycle time per route for service planning. If a cycle time is short, the same bus can rapidly come back to the beginning of the route and take a second load of customers. If the cycle time is long, additional buses will be needed. Knowing the cycle time is therefore necessary for determining the required fleet.

When proposing an initial service plan, one should already have the existing route travel times in mixed traffic. In order to estimate the cycle time for the proposed routes, one must replace the travel time inside the BRT structure assuming a typical speed (say 20 kph if the corridor is in a dense downtown area, or 29 kph if it is on a limited-access high-speed arterial with few intersections). In the next chapter, methods of calculating more refined projected speeds will be presented, but for this chapter, these baseline speeds will be assumed for inside the BRT trunk operations.

It should be noted that drivers must have some rest time at the end of the route; in short routes this can be done once per cycle. Even if it would be possible to reduce the time to turn the vehicle by changing drivers, the practice is to have the driver always using the same vehicle, which eases operations management and fleet maintenance as well as improving the quality of driving.

Once the cycle time is estimated for each planned service, it is possible to estimate the Maximum Demand Load per Cycle Time (MaxLoadperCycle). This is the number of customers that are likely to accumulate over the course of the cycle time expecting to cross the critical link of the route. In other words, how many customers will accumulate for a specific route at the critical link over a time period equal to the cycle time? This figure, which can be calculated from the surveys of existing routes, is critical in several calculations in service planning. This figure is basically the same thing as the number of customer places that need to be serviced with vehicles, and is sometimes identified as "passenger places served." It can be thought of as the size of the vehicle that would be needed if only one vehicle were used to service the peak hour demand.

For planning purposes, it is critical to know the peak load demand on a typical day over the course of a single cycle time (also during the peak period). If demand is reasonably constant throughout the day, and one can assume that hourly MaxLoad is constant, then MaxLoadperCycle would be estimated by:

Eq. 6.6a:

$$\text{MaxLoadperCycle} = \text{MaxLoad} * \text{TC}$$

Where:

- MaxLoadperCycle: Maximum demand load per cycle time;

- MaxLoad: Maximum hourly load on the critical link;
- TC: Cycle time in hours.

However, demand is rarely constant before and after the peak hour, nor even during the peak hour. If demand is at its peak, then the maximum demand load per cycle time will appear higher for an increment of time shorter than an hour than if it is averaged over an hour. For a cycle time longer than an hour, the maximum demand load for the cycle time will appear to be lower than for the peak hour because it is being averaged over a longer period of time during which the demand has already fallen. The more demand is peaked, the greater the distortion.

Therefore, to be more accurate, one has to apply a correction factor:

- Increases demand if the cycle time is shorter than one hour;
- Decreases demand if the cycle time is longer than one hour.

One way to apply such a correction is using the formula below:

Eq. 6.6b with "peak hour to cycle correction factor" (PHtoCC):

$$\text{MaxLoadperCycle} = \text{MaxLoad} * TC * [1 - \text{PHtoCC} * (\text{TC} - 1)]$$

Where:

- PHtoCC: Nonnegative correction factor, the calibration of which is based on survey data, is discussed in Box 6.2. The usual value is near 0.1;
  - If TC is larger than one hour: correction $1 - \text{PHtoCC} * (\text{TC} - 1)$ will result smaller than one;
  - If TC is smaller than one hour: correction $1 - \text{PHtoCC} * (\text{TC} - 1)$ will result larger than one;
  - If TC is equal one hour: correction $1 - \text{PHtoCC} * (\text{TC} - 1)$ will result in one;
  - If PHtoCC is equal zero, there will be no correction, and the formula is equal to the previous formula.

6.3.14 Waiting Time (Twait) and Waiting Time Cost (Costwait)

Throughout this chapter it will be necessary to compare the relative costs and benefits of different service planning scenarios. One of the most important costs to consider in service planning is the cost of time spent waiting by customers.

Assuming customers arrive randomly at a bus stop, the average waiting time for a customer is only half of the observed headway of the route. Hence, the wait time per customer is the headway multiplied by 0.5, plus a little extra if there is irregularity in the actual headways from scheduled service (Irr). The equation below expresses this, replacing headway with frequency (its inverse value).

Eq. 6.7:

$$T_{\text{wait}} = 0.5 * (1 + \text{Irr}_{\text{route}}) * \text{hdwy} = \frac{0.5 * (1 + \text{Irr}_{\text{route}})}{\text{Freq}}$$

Where:

- T_{wait}: Time spent waiting per customer;
- Irr: Irregularity index; measure of the variance between the actual headways and the scheduled headways (usually near 0.3, see Section 6.3.9);
- hdwy: Route Headway;
- Freq: Route Frequency.

The cost of waiting ($Cost_{wait}$) is defined as the amount an average customer would spend to avoid waiting for a vehicle, it is measured in currency per unit of time—for example: “5 Rp. per minute” and “6 US$ per hour”—and is calculated as a fraction of customer income. Costwait varies depending on a city’s income and proclivity, but typically, people value their time at about one-third of the average wage rate, and are willing to pay twice as much to avoid waiting for a vehicle (i.e., 66 percent of the average user wage).

Customers do not like to wait for a vehicle. If the demand of a given route proposed on a service plan is known (initially it can be approximated by using the demand on a similar existing route), the total waiting cost caused by a route is the sum of the cost of waiting time imposed on all its customers (assuming for now that this is captive demand), then multiplied by their value of waiting time:

Eq. 6.8a:

$$\mathrm{WaitCost_{route}} = \mathrm{D_{route}} * \mathrm{Cost_{wait}} * \mathrm{T_{wait}}$$

Where:

- $\mathrm{WaitCost_{Route}}$: Total waiting time cost for the users of the route (in US$);
- $\mathrm{D_{route}}$: Route demand (in passengers);
- $\mathrm{Cost_{wait}}$: Average user waiting cost ($/time);
- $\mathrm{T_{wait}}$: Average user waiting time (time/passenger).

This is the total cost of waiting faced by all the customers on a particular route during the peak hour. The average value of waiting as defined is the same all day.

The $\mathrm{D_{route}}$ formula for estimating the cost of waiting on the route would be more usefully expressed as a function of the maximum load on the critical link and of the route frequency because normally one has a sense of where the most crowded link on a public transport route is, and one can count the number of buses per hour, and estimate their occupancy from vehicle frequency and occupancy counts. One might know the total ridership on one route, but not all of them, so one can estimate the total demand on the corridor for all the routes by using an average renovation rate on the corridor. To do this, the formula can be rewritten as follows:

Eq. 6.3 can be rewritten:

$$\mathrm{Ren_{route}} = \frac{D_{\mathrm{route}}}{\mathrm{MaxLoad_{route}}} \Leftrightarrow \mathrm{D_{route}} = \mathrm{MaxLoad_{route}} * \mathrm{Ren_{route}}$$

This is simply true by definition. Remember that the renovation rate of the route is by definition the total demand on the route divided by the maximum load on the critical link, or that the demand on the route is a function of the maximum load on the critical link multiplied by the renovation rate.

We can then replace Droute and Twait from Equation 6.2 and Equation 6.6 in Equation 6.7, so that we have:

Eq. 6.8b:

$$\mathrm{WaitCost_{route}} = \mathrm{D_{route}} * \mathrm{Cost_{wait}} * \mathrm{T_{wait}}$$

$$\mathrm{WaitCost_{route}} = \frac{\mathrm{MaxLoad_{route}} * \mathrm{Ren_{route}} * \mathrm{Cost_{wait}} * 0.5 * (1 + \mathrm{Irr_{route}})}{\mathrm{Freq_{route}}}$$

Where:

- $\mathrm{WaitCost_{route}}$ = Total waiting time cost generated to the route users (now in $/hour because instead of giving Droute absolute value in passengers, it is being given in passengers/hour);
- $\mathrm{Ren_{route}}$: Renovation factor of a route;
- MaxLoadroute: Route demand on the critical link (now in passengers/hour or “pax” per hour);
- $\mathrm{Cost_{wait}}$: Average user waiting cost ($/time);

- Irrroute: Irregularity index of the route; measure of the variance between the actual headways and the scheduled headways (usually near 0.3, see Section 6.3.9);
- $Freq_{route}$: Frequency of the route (vehicles/time).

6.3.15 Vehicle Operating Cost

Often, in service planning, the costs of waiting for customers, which is a function of the frequency and regularity of service, will need to be balanced against the cost of operating more vehicles. As the costs of waiting have been calculated for the peak hour above, to make a valid comparison the vehicle operating costs should also be derived per hour. The formulas below can be used to estimate cost per bus (Costbus) and the fixed cost per bus (BusFixedCost or Costbus-fixed). Vehicle operating cost per hour is simply the total cost of operating a vehicle divided by the number of hours a vehicle is in service.

The fixed operating cost of a vehicle is the part of the vehicle operating cost that does not depend of the number of customers carried nor the size of the vehicle. It can be thought of as the cost operators would incur if they put a second vehicle in operation, but that vehicle never opened its doors and always ran empty. It is mostly the cost of the driver, but also the minimum cost in terms of fuel and maintenance that any vehicle would incur regardless of its size. This figure is important to calculating the optimal fleet size. This part of the cost exists whether one is expressing the costs per route, per vehicle, per vehicle hour, or per vehicle kilometer.

To calculate the total fixed operational cost for a route, simply multiply the fixed operating cost per vehicle times the total fleet needed to service that route, or:

Eq. 6.9:

$$\text{RouteFixedCost} = \text{BusFixedCost} * \text{Fleet}_{\text{route}}$$

Where:

- RouteFixedCost: Total fixed operational cost for the route;
- BusFixedCost: Fixed operating costs per vehicle;
- $Fleet_{route}$: Number of buses needed to operate the route.

Total operating cost per vehicle goes down when a stop is removed, as the speed of the vehicles increases. As such, total vehicle operating costs are used in Section 6.7 on limited stop services. When optimizing the size of the vehicle, as in Section 6.4, as well as when comparing direct against trunk-and-feeder services in Section 6.6, it is only the fixed costs of vehicle operation that need to be known because it will be necessary to determine the benefits of using larger vehicles, and what is eliminated by using larger vehicles is the cost of the vehicle that does not go up proportionally with the size of the vehicle. It can be calculated by simply calculating the hourly operating cost of the smallest vehicle in the fleet. Typically, this ranges from US$10 to US$100 per bus hour. It will vary from country to country, but not much from city to city, so it only needs to be calculated once in a given city or country. The BusFixedCosts value consists of a list of average costs per vehicle. Fixed maintenance and fuel costs, which are likely to vary somewhat by vehicle size, should be calculated for the smallest vehicle being considered, and any additional costs for these will be included in variable costs. In most of this chapter one should use a common $Cost_{bus\text{-}fixed}$ value of US$30 per vehicle hour.

6.4 Optimizing Vehicle Size and Fleet Size

The approach to service planning laid out in this guide generally assumes that the system operators can and will adjust the number of vehicles they operate per route, and the size of the vehicles used on each route, to best serve the demand on each route.

This section covers some basic formulas needed to calculate the vehicle fleet and optimal vehicle size. These are two critical considerations when making service planning decisions, so they are covered first. The two decisions have to be made at the same time, since the larger the vehicle, the smaller the fleet. The process of optimizing vehicle size and fleet size is an iterative one.

Selecting an appropriate vehicle size requires balancing the operational cost savings of larger vehicles with the social costs of customers having to wait longer for the next vehicle. There are returns to scale with larger vehicles; the cost per customer served tends to fall with size. Drivers usually represent a disproportionate share of vehicle operating costs, and as the number of drivers is generally fixed and does not change with vehicle size, the cost of the driver relative to the total customers tends to fall the larger the vehicle.

On the other hand, larger vehicles also directly translate into lower frequency, and lower frequency means longer waiting times. Therefore, the costs of these two effects need to be measured in specific conditions when selecting an optimal vehicle size.

Given the goal of having the lowest possible costs using the design load factor, if the vehicle size has been decided (there are only a limited number of options), and the route has been decided and its demand estimated, then the fleet size can be easily calculated. The fleet size is calculated based on the number of vehicles needed to serve the maximum customer load on the highest demand section of the corridor during the peak time, as is explained in detail below.

6.4.1 Vehicle Sizing, Basic Concepts

Vehicle types for BRT systems are not infinite, and for vehicles to operate inside a BRT corridor, there is rarely such low demand that a vehicle smaller than nine meters is ever likely to make sense. While new models are being launched in this market, manufacturers do not make an infinite number of vehicle sizes that are compatible with BRT infrastructure, so in general the range of vehicle options is limited to those listed in Table 6.6.

Table 6.6. Range of BRT Vehicle Options

Type	Vehicle Length (meters)	Capacity (customers)
Minibus	9	60
Bus	12	90
Articulated	18	150
Bi-Articulated	25	220

In practice, the number of systems that use 9 meter or bi-articulated buses is quite limited. Most BRT systems use either 12-meter buses or 18-meter articulated buses. Bi-articulated buses are very expensive, generally double the cost of an articulated bus, and their primary use is in corridors with very high demand with very limited road space. They were first introduced in Curitiba by Volvo, and since then some are also in use in Mexico City on the Insurgentes Corridor, in TransMilenio in Bogotá, and in Istanbul. A few new BRT systems are planning to use 9-meter buses, but so far none are operational.

Note that the relationship between the vehicle length and the vehicle capacity is roughly the length (in meters) minus three (meters for the driver/engine/stairs, etc.) times 10 (or 10 customers per meter of operable bus length), or:

Eq. 6.10:

$$\mathrm{V_{Size}} = (V_{\mathrm{Length}} - 3) * 10$$

Where:

- $\mathrm{V_{Size}}$: Vehicle capacity in passengers (also written "pax");
- $\mathrm{V_{Length}}$: Vehicle length in meters.

At the early stages of planning BRT services, one generally looks at the highest demand routes currently using the planned BRT corridor, and measures the maximum load on the critical link, i.e., the highest demand segment during the peak period.

The vehicle capacity (VSize) should be roughly equal to the maximum hourly load per route on the critical link (MaxLoad) divided by the frequency (Freq), or:

Eq. 6.11a:

$$\mathrm{V_{Size}} = \frac{\mathrm{MaxLoad}}{\mathrm{Freq} * \mathrm{LoadFactor}}$$

Where:

- $\mathrm{V_{Size}}$: Vehicle capacity;
- MaxLoad: Maximum hourly load on the critical link;
- Freq: Frequency;
- LoadFactor: Design load factor (usually 0.85).

This becomes clear by seeing the impact that vehicle size has on frequency:

Eq. 6.11b:

$$\mathrm{Freq} = \frac{\mathrm{MaxLoad}}{\mathrm{V_{Size}} * \mathrm{LoadFactor}}$$

Or a third format as follows:

Eq. 6.11c:

$$\mathrm{Freq} * \mathrm{V_{Size}} * \mathrm{LoadFactor} = \mathrm{MaxLoad}$$

As examples of capacity:

- To serve 4,500 passengers (per hour per direction) on the critical link, a corridor may have:
  - 50 buses (per hour) capable of carrying 90 passengers each; or
  - 30 buses (per hour) capable of carrying 150 passengers each; or
  - 18 buses (per hour) capable of carrying 250 passengers each.
- To serve 900 passengers (per hour), a corridor may have:
  - 10 buses (per hour) serving 90 passengers each;
  - 6 buses (per hour) serving 150 passengers each.

6.4.2 Vehicle Sizing, Initial Iteration

For reasons that will be explained in greater detail below, it is generally optimal to have a frequency set at about twenty-two vehicles per hour per route, as this tends to minimize the irregularity with which vehicle services operate while also minimizing waiting time. Once the frequency is above thirty or so, irregularity becomes a serious problem. At that point, it is generally advisable to introduce additional routes (i.e., limited stop routes, or routes serving other off-corridor destinations) rather than simply continuing to increase frequency or procuring larger and larger vehicles.

Since the BRT-compatible vehicle options are fairly limited, and generally the MaxLoad is known on existing bus routes from frequency and occupancy counts, it is sufficient as a starting point to use that maximum hourly load to determine vehicle size needed for each route. If the existing public transport routes' maximum load is known, some estimate of what demand will be like in ten years needs to be made, as the vehicle is likely to last ten years. A reasonably secure methodology is to double existing ridership on the route, and divide by twenty-two vehicles per hour (an optimal frequency).

Vehicle size can be determined by taking a given maximum load and dividing it by an ideal frequency of twenty-two vehicles per hour (Eq. 6.11a applied to the route):

Eq. 6.11d:

$$\mathrm{VSize_{route}} = \frac{\mathrm{MaxLoad_{route}}}{\mathrm{Freq_{route}} * \mathrm{LoadFactor_{route}}}$$

Where:

- $\mathrm{VSize_{route}}$: Vehicle serving the route capacity;
- $\mathrm{MaxLoad_{route}}$: Route demand on the critical link;
- Freqroute: Frequency of the route (ideal frequency suggested of 22 vehicles per hour);
- LoadFactor: Design load factor (usually 0.85).

Using that formula as a preliminary first pass, Table 6.7 shows that, with a maximum load greater than 3,500 existing customers per route, and a maximum 10-year estimated future load of 7,000, a frequency of 22 vehicles per hour, and a load factor of 0.85, the route should be separated into separate routes. If the maximum load on the critical link of a BRT route is currently between 1,500 and 3,000, bi-articulated buses can be used, but splitting the route should also be considered, as bi-articulated buses are expensive to purchase and maintain. For current loads between 1,000 and 1,500, articulated buses should be considered. Most BRT systems have more than one route per BRT corridor.

Table 6.7. Bus Size by Varying MaxLoad per Route Using the Ideal Frequency of Twenty-Two Vehicles per Hour: First Iteration for Bus Sizing

Existing Max Load	Future Max Load	Optimal Size	Proposal
3500	7000	374	Split the route
3250	6500	348	Split the route
3000	6000	321	Split the route
2750	5500	294	Split the route
2500	5000	267	Split the route
2250	4500	241	Split the route
2000	4000	214	Bi-articulated or split route
1750	3500	187	Bi-articulated or split route
1500	3000	160	Bi-articulated or split route

1250	2500	134	Articulated
1000	2000	107	Articulated
750	1500	80	12 meter bus
500	1000	53	9 meter bus
250	500	27	9 meter bus

This very initial estimate takes into consideration the need to minimize irregularity, but it does not consider the more critical element in bus size optimization, namely the relative costs of waiting (which will be higher for larger buses operating at lower frequencies) and the fixed cost of vehicle operation (which will be lower per customer for larger vehicles). Final vehicle size optimization will need to weigh these relative costs before finalizing the size.

This should only be a first iteration of vehicle size optimization. These preliminary vehicle-capacity figures can be used to calculate the necessary fleet, before returning to a more detailed methodology of calculating the optimal vehicle size.

6.4.3 Detailed Vehicle Size Optimization

Further along in the planning process, when the design team already has a general idea of the sorts of services that will operate and their likely maximum loads at the critical link should have been developed, the following approach gives a more refined methodology for calculating the optimal vehicle size. This approach initially assumes there is no limitation to the size of vehicles available, that limitation will be considered in the application examples.

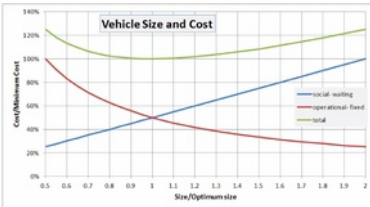

Figure 6.24. The social cost of waiting (blue line) increases and operational costs (red line) decrease as bus size increases. The trick is to balance the two to find the optimum where the sum of costs is minimized. Image *Elebeta*.

Put another way, vehicle capacity should be set where the cost of waiting faced by the users of that route (WaitCost) added to the fixed operating costs (FixedCost) of the route are minimized.

The total wait cost for a route ($\mathrm{WaitCost}_{\mathrm{route}}$) can be written as a function of bus capacity (VSize), by replacing Equation 6.11a:

$$\mathrm{V}_{\mathrm{Size}} = \frac{\mathrm{MaxLoad}}{\mathrm{Freq} * \mathrm{LoadFactor}}$$

with Eq. 6.2

$$\mathrm{Freq} = \frac{\mathrm{MaxLoad}}{V_{\mathrm{Size}} * \mathrm{LoadFactor}}$$

Resulting in Eq. 6.12:

$$\mathrm{WaitCost}_{\mathrm{route}} = \frac{\mathrm{MaxLoad}_{\mathrm{route}} * \mathrm{Ren}_{\mathrm{route}} * \mathrm{Cost}_{\mathrm{wait}} * 0.5 * (1 + Irr_{\mathrm{route}})}{\left(\frac{\mathrm{MaxLoad}_{\mathrm{route}}}{\mathrm{LoadFactor} * \mathrm{VSize}}\right)}$$

$$\mathrm{WaitCost}_{\mathrm{route}} = \mathrm{Ren}_{\mathrm{route}} * \mathrm{Cost}_{\mathrm{wait}} * 0.5 * (1 + Irr_{\mathrm{route}}) * \mathrm{LoadFactor} * \mathrm{VSize}$$

Where:

- WaitCostRoute: Total waiting time cost generated to the route users (in $);
- MaxLoadroute: Route demand on the critical link;
- Renroute: Renovation factor of the route;
- Costwait Average user waiting cost ($/time);
- Irrroute: Irregularity index of the route; measure of the variance between the actual headways and the scheduled headways (usually near 0.3, see Section 6.3.9);
- $\mathrm{Freq}_{\mathrm{route}}$: Frequency of the route;
- $\mathrm{V}_{\mathrm{Size}}$: Vehicle capacity;
- MaxLoad: Maximum hourly load on the critical link;

- LoadFactor: Design load factor (usually 0.85).

This shows that the cost to the customer rises as frequency falls. Hence, from the customer's perspective, the larger the vehicle, the more time he or she has to spend waiting for it. On a high-demand corridor, there is usually high frequency, and the wait will be short, but there will be many more customers suffering the wait.

Assuming the other values are known (and they are estimated once a service plan is proposed), this can be expressed as:

Eq. 6.13

$$\text{WaitCost}_{\text{route}} = A * VSize$$

Where:

- WaitCostRoute: Total waiting time cost to the route users (in $);
- V_{Size}: Vehicle capacity;
- A: Known constant value

$$A = \text{Ren}_{\text{route}} * \text{Cost}_{\text{wait}} * 0.5 * (1 + Irr_{\text{route}}) * \text{LoadFactor}$$

At the same time, fixed operating costs do not vary with vehicle size: the cost of the driver; the cost of the bus company's overhead, the minimum cost of fueling any vehicle, and maintaining any vehicle no matter its size.

So the total fixed costs of a route operation are only a function of the route fleet (as proposed in Equation 6.9:

$$\text{RouteFixedCost} = \text{BusFixedCost} * \text{Fleet}_{\text{route}}$$

The route fleet (the number of vehicles needed to serve a route) is, in turn, dependent on the vehicle capacity (VSize) according to the following:

Eq. 6.14:

$$\text{Fleet}_{\text{route}} = \frac{\text{MaxLoadperCycle}_{\text{route}}}{\text{VSize} * \text{LoadFactor}}$$

Where:

- $\text{Fleet}_{\text{route}}$: Number of vehicles needed to serve the route;
- $\text{VSize}_{\text{route}}$: Vehicle serving the route capacity;
- MaxLoadperCycleroute: Maximum demand across the critical segment of the route that will accumulate for the duration of one cycle during the busiest moment of the typical day (see Subsection 6.3.13);
- $\text{Freq}_{\text{route}}$: Frequency of the route (ideal frequency suggested of 22 vehicles per hour);
- LoadFactor: Design load factor (usually 0.85).

In one extreme, if the route operated with a vehicle as large as the demand willing to cross the critical segment of the route that would be waiting for the duration of one cycle, only one vehicle would be needed.

As the vehicle operating on the route is smaller, the necessary fleet to carry all these customers will be larger, and so the fixed costs will be higher.

If we apply Equation 6.14 in Equation 6.11a we have:

$$\text{FixedCost}_{\text{route}} = \frac{\text{BusFixedCost} * \text{MaxLoadperCycle}_{\text{route}}}{\text{VSize} * \text{LoadFactor}}$$

Assuming the other values are known (and they are estimated once a service plan is proposed), this can be expressed as:

Eq. 6.15:

$$\text{FixedCost}_{\text{route}} = \frac{B}{\text{VSize}}$$

Where:

- $\text{FixedCost}_{\text{route}}i$: Total fixed operating cost for the route (in $/hour);

- $\text{VSize}_{\text{route}}$: Vehicle serving the route capacity;
- B: Known constant value:

$$B = \frac{\text{BusFixedCost} * \text{MaxLoadperCycle}_{\text{route}}}{\text{LoadFactor}}$$

The graph in Figure 6.24 simply shows that the total social cost of waiting (the blue line) rises in direct linear proportion to the vehicle capacity, while the total fixed operational cost falls with vehicle capacity. The minimum total cost will be where Cw total (1 hour) = Cf total (1 hour).

The vehicle size that minimizes the cost of waiting imposed on the users (WaitCost) added to the fixed operating costs (FixedCost) to a given planned route is a vehicle size where FixedCost and WaitCost are equal.

$$\frac{d(\text{WaitCost}_{\text{route}} + \text{FixedCost}_{\text{route}})}{d(\text{VSize})} = \frac{d(A * \text{VSize} + \frac{B}{\text{VSize}})}{d(VSize)} = A - \frac{B}{\text{VSize}^2} = 0$$

$$A - \frac{B}{\text{VSize}^2} = 0 \Leftrightarrow A = \frac{B}{VSize^2} \Leftrightarrow \text{VSize}^2 = \frac{B}{A} \Leftrightarrow \text{VSize} = \sqrt{\frac{B}{A}}$$

The vehicle capacity (VSize) that provides minimal added cost will result in:

$$\text{WaitCost}_{\text{route}} = A * \text{VSize} = A * \sqrt{\frac{B}{A}} = \sqrt{\frac{A^2 * B}{A}} = \sqrt{A * B}$$

$$\text{FixedCost}_{\text{route}} = \frac{B}{\text{VSize}} = \frac{B}{\sqrt{\frac{B}{A}}} = \frac{B}{\sqrt{\frac{B}{A}}}\left(\frac{\sqrt{\frac{B}{A}}}{\sqrt{\frac{B}{A}}}\right) = \sqrt{\frac{B^2}{\frac{B}{A}}} = \sqrt{A * B}$$

The optimal size is one where the waiting costs imposed on the last set of users from reducing the frequency is precisely equal to the benefits to the vehicle operator in terms of reduced operating costs of using a slightly larger vehicle. Any movement away from this point, and the total cost of customers waiting, plus operating costs, will be higher.

Therefore, optimal vehicle capacity ($\text{VSize}_{\text{optimum}}$) is:

$$\text{VSize}_{\text{optimum}} = \sqrt{\frac{B}{A}} = \sqrt{\frac{\frac{\text{BusFixedCost}*\text{MaxLoadperCycle}_{\text{route}}}{\text{LoadFactor}}}{\text{Ren}_{\text{route}} * \text{Costi}_{\text{wait}} * 0.5 * (1 + Irr_{\text{route}} * \text{LoadFactor}}}$$

Eq. 6.16a:

$$\text{VSize}_{\text{optimum}} * \text{LoadFactor} = \sqrt{\frac{\text{BusFixedCost} * \text{MaxLoadperCycle}_{\text{route}}}{\text{Ren}_{\text{route}} * \text{Costwait} * 0.5(1 + Irr_{\text{route}}}}$$

Where:

- $\text{VSize}_{\text{optimum}}$: Optimal size of vehicle to serve the route capacity;
- BusFixedCost: Total fixed operating cost for the route (in $/hour);
- $\text{MaxLoadperCycle}_{\text{route}}$: Maximum demand across the critical segment of the route that will accumulate for the duration of one cycle during the busiest moment of the typical day (see Subsection 6.3.13);
- LoadFactor: Design load factor (usually 0.85);
- Renroute: Renovation factor of the route;
- Costwait Average user waiting cost ($/time);
- Irrroute: Irregularity index of the route; measure of the variance between the actual headways and the scheduled headways (usually near 0.3, see Section 6.3.9);

6.4.4 Vehicle Size Optimization Formula Applied

The following variables in Table 6.8 will be relatively constant, so the data can be collected either at the corridor level (Ren, Irr) or citywide (Costwait, BusFixedCost) and only needs to be done once. Below is some reasonable sample data, and because these tend to be consistent citywide, they can be turned into constants, except for the renovation rate, which needs to be calculated per corridor and is not consistent citywide.

Table 6.8. Sample Data Used for Examples

Variable	Symbol	Value	Unit
Fixed operating cost per bus	BusFixedCost	30	$/bus/hour
Waiting cost per passenger	Cost_Wait	12	$12/passenger/hour
Renovation factor on the corridor	Ren_route	1.5	
Irregularity Index on the corridor	Irr_route	0.3	

For this purpose, we can write Equation 6.16 as follows:
Eq. 6.16b:

$$\text{VSize}_{\text{optimum}} * \text{LoadFactor} = \sqrt{\frac{\text{BusFixedCost} * \text{MaxLoadperCycle}_{\text{route}}}{\text{Ren}_{\text{corridor}} * \text{Costwait} * 0.5 * (1 + Irr_{\text{city}})}}$$

$$\text{VSize}_{\text{optimum}} * \text{LoadFactor} = \sqrt{KA * \text{MaxLoadperCycle}}$$

Where:

- $KA = \frac{\text{BusFixedCost}}{\text{Ren}_{\text{corridor}} * \text{Costwait} * 0.5 * (1 + Irr_{\text{route}})}$

Using the data from the table and applying it to Equation 6.16, then:

$$KA = \frac{30}{1.5 * 12 * 1 + 0.3 * 0.5} = 2.56$$

In other words, so long as the basic information about fixed costs, the renovation rate, the irregularity rate, the cost of waiting, and so forth are all calculated for the corridor, the difference in the vehicle size for each route will be a function of the difference in the maximum load over the course of a cycle time under each scenario, or put another way, the number of customer places (Pl) that the vehicles need to serve.

In applying this to Equation 6.16, then:

$$\text{VSize}_{\text{optimum}} = \text{LoadFactor} = \text{MaxLoadperCycle}_{\text{route}} * 2.56$$

In this way, the optimum vehicle capacity is simply a function of the demand over the course of the route's cycle time that needs to be served under each scenario, times a constant, this of course must be divided by design load factor. Some examples of an application of this formula are shown in Table 6.9, where each row represents a different scenario.

For expediency in the examples below in Table 6.9, approximate values for MaxLoadperCycle are assumed rather than determining the actual value across multiple cycle times. A peak hour correction factor (PHtoCC) of 0.1 is also assumed, which is relatively typical. Other values are given in Table 6.9.

Using Equation 6.11 and the values in Table 6.9, optimal vehicle size (Cb_{optimum}) can be solved for, as shown in the last column of Table 6.9.

Eq. 6.17

$$\text{MaxLoadperCycle} = \text{MaxLoad} * TC * [1 - \text{PHtoCC} * (\text{TC} - 1)]$$

Where:

- MaxLoadperCycle: Maximum demand load per cycle time;

- MaxLoad: Maximum hourly load on the critical link;
- TC: Cycle time in hours.
- PHtoCC: Nonnegative correction factor, the calibration of which is based on survey data, is discussed in Box 6.2.

Table 6.9. Examples of Optimum Vehicle Size Derived from the Sample Data

MaxLoad	TC	PHtoCC	MaxLoadperCycle	Size*LoadFactor
pass/h	hours		passengers	passengers
20	0.25	0.1	5	4
200	0.25	0.1	49	11
2,000	0.25	0.1	488	35
20	1	0.1	18	7
200	1	0.1	180	21
2,000	1	0.1	1,800	68
8,000	1	0.1	7,200	136
20	4	0.1	48	11
200	4	0.1	480	35
2,000	4	0.1	4,800	111
8,000	4	0.1	19,200	222

On this very wide range of maximum hourly loads and cycle times, optimum size assuming load factor equal to 1.0, varies from a car to a bi-articulated vehicle. If the optimal vehicle size ($VSize_{optimum}$) is four, in most cases the demand is too low to justify the procurement costs of special new BRT vehicles, and such small vehicles do not come in BRT-compatible forms, so are likely to congest the BRT corridor. Hence, this route would simply be excluded from the proposed BRT services, or turned into a feeder route for the BRT corridor. As BRT vehicle options are not actually infinite, once the optimal vehicle capacity is identified using the formula, VSizeoptimum will need to be set by rounding up to the nearest vehicle suitable for the BRT services and design load factor.

Table 6.10. Examples for Determining Optimum Vehicle Size

MaxLoad	TC	PHtoCC	MaxLoadperCycle	Size*LoadFactor
pass/h	hours		passengers	passengers
20	0.25	0.1	5	Cut route
200	0.25	0.1	49	Cut route
2,000	0.25	0.1	488	60
20	1	0.1	18	Cut route
200	1	0.1	180	60
2,000	1	0.1	1,800	90
8,000	1	0.1	7,200	150
20	4	0.1	48	Cut route
200	4	0.1	480	60
2,000	4	0.1	4,800	150

8,000	4	0.1	19,200	220

6.4.5 Vehicle Fleet Optimization

One of the key purposes of developing a service plan is to know how many vehicles will need to be purchased. The factors involved in determining the operational size of the vehicle fleet include:

- Maximum hourly load on the critical link of a corridor (MaxLoad);
- Total cycle time (TC);
- Capacity of the vehicle (VSize);
- The degree to which demand is peaked (usually measured by a peak hour to cycle time correction factor, or PHtoCC as explained below);
- The need for a reserve fleet.

A reserve fleet needs to be added to the total fleet size, as vehicles will need to be serviced either preventatively or because they have broken down. As a rule, a reserve fleet is about 10 percent of the actual fleet needed to provide the service, although it can be lower than that.

6.4.5.1 Vehicle Fleet Calculation with Uniform Demand

As a first estimate of the fleet needed to provide a new BRT service, the maximum load on the critical link of the existing bus routes currently using the BRT corridor during the peak hour should be calculated. The existing bus route lengths and cycle times also need to be calculated. This can usually be done at low cost with a GPS. From this information it is possible to estimate the current needed fleet.

Eq. 6.18

$$\text{Fleet}_{\text{route}} = \frac{\text{MaxLoad}_{\text{route}} \cdot \text{TC}}{\text{VSize} \cdot \text{LoadFactor}}$$

Where:

- $\text{Fleet}_{\text{route}}$: Number of buses needed to serve the route;
- $\text{VSize}_{\text{route}}$: Vehicle serving the route capacity;
- $\text{MaxLoad}_{\text{route}}$:Maximum demand across the critical segment of the route that will accumulate for the duration of one hour, here is assumed constant;
- TC: Cycle time in hours;
- $\text{Freq}_{\text{route}}$:Frequency of the route;
- LoadFactor: Design load factor (usually 0.85);

To provide an example, assume the following:

- $\text{MaxLoad}_{\text{route}} = 224$;
- $TC = 2$hours
- $\text{VSize} = 72$;
- $\text{Load Factor} = 0.85$;

$$Fleet = \frac{224 * 2}{72 * 0.85} = 7.32$$

If the formula produces a fraction, round up to the next integer, since vehicles have to be procured in units of one. So, in this scenario, the result is eight vehicles.

Once other service planning decisions have been made, and the route structure has been optimized and the vehicle size has been optimized, and future demand for this specific service scenario has been modelled, the fleet required for the new services should then again be calculated using this formula.

To explain this formula, begin with cycle time. If the total round-trip cycle time for the vehicle is two hours, at the end of one hour, the first vehicle will still have an hour to go before it can reach the beginning of the route and pick up a second load of customers. Since demand is uniform in this example, there will be the same number of customers on the critical link needing service in the second hour as during the first hour. As such, having a cycle time of two hours means that vehicles that travelled during the first hour will not be back to pick up customers on the critical link in the second hour. They will only just be starting their return trip. Thus, a second set of vehicles will be needed to serve the same demand on the critical link during the second hour while the first set of vehicles is returning. This is why one should multiply the MaxLoad by the cycle time. In this scenario, it is as if the number of customers is doubled.

If the cycle time were one, however, the same vehicle could return to the starting position after one hour to take the second hour of customers. Therefore, the same fleet can serve the demand on the critical link each hour (and in this scenario, the demand is the same each hour). Thus, cutting the cycle time to one cuts the needed fleet in half:

- $\text{MaxLoad}_{\text{route}} = 224$;
- $TC = 1$hour
- VSize $= 72$;
- Load Factor $= 0.85$;

$$Fleet = \frac{224 * 1}{72 * 0.85} = 3.66$$

As the fleet has to be rounded up to the nearest integer, it would be four vehicles.

For this reason deadheading, or running some buses in the contra-peak direction without customers, can reduce the total cycle time, and hence the fleet needed.

The size of the vehicle (VSize) is also important. Bigger vehicles can move the same number of customers with a smaller fleet. In the example above with a cycle time of two hours, if an articulated vehicle is used that can hold 180 customers, only three vehicles are needed:

- $\text{MaxLoad}_{\text{route}} = 224$;
- $TC = 2$hours
- VSize $= 180$;
- Load Factor $= 0.85$;

$$Fleet = \frac{224 * 2}{180 * 0.85} = 2.923$$

By increasing the vehicle size, the required fleet size decreases. This means fewer vehicles are required, but the result is that the frequency is lower, and customers will wait longer. Similarly, by decreasing the vehicle size, a larger fleet is needed, but frequency increases, and customers will not have to wait as long.

6.4.5.2 Fleet Calculation with Peaked Demand

The above formula is good for rough calculations of fleet needs, but it is not sufficient to calculate the actual needed fleet in most real-world conditions where demand varies throughout the peak hours. Vehicles are expensive to purchase and operate, so more refined analysis is necessary.

To explain intuitively why the fleet needs for peaked demand are different than for uniform demand, the following example is useful. Assume a two-hour cycle time (TC) and sixty customers per vehicle (VSize), but this time, rather than assuming that MaxLoad is the same throughout three or four hours, from 6:00 a.m. to 9:00 a.m. assume that MaxLoad occurs only during the peak demand hour, let us say this is 6:45 a.m. to 7:45 a.m. just to get the idea.

With a two-hour cycle time, the first bus will return to pick up a second load of customers only after two hours. Thus, the total number of vehicles needed to serve the demand during the first peak hour is this plus the total needed to serve the demand during the second on-peak hour. A smaller fleet of vehicles is needed to serve that link during the second hour, because there are fewer customers.

The fleet needed is therefore not simply a function of the maximum load at the critical link and the vehicle size, but it is also a function of the cycle time and the degree to which demand is peaked.

Now, rather than simply calculating the fleet based on one single hourly demand, one must determine the maximum load on the critical link over the course of the cycle time, or MaxLoadperCycle. After the cycle time has passed, no more buses are needed as the first bus has returned to the beginning of the route.

The maximum load over the course of a cycle time is the total number of customers that will accumulate during one full route cycle time willing to cross the critical link on a given vehicle route. This can also be thought of as the number of passenger places that need to be served, or Pl.

Only so many vehicles are needed as would satisfy the customers that will accumulate before the first vehicle can complete its cycle and pick up a second round of customers. The original formula, Equation 6.5, can therefore be replaced with the following:

Eq. 6.19:

$$\text{Fleet}_{\text{route}} = \frac{\text{MaxLoadperCycle}_{\text{route}}}{\text{VSize} * \text{LoadFactor}}$$

Where:

- $\text{Fleet}_{\text{route}}$: Number of buses needed to serve the route;
- $\text{VSize}_{\text{route}}$: Vehicle serving the route capacity;
- $\text{MaxLoadperCycle}_{\text{route}}$: Maximum demand across the critical segment of the route that will accumulate for the duration of one cycle during the busiest moment of the typical day (see Subsection 6.3.13);
- $\text{Freq}_{\text{route}}$:Frequency of the route(ideal frequency suggested of 22 vehicles per hour);
- LoadFactor: Design load factor (usually 0.85);

This then requires the development of a methodology for calculating the maximum load over the course of a specific cycle time.

At this point in the service planning effort, the service planner will have collected ridership data in fixed increments of time, such as fifteen-minute intervals, and determined the critical link. With that data, in order to calculate the fleet requirements, two questions must be answered:

1. Given an expected cycle time (TC) period for a BRT route, what "TC period" of the day experiences the highest demand?
2. How does one calculate fleet numbers based on the peak TC period?

In order to answer the first question, the example in Table 6.11 is a sample of fifteen-minute increment ridership data. In this example, the cycle time (TC) is one hour, so one should look for the peak hour.

Table 6.11. Peak Period Critical Link Demand Profile for a Bus Route over Fifteen-Minute Increments and One-Hour TC Increments

15-Minute Time Increment	15-Minute Observed Demand	One-Hour Time Increment	TC = One- Hour Accumulated Demand
6:00–6:15	15	N/A	N/A
6:15–6:30	21	N/A	N/A
6:30–6:45	31	N/A	N/A
6:45–7:00	51	6:00–7:00	118
7:00–7:15	63	6:15–7:15	166
7:15–7:30	69	6:30–7:30	214
7:30–7:45	67	6:45–7:45	250

7:45–8:00	*66*	*7:00–8:00*	*265*
8:00–8:15	53	7:15–8:15	255
8:15–8:30	45	7:30–8:30	231
8:30–8:45	34	7:45–8:45	198
8:45–9:00	32	8:00–9:00	164
9:00–9:15	21	8:15–9:15	132

In Table 6.11, ridership data was collected and entered in fifteen-minute increments ("Fifteen-Minute Observed Demand").

Here the column on the right shows the accumulated demand over each distinct one-hour (i.e., TC) period. For example, from 6:00 to 7:00, all of the demand observed passing the critical link from 6:00 to 6:15, 6:15 to 6:30, 6:30 to 6:45, and 6:45 to 7:00 has accumulated, for a total of 118. Since a full hour has not yet passed until 7:00, N/A is entered into the first three cells.

Now Question 1—what is the highest demand period for a given cycle time?—can be answered by looking at the table and choosing the hour with the greatest accumulated demand. In this case, it is 7:00–8:00 when accumulated demand reaches its maximum at 265 (the row highlighted in yellow). This is called the maximum load per cycle time (MaxLoadperCycle). If the cycle time is one hour, the final result is MaxLoadperCycle = 265.

If the cycle time TC were two hours, the table would look different:

Table 6.12. Peak Period Critical Link Demand Profile over Fifteen-Minute Increments and Two-Hour TC Increments

15-Minute Time Increment	15-Minute Observed Demand	Two-Hour Time Increment	TC = Two- Hour Accumulated Demand
6:00–6:15	15	N/A	N/A
6:15–6:30	21	N/A	N/A
6:30–6:45	31	N/A	N/A
6:45–7:00	51	N/A	N/A
7:00–7:15	63	N/A	N/A
7:15–7:30	69	N/A	N/A
7:30–7:45	67	N/A	N/A
7:45–8:00	66	6:00–8:00	383
8:00–8:15	53	6:15–8:15	421
8:15–8:30	45	6:30–8:30	445
8:30–8:45	*34*	*6:45–8:45*	*448*
8:45–9:00	32	7:00–9:00	429
9:00–9:15	21	7:15–9:15	387

With a two-hour cycle time, the MaxLoadperCycle becomes 6:45–8:45 with a maximum demand of 448. Here, MaxLoadperCycle = 448.

If, on the other hand, the cycle time were fifteen minutes, the peak would be 7:15–7:30 and the MaxLoadperCycle = 69.

Now to address Question 2—how to calculate fleet numbers based on the peak TC period. There are two ways to obtain the fleet numbers. The simplest way is to determine the peak load over the course of the cycle time ($L_{\text{peak}}[TC]$), as shown above, and simply divide by vehicle capacity. That is:

Eq. 6.20:

$$\text{Fleet}_{\text{route}} = \frac{\text{MaxLoadperCycle}_{\text{route}}}{\text{VSize} * \text{LoadFactor}}$$

Where:

- $\text{Fleet}_{\text{route}}$: Number of buses needed to serve the route;
- $\text{VSize}_{\text{route}}$: Vehicle serving the route capacity;
- $\text{MaxLoadperCycle}_{\text{route}}$: Maximum demand across the critical segment of the route that will accumulate for the duration of one cycle during the busiest moment of the typical day (see Subsection 6.3.13);
- $\text{Freq}_{\text{route}}$:Frequency of the route(ideal frequency suggested of 22 vehicles per hour);
- LoadFactor: Design load factor (usually 0.85);

So, for a TC of one hour, using the observed MaxLoadperCycle of 265, it is calculated that:

$$\text{Fleet}(TC = 1\text{hour}) = \frac{265}{72 * 0.85} = 4.33$$

Thus, the fleet needed for that peak cycle time is five.

So, for a TC of two hours, using the actual MaxLoadperCycle of two hours based on the data:

$$\text{Fleet}(TC = 2\text{hours}) = \frac{448}{72 * 0.85} = 7.32$$

This equates to a fleet of eight vehicles. A cycle time that is twice as long as another does not necessarily result in doubling the fleet. In this case, the cycle time increased from one to two hours, but the needed fleet went from five to eight, instead of to ten.

Box 6.2. How to determine correction factor from hour to cycle time (PHtoCC) based on load observations

When one is analyzing many existing or potential routes with different cycle times, it is cumbersome to calculate the necessary fleet in the more intuitive manner listed above. For this reason, this section offers another way to calculate the fleet with the use of a common peak to cycle factor derived from corridor specific data. The maximum-hour load only can be determined and then a Peak Hour to Cycle Correction Factor (PHtoCC) can be applied to that to expand the demand across the full array of possible cycle times. The calculation of the PHtoCC should be done per corridor and should be made separately for weekdays, Saturdays, and Sundays.

To calculate the peak hour to cycle correction factor, we present an example of a typical demand profile for the critical link on a BRT corridor during the morning peak derived from on Table 6.13.

Table 6.13. Peak Period Critical Link Demand Profile

Time	15 Minute Loads	Cumulative
6:00 a.m.	15	15
6:15 a.m.	21	36
6:30 a.m.	31	67
6:45 a.m.	51	118
7:00 a.m.	63	181
7:15 a.m.	69	250
7:30 a.m.	67	317
7:45 a.m.	66	383

8:00 a.m.	53	436
8:15 a.m.	45	481
8:30 a.m.	34	515
8:45 a.m.	32	547
9:00 a.m.	21	568
9:00 a.m.	21	589
9:15 a.m.	19	608
9:30 a.m.	35	643
9:45 a.m.	24	667
10:00 a.m.	29	696
10:15 a.m.	25	721
10:30 a.m.	25	746

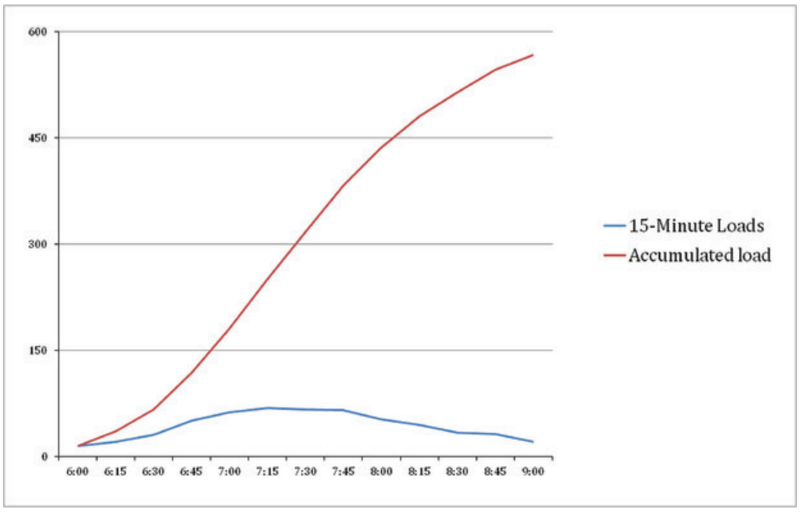

Figure 6.25. The graph shows 15-minute loads (blue) versus overall accumulated loads (red). Peak 15-minute period occurs where blue curve hits its max, or 7:00–7:15 a.m. *Arthur Szász.*

The blue line in Figure 6.25 is the number of customers every 15 minutes at the critical link, or the location where there is the maximum load (MaxLoad) of customers. The column labeled "15-minute loads" shows the number of people passing the critical link in 15-minute increments at different times. The red line is the accumulated load for the full peak period. The number of customers at 6:00 is fifteen. If the cycle time (TC) is two hours, the accumulation of customers at 8:00 (t + TC) is 436 minus the fifteen customers that were already on board at 6:00, or 421.

Note that the number of customers passing the critical link varies in each 15-minute interval. The maximum load for a 15-minute interval would be 69 at 7:15. This is equivalent to saying that the maximum load, or the number of customers that would be riding on vehicles past the critical link, if the cycle time were only 15 minutes, would be 69.

All of the possible time periods that are equivalent to the cycle time (TC) need to be tested to see which time period results in the maximum accumulated customers. To do this, create a table that simulates the number of customers that would accumulate per vehicle under different cycle times, such as in Table 6.14, where the first column to the right of the time cycle represents the observed loads at the critical link for every 15-minute interval. The second column places the 6:15 load next to the 6:00 load, and the 6:30 load next to the 6:15 load, and so on, because this is what the load would be for a 30-minute interval. It is not simply double the 6:00 a.m. demand, because the demand at 6:15 is different from the demand at 6:00 a.m. The third column places the 6:45 demand adjacent to the 6:30 demand, and so on.

Table 6.14. Peak Period Loads by Cycle Time

Time	5 minute loads	Accumulated Passengers	Time	15 minute loads	15 min	15 min	15 min	15 min	15 min	15 min	15 min	15 min	15 min
6:00	6	6	6:00	15	21	31	51	63	69	67	66	53	45
6:05	5	11	6:15	21	31	51	63	69	67	66	53	45	34
6:10	4	15	6:30	31	51	63	69	67	66	53	45	34	32
6:15	8	23	6:45	51	63	69	67	66	53	45	34	32	21
6:20	3	26	7:00	63	69	67	66	53	45	34	32	21	21
6:25	10	36	7:15	69	67	66	53	45	34	32	21	21	19
6:30	7	43	7:30	67	66	53	45	34	32	21	21	19	35
6:35	12	55	7:45	66	53	45	34	32	21	21	19	35	24
6:40	12	67	8:00	53	45	34	32	21	21	19	35	24	29
6:45	15	82	8:15	45	34	32	21	21	19	35	24	29	25
6:50	20	102	8:30	34	32	21	21	19	35	24	29	25	25
6:55	16	118	8:45	32	21	21	19	35	24	29	25	25	25
7:00	18	136	9:00	21	21	19	35	24	29	25	25	25	25
7:05	22	158	9:00	21	19	35	24	29	25	25	25	25	25
7:10	23	181	9:15	19	35	24	29	25	25	25	25	25	25
7:15	17	198	9:30	35	24	29	25	25	25	25	25	25	25
7:20	25	223	9:45	24	29	25	25	25	25	25	25	25	25
7:25	27	250	10:00	29	25	25	25	25	25	25	25	25	25
7:30	23	273	10:15	25	25	25	25	25	25	25	25	25	25
7:35	24	297	10:30	25	25	25	25	25	25	25	25	25	25
7:40	20	317	10:45	25	25	25	25	25	25	25	25	25	25
7:45	26	343	11:00	25	25	25	25	25	25	25	25	25	25
7:50	19	362	11:15	25	25	25	25	25	25	25	25	25	25
7:55	21	383	11:30	25	25	25	25	25	25	25	25	25	25
8:00	17	400	11:45	25	25	25	25	25	25	25	25	25	25
8:05	16	416	12:00	25	25	25	25	25	25	25	25	25	25

In Table 6.15, the 15-minute column is the same as the column above. The 30-minute column simply adds together the first two 15-minute columns from above, to give accumulated customers for a 30-minute interval. The 45-minute column totals the accumulated customers of the first three columns, and so on. In this simple way, a chart can be generated for the loads that would accumulate for each cycle time.

Table 6.15

Table 6.15. Accumulated Passengers for Different Cycle Times

Time	15 min	30 min	45 min	60 min	75 min	90 min	105 min	120 min	135 min	150 min	165 min	180 min
6:00	15	36	67	118	181	250	317	383	436	481	515	547

6:15	21	52	103	166	235	302	368	421	466	500	532	553
6:30	31	82	145	214	281	347	400	445	479	511	532	553
6:45	51	114	183	250	316	369	414	448	480	501	522	541
7:00	63	132	199	265	318	363	397	429	450	471	490	525
7:15	69	136	202	255	300	334	366	387	408	427	462	486
7:30	67	133	186	231	265	297	318	339	358	393	417	446
7:45	66	119	164	198	230	251	272	291	326	350	379	404
8:00	53	98	132	164	185	206	225	260	284	313	338	363
8:15	45	79	111	132	153	172	207	231	260	285	310	335
8:30	34	66	87	108	127	162	186	215	240	265	290	315
8:45	32	53	74	93	128	152	181	206	231	256	281	306
9:00	21	42	61	96	120	149	174	199	224	249	274	299
9:00	21	40	75	99	128	153	178	203	228	253	278	303
9:15	19	54	78	107	132	157	182	207	232	257	282	307
9:30	35	59	88	113	138	163	188	213	238	263	288	313
9:45	24	53	78	103	128	153	178	203	228	253	278	303
10:00	29	54	79	104	129	154	179	204	229	254	279	304

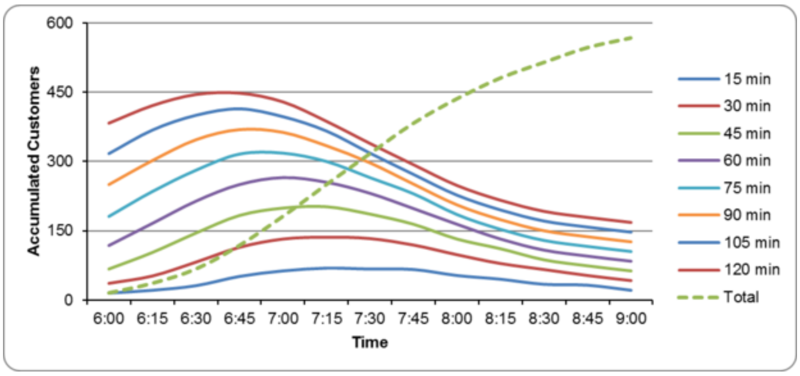

Figure 6.26. Accumulated demands for varying cycle times, using the same data as in Tables 6.13 – 6.15. *Arthur Szász.*

The maximum point on each curve shows the maximum accumulated customers, which is needed to derive the necessary fleet. Table 6.15 shows that the longer the cycle time, the more demand will accumulate before the same vehicle can get back to the beginning of the route to pick up more customers.

For the first example (the top brown-red line), different accumulated demands are graphed for different two-hour periods. Between 6:00 a.m. and 8:00 a.m. accumulated customers are 383 (the first data point at 6:00 a.m. on the top brown-red line). This is because at 8:00 a.m. there are already fifteen customers, and after two hours, 398 customers have accumulated, so enough vehicles to carry 383 (398-15) customers are needed. The accumulated customers from 6:00 to 8:00 are not the same, however, as the accumulated customers from 6:15 to 8:15, or from 6:30 to 8:30, etc. The top brown red line graphs the accumulated customers for each two-hour time increment are listed in Table 6.15 in the column labeled “120 minutes.” The peak period for this cycle time is about 6:45 to 8:45, when 448 passengers accumulate over two hours. Thus, for a two-hour cycle time, we can say that 448 is the MaxLoadperCycle = 448.

In each scenario, the load that needs to be accommodated with a fleet is the maximum load for each cycle time, or MaxLoadperCycle. In Table 6.15, the maximums are shown at the bottom of each cycle time. Because of the shape of the peak in demand, the maximum loads will vary depending on the cycle time. If the accumulated customers (load) per cycle time are divided by the cycle time, this gives the hourly load (MaxLoad [one hour]) for a specific cycle time.

Table 6.16. Calculation of How the Maximum Load Varies with Cycle Time

Hours	0.25	0.5	0.75	1	1.25	1.5	1.75	2	2.25	2.5	2.75	3
Cycle time (min)	15	30	45	60	75	90	105	120	135	150	165	180
MaxLoadper-Cycle	69	136	202	265	318	369	414	448	480	511	532	553
MaxLoad	276	272	269	265	254	246	237	224	213	204	193	284
ML	1.04	1.03	1.02	1	0.96	0.93	0.89	0.85	0.81	0.77	0.73	0.7

If the maximum load for each cycle time is then further divided by the maximum load for a one-hour cycle time (265), then this gives an indicator (ML) that shows how much the maximum load for a specific cycle time varies from the maximum load for one hour. The peak hour to cycle correction factor (PHtoCC) is the slope of this line, indicating the degree to which the maximum load varies by the cycle time in general. In this way, a PHtoCC can be derived that can then be applied in the future to calculate the fleet needs for many routes of different cycle times.

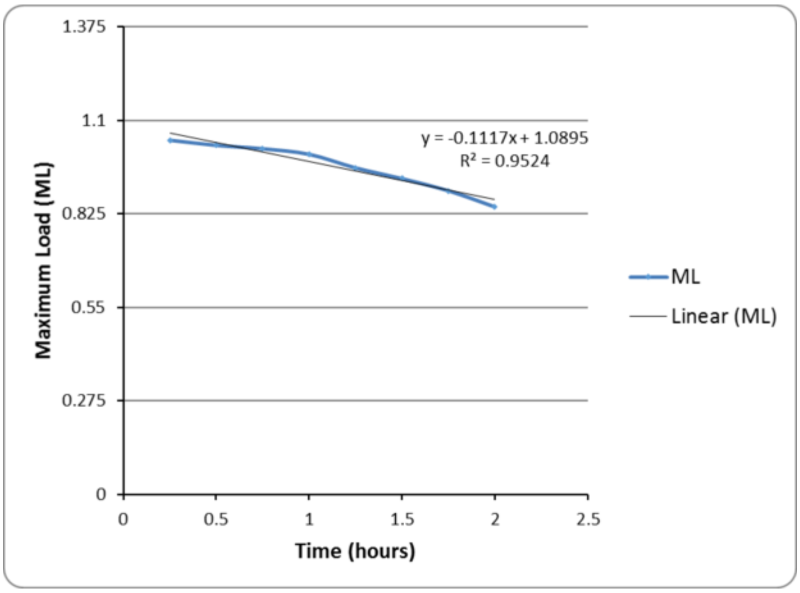

Figure 6.27. Accumulated maximum load (ML) for various cycle times as a proportion of the accumulated max load for a one-hour cycle time. The slope, as shown by the formula and the straight black line, represents the PHtoCC. Image *Arthur Szász*.

In Figure 6.27, rounding a bit, the PHtoCC = 0.11. MS-Excel will generate this number if instructed to provide the formula for a trend line when generating a graph.

Once the PHtoCC is known, the following formula may be used to determine MaxLoadperCycle for varying cycle times with peaked demand from the known MaxLoad, which is determined per hour. This formula is a simplification of a derivative, i.e., it describes a set of relationships that are linear in most real-world applications but that do not hold at the extremities, resulting in the previously presented.

Eq. 6.21a $\mathrm{MaxLoadperCycle} = \mathrm{MaxLoad} * TC * [1 - \mathrm{PHtoCC} * (\mathrm{TC} - 1)]$

Where:

- PHtoCC: Nonnegative correction factor, the calibration of which is based on survey data, is discussed in Box 6.2. The usual value is near 0.1;

- If TC is larger than one hour: correction $1 - \text{PHtoCC} * (\text{TC} - 1)$ will result smaller than one;
- If TC is smaller than one hour: correction $1 - \text{PHtoCC} * (\text{TC} - 1)$ will result larger than one;
- If TC is equal one hour: correction $1 - \text{PHtoCC} * (\text{TC} - 1)$ will result in one;
- If PHtoCC is equal zero, there will be no correction.

And therefore the fleet needed for any route with any cycle time can be calculated as follows, by expanding Equation 6.14 with Equation 6.6b.

Eq. 6.21b

$$\text{Fleet}_{\text{route}} = \frac{\text{MaxLoadperCycle}_{\text{route}}}{\text{VSize} * \text{LoadFactor}}$$

$$\text{Fleet}_{\text{route}} = \frac{\text{MaxLoad} * TC * [1 - \text{PHtoCC} * (\text{TC} - 1)]}{\text{VSize} * \text{LoadFactor}}$$

Where:

- $\text{Fleet}_{\text{route}}$: Number of buses needed to serve the route;
- MaxLoad: Maximum hourly load;
- $\text{VSize}_{\text{route}}$: Vehicle serving the route capacity;
- $\text{Freq}_{\text{route}}$:Frequency of the route(ideal frequency suggested of 22 vehicles per hour);
- LoadFactor: Design load factor (usually 0.85);

This approximation expands the peak one-hour load based on the degree to which the one-hour load is peaked within the full cycle time.

So, for a TC of two hours using the example from above, the maximum load is:

$$MaxLoadperCycle = 265 * 2 * 1 - 0.11 * 2 - 1 = 471.7$$

Hence, for a TC of two hours, the fleet needed is:

$$265 * 2 * 1 - 0.11 * 2 - 160 = 7.50$$

$$Fleet2hours = 265 * 2 * 1 - 0.11 * 2 - 172 * 0.85 = 7.71$$

The resulting 7.71 is a close approximation to the 7.32 used in the other formula, and again, one should round up to eight vehicles. (The discrepancy is because both formulas are simplifications to avoid the use of derivatives, to make the math easier in a way that is sufficient for most real-world uses.)

In most real-world cases, the peak hour to cycle correction factor (PHtoCC) is around 0.1. For a rough approximation, in a relatively normal peaked corridor, one can make a back-of-the-envelope adjustment by just using a generic peak factor such as 0.1, but it is better to calculate the actual peak factor. While this impact of the peak factor on the needed fleet is significant when calculating the fleet for any vehicle route, it makes a very big difference when a multitude of direct-service routes are severed into a trunk route and multiple feeder routes.

6.5 Determining Which Routes to Include Inside BRT Infrastructure

> *"An almost indispensable skill for any creative person is the ability to pose the right questions. Creative people identify promising, exciting, and, most important, accessible routes to progress—and eventually formulate the questions correctly."*
>
> — Lisa Randall, theoretical physicist, 1962–

At this point one should have some basic idea of how to calculate the best vehicle size and how to calculate the necessary fleet for a variety of alternative services one might want to run inside the BRT infrastructure. One now has enough information to start doing the basic service planning for a proposed BRT corridor.

The first question that needs to be answered is what of the existing bus services currently using the corridor should one include, at least in some form, as part of the new BRT services. If properly designed, new BRT infrastructure should increase the speed of all the vehicles that use the BRT infrastructure. Ideally, then, *all* the customers currently using the BRT corridor should be served by the BRT system's new operations. The simplest way to ensure this is being done is to simply include as new BRT services all of the services currently using the corridor. Most of these will be direct services that use the BRT corridor for only a part of their route.

However, there are a variety of circumstances where the benefits to the customers of specific bus services are outweighed by the disadvantages that allow this bus route to use the BRT system would impose on the remainder of the BRT customers. There are three reasons to exclude some of the existing services:

1. Avoidance of station saturation;
2. Lack of administrative authority over an operator with incompatible operations;
3. Minimal overlap with the corridor.

If a preexisting bus route is excluded from the BRT infrastructure, there are a few things that can happen to it. First, it can be allowed to continue to operate in the mixed traffic lanes along the BRT corridor. Most of the examples in this first section assume that if the route is not allowed to use the BRT infrastructure, it will operate in the mixed traffic lanes. The route could also simply be cancelled, and its demand transferred onto some similar service.

However, there are other alternatives. It could be allowed to operate inside the BRT corridor but not stop at BRT stations. This option is worth considering in situations when there are no important stations on a particular route along a BRT trunk corridor. Finally, the route could be converted into a feeder route. This option will be considered in the next section on trunk-and-feeder routes.

6.5.1 Administrative Authority

The best BRT systems minimize boarding and alighting delay by requiring special vehicles that have a clean interface with the station, as described below. Further, the image and quality of service of the BRT system matters.

On any given corridor, there may be a wide variety of bus and minibus operations owned by different companies or government agencies and regulated and administered by different government entities. For instance, a major arterial might have school buses, charter buses, intercity buses, regional buses, private express buses, and local buses.

The best BRT systems limit access to special BRT infrastructure to prescribed operators that operate with the specific permission of a BRT authority and provide bus services following detailed technical specifications required by the BRT authority. These are sometimes called "closed systems." In general, the highest-quality examples of BRT, such as Bogotá, Lima, Guangzhou, Brisbane, and Curitiba, take advantage of the possibility of restricting access to the new BRT infrastructure to leverage improvements in bus services. In Bogotá and Lima, companies compete for the right to provide public transport services in the BRT system through a process of competitive tendering. These systems only permit vehicles with highly defined specifications operating under a specific contract to a single public authority to operate on the corridor. Because BRT systems try to maintain a higher quality of service than regular bus services, BRT operating contracts are generally far tougher than regular bus operating contracts, and the number of vehicles able to use the BRT infrastructure is normally limited to levels that will avoid saturation of the busway.

By contrast, systems that have implemented a simple busway system open to some bus operations not under the full administrative control of a BRT authority are known as "open systems." Very few BRT systems have completely open access: Regional or intercity buses, charter buses, and school buses are rarely allowed access to BRT infrastructure. As a rule of thumb, if the BRT authority cannot regulate the vehicle specification and the operation of the bus operator, it is not a good idea to allow that service to operate inside special BRT infrastructure.

Many cities with simple busways that do not qualify as BRT using *The BRT Standard*, or qualify in some cases as "basic" BRT, utilize an open-system structure, where any bus regardless of type is allowed to use the bus lane. One of the major problems with open busways is that the lack of regulation tends to lead to lower service quality. For instance, in the Delhi busway, which is open to a wide variety of bus operations reporting to different regulatory bodies, some of them with extremely weak maintenance oversight, frequent bus breakdowns tend to plague the services inside the busway. Another problem typical of open busways is that they are more likely to become congested, as the number of buses is harder to control at levels that will avoid saturation.

In general, a closed structure is more conducive to efficient traffic operations. Since the number of operators and the number of vehicles are controlled, a closed system can be designed around the optimum conditions for customer movement.

Furthermore, limiting access to new BRT infrastructure is often effectively used by governments to leverage industry modernization and higher quality of service, as discussed in Volume IV: Business Plan, especially Chapter 13: Business Structure. By placing certain minimum requirements on potential bus operators as a condition to bid for a BRT operating contract, the BRT administrative authority can use this leverage in a variety of ways, from encouraging ownership structures that include adversely impacted former operators, to requiring companies to comply with best modern business practices, and so forth.

The vehicle types allowed will also greatly affect several performance indicators, including boarding and alighting times and station congestion levels. A single small bus with a very small door can badly congest an exclusive BRT lane, and for this reason, such buses are incompatible with high-speed, high-capacity BRT systems. Specifying maximum vehicle age and maintenance practices can also affect performance. Breakdowns contribute to corridor congestion. Thus, weak regulatory control over the vehicle fleet is incompatible with consistent high-speed, high-capacity, and high-quality service. Tight regulation of emissions, operating speeds, and noise is also important to protecting the environmental quality of the corridor.

Prior to developing its TransMilenio system, Bogotá actually operated a median busway on its Avenida Caracas corridor. The Avenida Caracas busway operated as an open system, permitting all existing operators to utilize the infrastructure. The result was excessive busway congestion and average commercial speeds of approximately 10 kph (Figures 6.29 and 6.30). The busway was partially effective in improving conditions for mixed traffic, but did little to improve travel conditions for public transport customers. It should be noted, though, that having a closed system is a necessary but insufficient condition for ensuring good system performance.

Emergency vehicles, such as ambulances, are generally permitted access on most BRT systems (Figures 6.31 and 6.32), whether they are open or closed systems. This public service provides an additional motivation for approving a BRT project, especially since many rail options are not compatible with emergency vehicles. In many cities, mixed traffic congestion significantly inhibits emergency access and delivery. By facilitating rapid emergency services for the injured and critically ill, the BRT system is in effect helping save lives.

Some cities also permit "official" vehicles to utilize the busway. This usage may include presidential and ministerial motorcades, as well as travel for low-ranking

Figure 6.28. Open busway congestion in Delhi. *ITDP.*

Figure 6.29. Bogotá originally operated an open busway system. Individually owned, unreformed informal "collectivo" bus services with merely a route license, but no formal operating contract plied the corridor. The bus operators were largely unaccountable. Vehicles were polluting, poorly maintained, and of a variety of types that did not interface cleanly with BRT infrastructure. Frequencies were too high to avoid congestion. *TransMilenio SA.*

Figure 6.30. By contrast, the development of the closed TransMilenio system along the same corridor, where schedules are fixed and where operators meeting certain minimum corporate standards have to comply with tight technical specifications and maintain quality-of-service standards, has dramatically improved travel times and customer comfort *Lloyd Wright*

Figure 6.31. In cities such as Quito, the exclusive busways also permit emergency vehicles. *Lloyd Wright.*

Figure 6.32. Allowing emergency vehicles to avoid traffic delays should provide quicker responses to those in need. *Lloyd Wright.*

public officials (Figure 6.33). The justification for such usage can be questionable. Certainly, for the highest-ranked officials, such as a president or prime minister, the exclusive busway does allow for potentially safer movements. The usage by lower-ranking officials is harder to justify and can ultimately have a highly detrimental impact on system speeds and capacity. In Quito, sometimes the appropriation of busway space even extends to public utility vehicles, such as garbage trucks (Figure 6.34). The presence of such vehicles can do much to hinder proper BRT operation.

6.5.2 Overlap with the BRT Corridor

On most BRT corridors, some existing public transport routes overlap the corridor for a short segment. If the segment is very short, it may not be worth incorporating the service into the BRT system. Usually, incorporating a bus route into the BRT system requires buying special new vehicles for that route, and if the benefits of including the route in the BRT system are low because it only overlaps with the BRT for a short segment, these benefits may not outweigh the cost of buying a new BRT vehicle.

In Table 6.1, existing routes are shown to the degree to which the route overlaps the planned BRT infrastructure. If the overlap is less than 20 percent of the total length of the route, it may not be worth incorporating it into the BRT service plan.

In many cases, BRT service planners start by mapping the existing route and then exclude the routes that overlap the planned BRT corridor for less than 20 percent of their route. This is not a hard-and-fast rule; it is just what is normally done. In situations of low station saturation and high-frequency routes, the percentage may be as low as 10–15 percent, but in capacity-constrained settings, a range of 20–30 percent is more typical.

If the part of the route that overlaps with the BRT corridor is downtown, on a highly congested road, or it includes some very high-demand stations, there may be significant benefits to incorporating the route into the BRT system, but in most cases 20 percent overlap is a reasonable rule of thumb for excluding a route. In case of doubt, the operational cost savings and time savings that would accrue from using the BRT infrastructure could be compared to the additional costs associated with buying special vehicles, if the BRT requires new vehicles. If the overlap is below 20 percent, but there is no particular need for the route to stop on the BRT corridor, one might consider allowing the route to use the BRT corridor for this short segment, while not stopping at any of the BRT station stops.

Figure 6.33. When usage of the exclusive busway by lower-ranking government officials becomes commonplace, there can be negative impacts on the efficiency of the system. *Lloyd Wright*

Figure 6.34. In Quito, even garbage trucks take advantage of the exclusive busway. *Lloyd Wright.*

6.5.3 Avoiding Station Saturation

Once the routes that have only a tangential relationship to the BRT trunk service have been excluded from the proposed BRT system services, ideally the BRT infrastructure should be designed to accommodate the demand from all of the remaining bus routes. However, this may be impossible. If the capacity of what can be designed is less than the remaining demand, it may be necessary to make further decisions about which routes to include in the BRT services, and which to leave in mixed traffic, or reroute off the corridor. In this sense, service planning is iterative with infrastructure planning. The next chapter provides the formulas needed to calculate the capacity and speed of a BRT corridor depending on *The BRT Standard* elements used. The normal situation where one needs to exclude some bus routes in the manner described in this section is when a single-lane BRT with no sub-stops or passing lanes has been designed.

Having many routes is not a problem per se; it only becomes a problem if frequencies are high enough that stations begin to become saturated, and the speed of the BRT system begins to slow. Since new BRT infrastructure will allow vehicles to increase their speed, ideally as many customers as possible should be able to use it. Usually, a corridor will be chosen for BRT that already has a lot of bus or minibus services along it, and normally these preexisting services are a reasonable match to public transport demand patterns. As such, the first principle of service planning is to incorporate as many preexisting bus routes as possible into the services that will use the new BRT infrastructure. This will maximize the number of beneficiaries and minimize the disruption of service.

In specific cases where current bus services already take up more than one mixed traffic lane, the BRT system may begin to become congested if too many routes are brought into the dedicated infrastructure, at which point the speeds will slow. Eventually, as saturation worsens, speeds inside the BRT system can drop to levels below the original mixed traffic speeds. Then, unless the design of the busway can be modified to accommodate all of the bus routes, the service planner will need to exclude some of the bus routes from the system.

An example of this problem occurred with the Seoul BRT. The system was initially designed with insufficient capacity to handle the vehicle demand in the corridor. As a result, in the first several months of operation, the corridor became saturated, and vehicle speeds dropped below the pre-BRT speeds. After diverting some of the routes back to the mixed traffic lanes so the busway was not saturated, the overall system yielded significant user benefits. The methodology sketched out below should be used in similar circumstances when deciding which routes to put back into mixed traffic.

The process of determining how many routes to include in the services for the planned BRT system has two basic steps. First, calculate which future BRT station or stations are most likely to become saturated. This will be the station projected to have the highest frequency and boarding and alighting volumes, because high frequency and high boarding and alighting volumes are the most likely causes of station saturation.

In nearly all cases, BRT system saturation happens at stations where the capacity is too low to handle the frequency and boarding and alighting volumes, so vehicles begin to bunch. The formulas for calculating station saturation are covered in Chapter 7: Capacity and Speed.

Second, a calculation should be performed to determine, given the characteristics of each route (demand, vehicle type, frequencies, and demand to that particular station, etc.), how many routes and which routes should be included as part of the new BRT services and which should be excluded. To do this, the routes should be ordered based on the seconds consumed at that specific station multiplied by the number of customers that are passing by that bottleneck station. In other words:

The first criteria used to select routes for inclusion in the BRT system is frequency and proportion of overlap with the BRT corridor. If the route only uses the BRT corridor for a short distance, or carries few customers, the benefits may not justify the cost of purchasing a BRT-infrastructure-compatible bus.

For systems where there is a danger that the busway will become saturated and speeds will slow, a second method should be used: routes should be ranked based on the number of customers that a route can move through the bottleneck station for each second of dwell time they consume at the bottleneck station. Routes moving more customers per second of dwell time should continue to be included until the total delay caused to the busway of adding the last route is greater than the time savings benefits of adding the last route.

The existing bus route that uses the busway most efficiently will be the route that carries the most customers with the fewest customers getting off at the bottleneck station. For instance, if the bottleneck station in a BRT system is Times Square, and there is an express route, “T1,” that carries large numbers of customers through Times Square but does not stop at Times Square, it should certainly be included in the busway, as it does not contribute at all to the bottleneck at Times Square station. By contrast, a route that carries relatively few customers, yet all of them get off at Times Square, should be the first route to be excluded.

In this section we provide formulas to determine how many and which vehicle routes to include in the BRT system. Given that every effort has already been made to design the system with a capacity that will avoid saturation, but, for one reason or another, design compromises had to be made, and the design has already been fixed in a way that does not accommodate all public transport customers who want to use the corridor. It is assumed that if some existing routes are not excluded, the bus speeds in the corridor will slow down. This is fairly common in the developing world, but not so common in the United States or Europe. Each scenario is progressively more complex—and more realistic; however, they do not cover every possibility. Service planners will need to understand the fundamentals laid out in this chapter and make modifications to fit a given situation.

In these scenarios, there are two possible ways for running buses:

1. BRT corridor: The BRT corridor is generally described in text as "BRT infrastructure" or "busway" and is indicated in formulas with the subscript "inside."
2. Mixed-traffic lane: The mixed-traffic lane is assumed to run parallel to the BRT corridor. The mixed-traffic lane is where bus routes that are excluded from the BRT infrastructure will run. The mixed-traffic lane is referred to in text as "outside the BRT corridor" and is indicated in formulas with the subscript "outside." It is assumed that speeds in the mixed-traffic lane do not vary based on the number of buses in it, since buses generally constitute a relatively small share of total traffic, and it is generally possible for buses to pass each other in the mixed traffic lanes. If bus volumes in the mixed traffic lanes are likely to affect mixed traffic speeds, a more detailed analysis of the mixed traffic lanes should be made.

In the following scenarios, one should aim to minimize aggregate travel time for all customers (ATT_{total}), both inside and outside the BRT corridor. One assumes that there is a total number of bus routes, both inside and outside the BRT corridor operating at a combined total frequency, indicated by Fi_{total}. Bus routes operate as units, so that one cannot remove a few buses of the route "f" from the busway; the entire route must be removed.

In all scenarios below, the part of the corridor that will receive BRT infrastructure is assumed to be 5 kilometers long and the speed in the mixed traffic lanes along this corridor is assumed to be 10 kph. The speed within the busway will vary by the scenario, while the speed in the mixed traffic lane will be assumed to stay at 10 kph.

Table 6.17. Example of Average Peak Hour Riders and Times

Departure	Arrival	Travel Time	Passengers
6:00 a.m.	8:00 a.m.	2:00	25
6:15 a.m.	8:15 a.m.	2:00	25
6:30 a.m.	8:30 a.m.	2:00	25
6:45 a.m.	8:45 a.m.	2:00	25
7:00 a.m.	9:00 a.m.	2:00	25
7:15 a.m.	9:15 a.m.	2:00	25
7:30 a.m.	9:30 a.m.	2:00	25
7:45 a.m.	9:45 a.m.	2:00	25

Further, the peak hour was already identified as between 6:15 and 7:14, the peak hour ridership is a hundred, and the peak hour travel time is two hours. It is assumed that all bus routes travelling through the corridor before the busway was introduced took a half hour to pass through the corridor. It means that at any given moment, with the hourly frequency of four, two buses of route A would be visible operating on the BRT corridor; the moment the bus ahead leaves the segment (after half an hour), another bus would get in at the beginning (being thirty minutes behind).

Before the BRT system is implemented, all bus routes are operating "outside" the BRT. Therefore, during one hour we would have seen *Aggregate Travel Time OUTSIDE the BRT*, operating along a planned BRT corridor, of two hours for this route. That is simply four bus trips per hour, each taking half an hour.

If this route is included inside the BRT infrastructure where average speed (without congestion that is the aim) is 25 kph, it would take only 12.5 minutes to cross the corridor. In this case, the Aggregate Travel Time INSIDE the BRT is 12.5 times 4 or 50 minutes. This is a net improvement over the no-build scenario of one hour and ten bus minutes. Another way to think of this is that after only 12.5 minutes the first bus will exit the BRT, but the next bus would not appear on the segment for another 2.5 minutes, so if we look at the corridor once a minute over an hour, only 50 times in 60 times will we see a bus riding in the segment. In this situation the *Aggregate Travel Time INSIDE the BRT* added 50 minutes for this route (or 5/6 of hour or 0.833 hour).

For each of the examples, the total dwell time of each bus (Td) at a station inside the busway, assuming boarding and alighting through all doors will be a function of the fixed dwell time (T0), also known as dead time or the time the bus takes to pull up to the station, open and close its doors, and pull away, and the average boarding time per customer for buses with the given configuration (Tb) multiplied by the number of boarding customers and the average alighting time per customer for buses with the same configuration (Ta) times the number of alighting customers, or:

Eq. 6.22

$$T_d = T_0 + T_b + T_a$$

Or

$$Td = T_0 + t_b * P_b + t_a * P_a$$

Where:

- T_d: Total dwell time;
- T_0: Fixed dwell time (or "dead time");
- T_b: Total boarding time per vehicle ((given by $tb * Pb$);
- t_b: Boarding time per customer;
- P_b: Number of boarding customers;
- T_a: Total alighting time per vehicle (given by $ta * Pa$);
- t_a: Alighting time per customer;
- P_a: Number of alighting customers.

As discussed in Chapter 7: Capacity and Speed, boarding and alighting times per customers are a function of bus configuration and bus station interface (number and width of doors, at-level boarding or boarding via several steps, internal or external fare collection, position of turnstiles, etc.) and bus occupancy at the station. A linear proxy, i.e., using average customers per second of surveyed boarding and alighting times under conditions similar to those being designed is a more accurate way of estimating dwell time per station than using a flat average dwell time per station, so long as the busway is not beginning to become saturated (saturation below 0.4). Avoiding saturation is the design goal of the examples. Outside the BRT infrastructure, it is assumed that buses' speeds are the current commercial speed, which already include dwell times at station stops.

6.5.3.1 Scenario I: All Routes Are Similar

In this scenario, all vehicles, routes, and stations inside the BRT infrastructure have the same operational characteristics. In other words, they have roughly the same number of customers getting on and off at each stop; have the same number of doors; have the same frequency; use the same vehicle type; have floors level with the vehicle platform; and hence have the same dwell time per customer. As a result, one should not care which routes are included or excluded, one should only care about the number of routes one includes. In this simplified scenario, since all of the routes have the same dwell time per customer, and the same number of customers benefitting from the busway, there is no need to rank the bus routes. Given this uniform demand, all stations will become saturated equally. Vehicles operating inside the BRT infrastructure will become congested if there are too many vehicles using the bus lane. These assumptions allow for busway congestion to be isolated as the only factor that would cause a variance in total travel time when all else is constant.

In this scenario, given that all bus routes have the same demand and vehicle size, it is assumed that all routes have the same frequency. In later examples the frequency will vary by route. All routes are also assumed to have the same dwell time, since they have the same demand and vehicle size. It is assumed that the total dwell time Td is the same for all vehicle routes, because both the fixed and variable dwell times are the same for all vehicles:

L_{corridor}: Corridor length = 5 km;

V_{outside}: Velocity outside the busway = 10 km/h;

V_{inside}:Velocity inside BRT at free-flow speed = 25 km/h;

N_{stations} = 10;

F_{total}: Total frequency of all services = 200 vehicles/h.

T_d: Dwell time per vehicle at each station = 18 seconds = 0.005 h

T_b: Time per customer boarding = 3 seconds;

T_a: Time per customer alighting = 2 seconds;

T_0: Fixed dwell time per vehicle = 12 seconds.

To determine the optimal number of vehicle routes to include in a BRT corridor, as many buses as possible should be brought into the BRT corridor until the point where time-savings benefit for the last bus added to the corridor is less than the congestion delay it causes to the remaining vehicles in the busway.

By measuring the total vehicle travel time over the course of one hour for all vehicles on a single corridor (ATT_{total}) both inside (ATT_{inside}) and outside (ATT_{outside}) the BRT infrastructure, it is clear that it is often beneficial to leave some routes out of the BRT corridor. The ATT both inside and outside the BRT infrastructure will be the number of buses per hour (F_{inside} and Foutside) multiplied by the travel time per bus (TT_{inside} and TT_{outside} respectively). In all cases one will assume that the frequency outside the BRT corridor does not affect the travel time outside the corridor. Therefore, all of the total travel times (ATT) are expressed as a function of the frequency inside the busway (F_{inside}).

Eq. 6.23

$$ATT_{\text{total}} = ATT_{\text{outside}} + ATT_{\text{inside}}$$

Or:

$$ATT_{\text{total}} = TT_{\text{inside}} * F_{\text{inside}} + TT_{\text{outside}} * F_{\text{outside}}$$

Where:

- ATT_{total}:Total vehicle travel time over the course of one hour for all vehicles on a single corridor;

- ATT_{outside}: Total vehicle travel time over the course of one hour for all vehicles on a single corridor outside of the BRT infrastructure ($ATT_{\text{outside}} = TT_{\text{outside}} * F_{\text{outside}}$);
- ATT_{inside}: Total vehicle travel time over the course of one hour for all vehicles on a single corridor inside of the BRT infrastructure($ATT_{\text{inside}} = TT_{\text{outside}} * F_{\text{outside}}$);
- TT_{inside}: Travel time per bus inside the busway;
- F_{inside}: Number of buses per hour inside the busway;
- TT_{outside} : Travel time per bus outside the busway;
- F_{outside} : Number of buses per hour outside the busway.

 Because TT_{outside} is fixed, one can easily calculate it as:
 Eq. 6.24a

$$TT_{\text{outside}} = \frac{L_{\text{corridor}}}{V_{\text{outside}}}$$

Where:

- TT_{outside}: Travel time per bus outside the busway;
- L_{corridor}: Length of the corridor;
- V_{outside}: Velocity outside the busway.

 So, using the values defined above for the corridor:

$$TT_{\text{outside}} = \frac{5\text{km}}{10\text{km/hr}} * 1\text{hr} = \frac{5\text{hr}}{10} = 0.5\text{hours}$$

TT_{outside} will remain 0.5 hours (30 minutes) per bus no matter how many buses are operating outside the corridor.

Travel time inside the BRT infrastructure (TT_{inside}), however, varies in this simplified example as a simple function of frequency. That is, with each new vehicle added to the busway, a slight congestion is introduced and the total travel time inside increases.

Travel time for a bus within a busway is the sum of the time spent:

1. In motion (free running time);
2. At intersections;
3. At stations;
4. In congestion.

In most conditions, the stations become saturated long before the traffic signal or the busway itself is saturated, so generally one should assume that the bottleneck is the station and not the intersections or the busway. Even at quite low frequencies, it often occurs that one vehicle is unable to approach the station, because another vehicle is already occupying that location, and these delays can rapidly become very significant.

Design techniques for reducing dwell time at stations are discussed extensively in Chapter 7: Capacity and Speed. In this chapter, these design issues are not discussed; instead, one should assume that the best possible design has been used, so the boarding and alighting time at stations per passenger ($T_b + T_a$) is already fixed by these design characteristics. In this scenario, the only factor that varies is ("In congestion") and it varies based only on vehicle queuing at stations (T_q). Scenario II will consider variations in dwell times, but for now one should assume a fixed dwell time for all vehicles on the corridor.

So in this scenario the first three aspects of travel time in the busway are fixed and constitute the base speed ($_{\text{Vinside-no-congestion}}$) and travel time for any vehicle in the busway before the busway begins to become congested. Further, if only one vehicle is in the busway, there is no possibility of congestion, and that vehicle will experience this base travel time as:

Eq. 6.24b

$$TT_{\text{inside-no-congestion}} = \frac{L_{\text{corridor}}}{\text{Vinside-no-congestion}}$$

Where:

- $TT_{\text{inside-no-congestion}}$: Travel time per bus inside the busway without delays at stations;
- L_{corridor}: Length of the corridor;
- $V_{\text{inside-no-congestion}}$: Velocity inside the busway, when there is no congestion delay at stations.

If one wants to know the speed inside the busway without any vehicle congestion, one should calculate the initial value of TT_{inside}, with only one vehicle in the corridor:

$$TT_{\text{inside-no-congestion}} = \frac{5\text{km}}{25\text{km/hr}} = \frac{5\text{hr}}{25} = 0.2\text{hours}$$

Usually, when performing this type of analysis, if one is planning to build a Silver or Gold Standard BRT, one would normally assume that the average speed of the BRT corridor before saturation would be around 20 kph in a dense urban area or downtown and around 25 on a major arterial, based on empirical observation of BRTs in different conditions. As soon as any additional vehicles are added to the busway, some possibility of queuing emerges. One should measure queuing delay on a per-station basis; however, in this scenario, it can be assumed that the queuing delay (T_q) will be the same at every station. One must thus expand Equation 6.17b to all vehicles as:

Eq. 6.24c

$$TT_{\text{inside}} = \frac{L_{\text{corridor}}}{V_{\text{inside-no-congestion}}} + T_q * N_{\text{stations}}$$

Where:

- TT_{inside}: Travel time per bus inside the busway;
- L_{corridor}: Length of the corridor;
- $V_{\text{inside-no-congestion}}$: Velocity inside the busway without delay at stations;
- T_q:Delay for a single vehicle at a single station due to queuing;
- N_{stations}: Number of stations.

Because queuing in a busway (T_q) is generally a direct result of station saturation, one should begin with the formula for station saturation. Detailed methodologies for calculating station saturation under different scenarios are provided in Chapter 7: Capacity and Speed, but for now one should use the basic consideration for station saturation under these extremely simplified conditions.

In this example, saturation at each station is expressed by the equation below.

Eq. 6.25

$$x = T_d * F_{\text{inside}}$$

Where:

- x: Saturation at each station for a specific frequency inside the busway;
- T_d: Dwell time per bus;
- F_{inside}: Number of buses per hour inside the busway.

If one includes 80 vehicles in the BRT corridor, and one knows the dwell time is 18 seconds (0.005 hours) per bus, station saturation, x, will be 40 percent.

$$x = 0.005 * 80 = 0.4$$

In this case, "x" is the average percentage of time that the station is occupied by vehicles loading and unloading, but it can be thought of as the probability that a vehicle approaching a station will find the station occupied. In our example, if a person (or a BRT vehicle) about whom we know nothing else arrives at the station, he/she/it has a 40 percent chance of finding a station with BRT vehicles using it and a 60 percent chance that no buses are there at that exact moment.

Let us now focus our attention on this 40 percent of time that the station is occupied, the probability of a BRT vehicle arriving at the station when another vehicle is already there is still 40 percent of the time the station is occupied, if nothing else is known. So the chance of a vehicle being a second vehicle queueing at the station is 40 percent of 40 percent (or 16 percent). This means that 16 percent of the time a bus will have to wait until the docking bay is cleared by at least one bus. Thus, 40 percent of these 16 percent, or 6.4 percent of the wait, will be for two or more buses to clear the station and so on.

Station saturation, as described above, begins to result in delay when vehicles are forced to queue up to the station waiting to dock. The probability that a vehicle will find the station occupied is approximately given by x, and the chance that the next vehicle will also face a queue is x2, and the vehicle after that would face a probability of x3. The average queue in such a situation would be given by:

Eq. 6.26

$$\text{Average Queue Size} = \frac{x^2}{(1-x)}$$

Where:

- $AverageQueueSize$: Number of vehicles on average in queue;
- x: Probability a vehicle will find the station occupied.

If arrivals and departures are random, the average waiting time in queue per vehicle would be given by:

Eq. 6.27:

$$\text{Average Waiting time} = \frac{x^2}{(1-x)} * \frac{1}{F_{\text{inside}}}$$

Where

- Average Queue Size: Number of vehicles on average in queue;
- x: Probability a vehicle will find the station occupied;
- F_{inside}: Number of buses per hour inside the busway.

This is a derivation of what is known as Little's Law: If the average waiting time in a queue is two hours and customers arrive at a rate of three per hour (Frequency) then, on average, there are six customers in the queue, or:

Eq. 6.28:

$$\text{Average Queue Size} = \text{Average Waiting Time} * \text{Frequency of Arrivals}$$

Where:

- Average Queue Size: Number of vehicles on average in queue;
- Average Waiting Time: Average waiting time in a queue;
- Frequency of Arrivals: Number of customers arriving per a given amount of time.

In our example, the average queue is known as 0.2667 vehicles (= 4/15 vehicle) and there are an average of 1.333 vehicles arriving per minute (80 vehicles per hour = 4/3 per minute), so in average they must be waiting 1/5 of a minute (= 12 seconds).

Considering this distribution of arrivals and departures, theoretical queuing time per bus at each station would be given by:

Eq. 6.29

$$T_q = \frac{0.5(Irr_{\text{arrival}} + Irr_{\text{departure}}) * x^2}{1-x} \frac{1}{F_{\text{inside}}}$$

Where:

- T_q: One vehicle queueing time at each station;
- x: Saturation of the station;
- F_{inside}: Number of buses per hour inside the busway;
- Irr_{arrival}: Irregularity of arrivals ($Irr_{\text{arrival}} = \frac{\text{Variance}_{\text{arrivals'intervals}}}{\text{Mean}^2_{\text{arrivals'intervals}}}$);
- $Irr_{\text{departure}}$: Irregularity of departures ($Irr_{\text{departure}} = \frac{\text{Variance}_{\text{departures'intervals}}}{\text{Mean}^2_{\text{arrivals'intervals}}}$).

The mean of arrival and departure intervals is the headway and the variance would be similar to boarding and alighting variance if there were no traffic lights and starting schedules were followed to the letter. Equation 6.20 is the particular case where irregularities for arrival and departure are random ($Irr_{\text{arrivals}} = Irr_{\text{departures}} = 1$).

Empirical observation shows that using the coefficient of 0.7 mimics the series of probabilities in high-frequency (above 80 vehicles per hour) busways in urban conditions. In fact, empirical observation of busways with full BRT characteristics do tend to saturate at around 80 vehicles per hour, and for a busway 0.4 is considered the beginning point of station saturation, so service planners will avoid designing services with frequencies where x > 0.4. In any case, queuing time per vehicle can be expressed (as a portion of an hour by):

Eq. 6.30a

$$T_q = \frac{0.7 * x^2}{1-x} \frac{1}{F_{\text{inside}}}$$

Where:

- T_q: One vehicle queueing time at each station;
- x: Saturation of the station;
- F_{inside}: Number of buses per hour inside the busway;

Since empirical observation shows that this phenomenon is just as well captured by the much simpler formula above, it is not necessary to use the theoretical formula. It may also be interesting to note that this equation can also be written as a function of dwell time and saturation, or only as a function of dwell time and frequency inside the busway, as the three are related by Equation 6.25:

Eq. 6.25

$$x = T_d * F_{\text{inside}} \Leftrightarrow Td = \frac{x}{F_{\text{inside}}}$$

Where:

- T_d: Dwell time per bus;
- x: Saturation of the station;
- F_{inside}: Number of buses per hour inside the busway;

Eq. 6.30b

$$T_q = \frac{0.7 * x^2}{1-x} \frac{1}{F_{\text{inside}}} = \frac{0.7 * x}{1-x} \frac{x}{F_{\text{inside}}} = \frac{0.7 * x}{1-x} * T_d$$

$$T_q = \frac{0.7 * (T_d * F_{\text{inside}})^2}{1 - (T_d * F_{\text{inside}})} \frac{1}{F_{\text{inside}}} = \frac{0.7 * T_d^2 * F_{\text{inside}}}{1 - (T_d * F_{\text{inside}})}$$

Where:

- T_q: One vehicle queueing time at each station;
- x: Saturation of the station;
- F_{inside}: Number of buses per hour inside the busway;

Going back to Equation 6.24c

Travel time inside the corridor can be expressed as function of the frequency inside the corridor:

Eq. 6.24c

$TT_{\text{inside}} = \frac{L_{\text{corridor}}}{V_{\text{inside-no-congestion}}} + T_q * N_{\text{stations}}$ $TT_{\text{inside}} = \frac{L_{\text{corridor}}}{V_{\text{inside-no-congestion}}} + \frac{0.7*T_d^2*F_{\text{inside}}}{1-(T_d*F_{\text{inside}})} * N_{\text{stations}}$

Where:

- TT_{inside}: Travel time per bus inside the busway;
- L_{corridor}: Length of the corridor;
- $V_{\text{inside-no-congestion}}$: Velocity inside the busway if there is no queueing at stations;
- T_d: Dwell time per bus at each station (equal for all buses in all stations in this scenario);
- F_{inside}: Number of buses per hour inside the busway;
- N_{stations}: Number of stations along the busway.

Because it is assumed in this case that all stations will saturate equally (because the boarding and alighting customer volumes and frequencies are assumed to be constant), one can simply add the free-flow speed ($\frac{L_{\text{corridor}}}{V_{\text{inside-no-congestion}}}$) to the queue delay at each station and multiply it by the number of stations (N_{stations}). Later, it will be necessary to calculate the queue delay at each station and sum it across stations.

On the BRT corridor, if our sample frequency of 80 vehicles inside the corridor is tried, the travel time per vehicle inside the corridor is:

$$TT_{\text{inside}}(F_{\text{inside}} = 80) = 0.2 + (\frac{\frac{0.7*0.4^2}{(1-0.4)}}{80} * 10) = 0.2233\text{hours}$$

By fixing the other values in Equation 6.17 as proposed for our scenario ($L_{\text{corridor}} = 5\text{km}$, $V_{\text{inside-no-congestion}} = 25\text{km/hour}$, $T_d = 18\text{seconds}$ (or 0.005 hour) and $N_{\text{station}} = 10$), one can calculate the travel time per bus inside the corridor (TT_{inside} shown in the graphic on Figure 6.35), as a function of the bus frequency inside the corridor, up to the maximum $F_{\text{total}} = 200$. By considering that $F_{\text{outside}} = 200 - F_{\text{inside}}$ and using equations 6.16 and 6.17a, one may also calculate total aggregate time as a function of frequency inside as shown in Table 6.18.

On the figure, the orange line, TT_{outside}, remains constant at 0.5 hours, as described earlier, regardless of the frequency of buses outside the corridor. The blue line, however, increases as a function of bus frequency, from a minimum of 0.2 hours to a maximum reaching toward infinity (i.e., the vehicles are not moving at all) if all 200 vehicles are included in the BRT corridor.

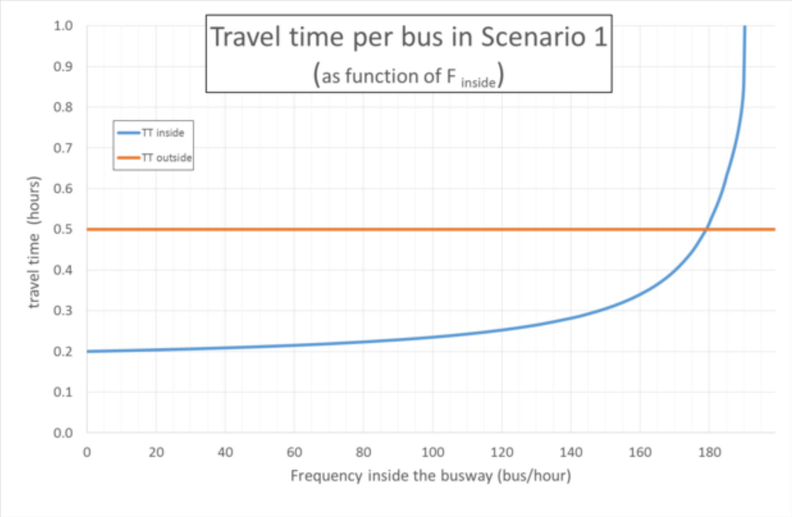

Figure 6.35. Scenario I travel time inside the BRT corridor (blue line) and outside the BRT corridor (orange line) as a function of bus frequency brought inside the corridor. *Elebeta.*

Figure 6.35 shows that the travel time within the bus lane reaches the travel time outside of the bus lane at approximately $F_{\text{inside}} = 179$. Thus, if 179 vehicles were included inside the corridor, there would be no benefit at all. Above 179 vehicles inside the busway, the travel time would be slower than the mixed traffic.

One should keep in mind that the travel times will affect all vehicles and that it is not actually the *per bus* travel times we are interested in but rather the aggregate travel times inside and outside the corridor (ATT_{inside} and ATT_{outside}). More precisely, we are most interested in the aggregate travel times *for customers* inside and outside the corridor. However, in this simplified case, where customer volumes are the same from one bus to another, we leave customer volumes out of the equation with no consequence.

Aggregate travel times give the full picture of the overall benefit to all customers inside and outside the corridor each time a vehicle is added to the corridor. By optimizing the aggregate travel times inside and outside of the corridor so that the total aggregate travel time is minimized, we find the best F_{inside} for the corridor.

Continuing the example, one can now calculate the aggregate travel times both inside and outside the corridor, assuming that one will include 179 vehicles in the BRT corridor. The average travel time per vehicle when there are 179 vehicles in the corridor is 0.5 hours. So using Equation 6.23, one should multiply the per vehicle travel time inside the BRT corridor at a frequency of 179 vehicles by 179, to get the aggregate travel time for 178 vehicles inside the corridor. That is:

$$ATT_{\text{inside}}(F_{\text{inside}} = 179) = 0.5\text{hours} * 179 = 89.5\text{hours}$$

If one includes 179 vehicles inside the BRT corridor, then 21 are left out. The travel time per bus outside of the BRT corridor (TT_{outside}) is fixed at 0.5 hours (again, equal to TT_{inside} only in this case). So one should multiply the per bus travel time outside the BRT corridor by 21 to get the aggregate travel time for 21 buses outside the corridor. That is:

$$ATT_{\text{outside}}(F_{\text{inside}} = 179) = 0.5\text{hours} * 21 = 10.5\text{hours}$$

Thus,

$$ATT_{\text{total}}(F_{\text{inside}} = 179) = 89.5 + 10.5 = 100\text{hours}$$

Exploring visually the properties of Equation 6.16, Figure 6.36 shows the aggregate travel times both inside and outside the BRT corridor when 179 vehicles are included inside the corridor ($F_{\text{inside}} = 178$). Aggregate travel times are indicated by the blue (TT_{inside}) and orange (TT_{outside}) shaded areas. Note that the shaded areas are rectangular in shape. This is because every bus in either category (F_{inside} or F_{outside}) experiences a travel time equal to every other bus in its category.

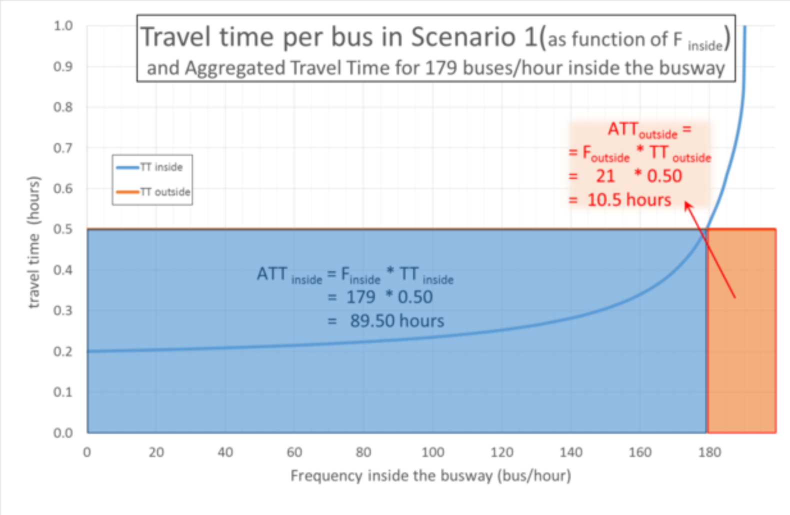

Figure 6.36. Scenario I aggregated travel times, obtained by multiplying by the fixed travel time for all buses (0.5) by the number of buses inside the busway (179, represented by the blue shading) and outside the busway (21, represented by the orange shading), one should get $ATT_{\text{inside}}(F_{\text{inside}} = 179) = 89.5$hours and $ATT_{\text{outside}}(F_{\text{inside}} = 179) = 10.5$hours, respectively. *Elebeta.*

One can already tell that $F_{\text{inside}} = 179$ is not the optimal frequency for this corridor, since one knows that total area (an ATT_{total} of 100 hours) is not the lowest aggregate travel time that is achievable in this example and can be diminished. Figure 6.37 shows an example of a reduced area for $F_{\text{inside}} = 150$ totaling 70.75 hours, i.e., $ATT_{\text{total}}(F_{\text{inside}} = 150) = 70.75$hours.

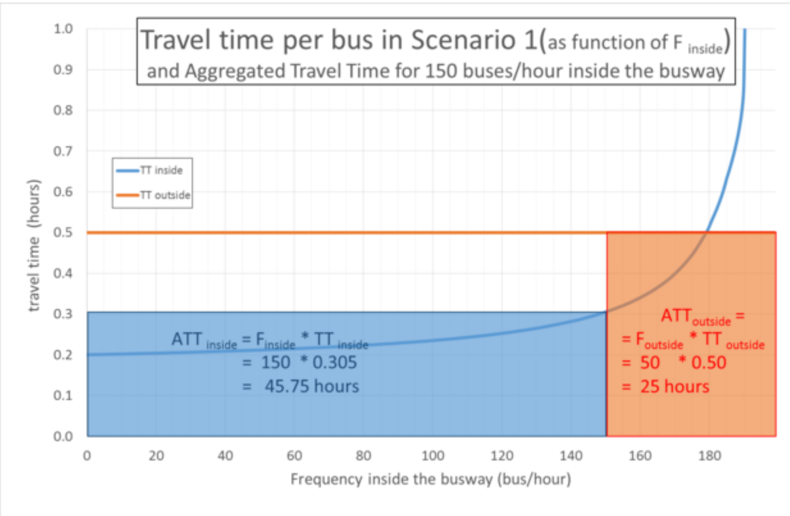

Figure 6.37. Scenario I aggregated travel times, obtained by multiplying by the fixed travel time for all buses inside the busway (0.305 hour) by the number of buses inside the busway (150, represented by the blue shading) added with the travel time outside the busway (0.50) multiplied by number of buses outside (50, represented by the orange shading), one should get $ATT_{\text{Tinside}}(F_{\text{inside}} = 150) = 45.75$hours and $ATT_{\text{outside}}(F_{\text{outside}} = 179) = 25$hours, respectively. *Elebeta.*

We determine the lowest aggregate travel time achievable by evaluating the time savings and time losses of shifting an additional bus route (or the bus frequencies of that route) onto the corridor. Each time a vehicle is added to the corridor, some time savings are realized to the customers on the vehicle that has been shifted, due to the higher speed of the bus lane. At the same time, delay is created for all the customers on vehicles already in the bus lane, which now suffer some new (marginal) congestion due to a larger number of vehicles travelling there.

In order to determine the savings, one should subtract the travel time for one vehicle inside the bus lane from the travel time for one bus outside the bus lane. When calculating the travel time per vehicle inside the bus lane, one does so based on congestion incurred by the *new* frequency (i.e., $F_{\text{inside}} + 1$), since the new travel time caused by that vehicle is ultimately the travel time that vehicle will experience. One therefore defines the benefit of adding one vehicle to the corridor as:

Eq. 6.31

$$ATT_{\text{savings}}(1) = TT_{\text{outside}} - TT_{\text{inside-after-shift}}$$

$$ATT_{\text{savings}}(1) = TT_{\text{outside}} - TT_{\text{inside}}(F_{\text{inside}} = F_{\text{inside-before}} + 1)$$

Where:

- $ATT_{\text{savings}}(1)$: Benefit of adding one vehicle to the busway;
- TT_{outside}: Travel time outside the busway;
- $TT_{\text{inside-after-shift}} = TT_{\text{inside}}(F_{\text{inside}} = F_{\text{inside-before}} + 1)$: Travel time per bus inside the busway based on congestion incurred by the new frequency of adding one vehicle inside the busway.

$ATT_{\text{savings}}(1)$ indicates that one vehicle is added to the corridor. Were one to be complete, one would multiply this benefit by the number of customers on the vehicle shifted into the bus lane. Again, since customer volumes are the same from one vehicle to another, this can be left out for now.

If expanded to shifting multiple vehicles (N_{shift}) to the corridor, one must calculate TT_{inside} based on the old frequency plus the number of new vehicles (i.e., $F_{\text{inside}} + N_{\text{shift}}$). Additionally, the benefit is realized not just by the customers on one vehicle but by the customers on all the vehicles shifted to the corridor. So the entire savings calculation must be multiplied by the number of vehicles added (and by the number of customers shifted in later scenarios).

Eq. 6.32

$$ATT_{\text{savings}}(N_{\text{shift}}) = TT_{\text{outside}} - TT_{\text{inside-after-shift}} * N_{\text{shift}}$$

$$ATT_{\text{savings}}(N_{\text{shift}}) = TT_{\text{outside}} - TT_{\text{inside}}(F_{\text{inside}} = F_{\text{inside-before}} + N_{\text{shift}}) * N_{\text{shift}}$$

Where:

- $ATT_{\text{saving}}(N_{\text{shift}})$: Aggregated travel time savings of adding Nshift vehicles to the busway;
- TT_{outside}:Travel time per bus outside the busway (it does not change with frequency);
- $TT_{\text{inside-after-shift}}(F_{\text{inside}} = F_{\text{inside-before}} + N_{\text{shift}})$: Travel time per bus inside the busway based on the old frequency plus the number of new vehicles;
- N_{shift} : Number of shifting vehicles inside the busway.

The time losses of shifting one vehicle onto the busway are felt by all the customers on the other vehicles already travelling within the BRT infrastructure, since every new vehicle adds some congestion to the busway. This is calculated by subtracting the travel time before the shift from the travel time after the shift, as this is the marginal cost to each previously existing vehicle of shifting new vehicles. Next, one should multiply this by the total number of previously existing vehicles to get the full cost of adding new vehicles. The cost is defined as:

Eq. 6.33

$$ATT_{\text{losses}}(N_{\text{shift}}) = (TT_{\text{inside-after-shift}} - TT_{\text{inside-before-shift}}) * F_{\text{inside-before-shift}}$$

$$ATT_{\text{losses}}(N_{\text{shift}}) = (TT_{\text{inside}}(F_{\text{inside}} = F_{\text{inside-after-shift}}) - TT_{\text{inside}}(F_{\text{inside}} = F_{\text{inside-before-shift}})) * F_{\text{inside-before-shift}}$$

$ATT_{\text{losses}}(N_{\text{shift}}) = (TT_{\text{inside}}(F_{\text{inside}} = F_{\text{inside-before-shift}} + N_{\text{shift}}) - TT_{\text{inside}}(F_{\text{inside}} = F_{\text{inside-before-shift}})) * F_{\text{inside-before-shift}}$

Where:

- $ATT_{\text{losses}}(N_{\text{shift}})$: Aggregated time losses by moving N_{shift} vehicles onto the busway;
- $TT_{\text{inside-in-situation}}$: Travel time per bus inside the busway as a function of the frequency inside the busway in given situation;
- $TT_{\text{inside}}(F_{\text{inside}} = K)$: Travel time per bus inside the busway based on a frequency of K vehicles inside the busway;
- $F_{\text{inside-before-shift}}$: Number of buses per hour inside the busway before moving vehicles;
- $F_{\text{inside-after-shift}}$: Number of buses per hour inside the busway after moving vehicles.

Continuing the example, suppose the decision was initially made to include 80 vehicles in the corridor, and now one wants to know whether it would be better to include 90. So 10 vehicles are being shifted onto the corridor.

The aggregated time savings can be calculated using Equation 6.32:

$$ATT_{\text{savings}}(10) = TT_{\text{outside}} - TT_{\text{inside}}(90) * 10$$

$$TT_{\text{outside}} = 0.5$$

$$TT_{\text{inside}}(90) = \frac{L_{\text{corridor}}}{V_{\text{inside-no-congestion}}} + \left(\frac{0.7 * T_d^2 * F_{\text{inside}}}{1 - (T_d * F_{\text{inside}})} * N_{\text{stations}}\right) = 0.2286$$

So, $ATT_{\text{savings}}(10) = (0.5 - 0.2286) * 10 = 2.714$hours

The aggregated travel time losses can be calculated using Equation 6.25:

$$ATT_{\text{losses}}(10) = TT_{\text{inside}}(90) - TT_{\text{inside}}(80) * 80$$

above, $TTinside(90) = 0.2286$

And from the first moment of this example (saturation):

$T_{\text{Tinside}}(80) = 0.2233$.

So, $ATT_{\text{losses10}} = 0.2286 - 0.2233 * 80 = 0.424$hours.

On the corridor, the benefits of increasing the number of vehicles inside the busway from 80 to 90 outweigh the costs by a total of $2.714 - 0.424 = 2.29$hours. The 10 buses should therefore be shifted in.

In Figure 6.38, the blue box shows the ATT_{inside} for 80 vehicles and the light orange box shows the ATT_{outside} for the remaining 120 buses outside the corridor. If another 10 vehicles are added to the corridor, the blue box expands to 90, and the orange box shrinks to 110, with the purple area being transferred from one to the other. The benefit of including the 10 new vehicles in the corridor is shown by the green rectangle where the aggregate travel time savings is realized. This benefit is realized for the customers on the 10 new vehicles that can now use the bus lane.

Meanwhile, the “cost” of including 10 new vehicles in the corridor is shown in the yellow sliver between 0.2233 and 0.2286, where the 80 vehicles that previously travelled the corridor now need to accommodate an additional 10 vehicles, slowing down the travel time for all the customers on those buses. The cost is therefore on the customers on the 80 vehicles now suffering the new congestion.

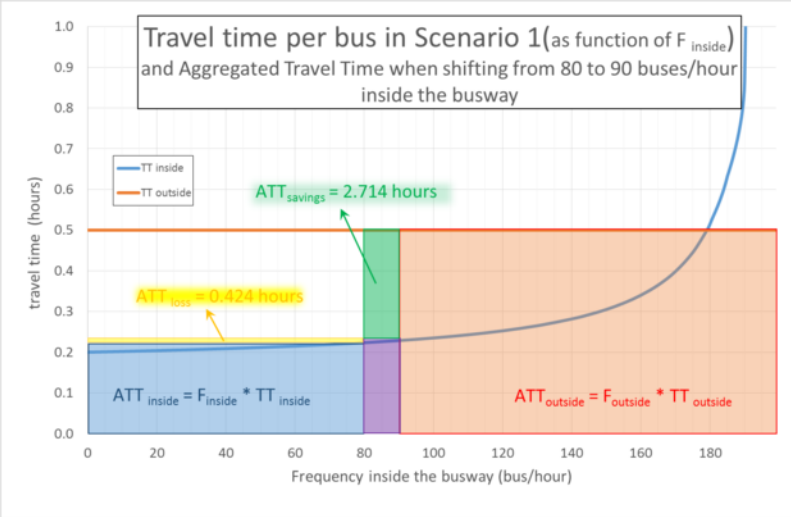

Figure 6.38. The losses to the buses inside the busway, ATT_{loss} as represented by the light yellow rectangle, of shifting 10 buses into the corridor, amount to 0.424 hours. The aggregated time savings of those 10 buses, ATT_{savings} as represented by the green rectangle, amounts to 2.714 hours. Since the time savings are greater for those 10 buses than the losses to other buses already inside the corridor, it is still beneficial to shift in more buses. *Elebeta.*

To minimize aggregated travel time, the goal is to maximize the white area under the orange line for any given frequency inside the BRT in Figure 6.38, which in the shifting example includes the green area and loses the yellow area. So long as the area of the green rectangle (the time gains by customers on buses outside the BRT, or ATT_{savings}) is greater than the yellow rectangle (the time lost to the customers on buses inside the BRT due to congestion, or ATT_{loss}), more buses should be shifted in. For lower vehicle frequencies, the benefit of adding more vehicles to the BRT lane is even larger and the losses smaller. The benefit is larger than the cost because the new vehicles are going faster inside the BRT, and they are not yet adding much congestion to the bus lane (i.e., the curve is flatter at lower frequencies). Conversely, at higher frequencies, the benefit drops, and the costs increase. An optimal frequency is reached when the benefits equal the marginal costs of the last vehicle added, or where the area of the white rectangle is maximized.

The simplest way to make this determination is to include the formulas above in a table and simply calculate ATT_{total} at each frequency. One can do this in increments of 5. The resulting Table 6.18 is as follows:

Table 6.18. Optimal Frequency inside a BRT Corridor

F inside (bus/hour)	F outside (bus/hour)	TT inside (hour/bus)	TT outside (hour/bus)	ATT inside (hour)	ATT outside (hours)	ATT total (hours)
0	200	0.20000	0.5	0.00	100.00	**100.00**
10	190	0.20184	0.5	2.02	95.00	**97.02**
20	180	0.20389	0.5	4.08	90.00	**94.08**
30	170	0.20618	0.5	6.19	85.00	**91.19**
40	160	0.20875	0.5	8.35	80.00	**88.35**
50	150	0.21167	0.5	10.58	75.00	**85.58**
60	140	0.21500	0.5	12.90	70.00	**82.90**
70	130	0.21885	0.5	15.32	65.00	**80.32**
80	120	0.22333	0.5	17.87	60.00	**77.87**
90	110	0.22864	0.5	20.58	55.00	**75.58**

100	100	0.23500	0.5	23.50	50.00	**73.50**
110	90	0.24278	0.5	26.71	45.00	**71.71**
120	80	0.25250	0.5	30.30	40.00	**70.30**
130	70	0.26500	0.5	34.45	35.00	**69.45**
135	65	0.27269	0.5	36.81	32.50	**69.31**
140	60	0.28167	0.5	39.43	30.00	**69.43**
145	55	0.29227	0.5	42.38	27.50	**69.88**
150	50	0.30500	0.5	45.75	25.00	**70.75**
155	45	0.32056	0.5	49.69	22.50	**72.19**
160	40	0.34000	0.5	54.40	20.00	**74.40**
165	35	0.36500	0.5	60.23	17.50	**77.73**
170	30	0.39833	0.5	67.72	15.00	**82.72**
175	25	0.44500	0.5	77.88	12.50	**90.38**
179	21	0.49833	0.5	89.20	10.50	**99.70**
180	20	0.51500	0.5	92.70	10.00	**102.70**
185	15	0.63167	0.5	116.86	7.50	**124.36**
190	10	0.86500	0.5	164.35	5.00	**169.35**
199	1	7.16500	0.5	1425.84	0.50	**1426.34**

Table 6.18 shows that the ATT_{total} reaches its minimum somewhere around $F_{\text{inside}} = 135$. At that point, $ATT_{\text{total}} = 69.3$. It is worth noting also that at $F_{\text{inside}} = 199$, ATT_{inside} suddenly skyrockets. This is because 200 is where saturation, x, reaches 1. At $F_{\text{inside}} = 195$,$x = 0.975$ and already ATT_{inside} is increasing more dramatically. But in the shift of the last five vehicles, the functioning of the busway breaks down, and at 200, it is saturated.

One can also plot this in order to see graphically the point of the minimum aggregate travel time.

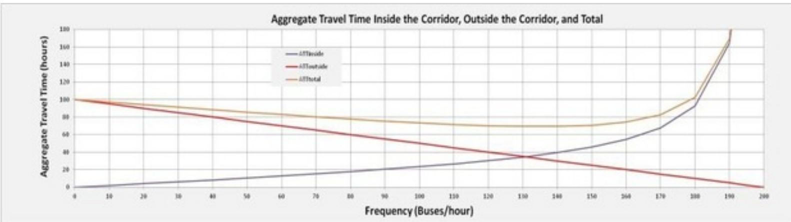

Figure 6.39. Plot of $ATT_textinside$, $ATT_textoutside$, and ATT_{Total} for each new bus added to the corridor. The minimum aggregate travel time is reached where ATT_{Total} is the lowest, i.e., between 130 and 140 buses per hour. *Elebeta.*

So the approximate optimal frequency inside the busway is 135. However, one does not know whether it is precisely 135. At $F_{\text{inside}} = 130$, $ATT_textinside = 69.5$ and at $F_{\text{inside}} = 140$, $ATT_{\text{inside}} = 69.4$. It is possible that the minimum ATT_{inside} falls somewhere between $F_{\text{inside}} = 130$ and $F_{\text{inside}} = 140$. One should look more closely, and with a greater degree of precision, at ATT_{inside} for each of the values between $F_{\text{inside}}(130)$ and $F_{\text{inside}}(140)$.

Table 6.19. Optimal Frequency Inside the Busway

F inside (bus/hour)	F outside (bus/hour)	TT inside (hour/bus)	TT outside (hour/bus)	ATT inside (hour)	ATT outside (hours)	ATT total (hours)

130	70	0.26500	0.5	34.45	35.00	**69.45**
131	69	0.26645	0.5	34.90	34.50	**69.40**
132	68	0.26794	0.5	35.37	34.00	**69.37**
133	67	0.26948	0.5	35.84	33.50	**69.34**
134	66	0.27106	0.5	36.32	33.00	**69.32**
135	65	0.27269	0.5	36.81	32.50	**69.31**
136	64	0.27438	0.5	37.32	32.00	**69.32**
137	63	0.27611	0.5	37.83	31.50	**69.33**
138	62	0.27790	0.5	38.35	31.00	**69.35**
139	61	0.27975	0.5	38.89	30.50	**69.39**
140	60	0.28167	0.5	39.43	30.00	**69.43**

Table 6.19 confirms that the minimum aggregate travel time (69.31) is indeed at F_{inside} = 135.

One can also zoom in to the graph from above to see that more clearly.

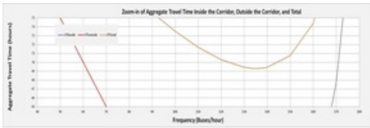

Figure 6.40. Zoom-in of Figure 6.39 above to confirm minimum ATTTotal at 130 to 140 buses per hour. Image *Elebeta*.

Therefore, as a first pass, if bus routes have similar levels of demand and fleet characteristics, services should be selected so that routes with a total frequency of about 135 vehicles per hour should be included in the BRT corridor, and routes with the remaining 55 vehicles per hour should be left to operate in mixed traffic.

6.5.3.2 Scenario II: Dwell Times and Demand Vary from Route to Route, and All Stations Are Similar

In this example, customer volumes, dwell times, vehicle type, and route frequencies all vary. In this case, maximizing total benefits will require deciding which bus routes to include in the BRT system and which routes to exclude. To do this, first calculate average passenger volumes and dwell times by route so that the variation is between routes, rather than between buses. For this example we will assume that stations become saturated equally. Although this seems a too hypothetical situation, a central BRT section with high renovation factor could look somewhat like this and still keep the same loads along the section. As load is relevant to this example and we are assuming it is constant through all stations, to visualize this situation one should imagine that the number of boardings is similar to the number of alightings in every station. In this example, it is assumed that one is unable, due to lack of political will, to take sufficient road space to build stations with the necessary passing lane and sub-stops to avoid station saturation. The following is also assumed:

L_{corridor}: Corridor length = 5 km;

V_{outside}: Velocity outside the busway = 12 km/h;

V_{inside}:Velocity inside BRT at free-flow speed = 25 km/h;

N_{stations} = 10;

In this scenario, besides varying demand levels at stations, bus types are also different. Because it is not always possible to replace the entire fleet of buses with BRT vehicles all at once, the vehicles are going to vary in size and configuration in ways that will change the dwell time per customer. Because of this varying dwell time per customer, the BRT infrastructure will saturate to different degrees depending on which routes are incorporated into the BRT system. This will be one important change from Scenario I. Now, rather than simply determining how many routes to include, it is possible to determine *which* routes to include. This requires using a time savings formula to be applied to the number of customers instead of to the vehicles.

The service planner would have collected two types of data about each route:

- *Frequency and occupancy surveys*, which will give the system planner the number of vehicles per route per hour, and their estimated occupancy;
- *Boarding and alighting data* per route, which will give the number of passengers boarding and alighting at each station stop.

Table 6.20 provides an example showing thirteen bus routes with varying dwell times and customer volumes. This example will be used to demonstrate the methodology for determining which routes to include.

Table 6.20. Example of Route Choice

Route	Frequency (surveyed or planned)	Occupancy (surveyed, planned or simulated)	Customers of route i passing through station	Average number of boarding and alighting passengers at station per bus (surveyed or planned or simulated)	Bus type (existing or planned)	Dead time (function of bus type)	Boarding and alighting time per pax (function of bus type)	Boarding and alighting delay	Total dwell time per bus at station	Total dwell time per route at station	Bus station use required by route	Priority index (passangers in the system per second of station use)
i	F_i	O_i	Load_i = O_i * F_i	P_b + P_a	T_d	T_o	t_b, = t_a	T_a + T_b = t_b * P_b + t_a * P_a	T_d = T_o + T_a + T_b	F_i * T_d	x_i = T_d * F_i /3600	priority_i = Load_i / T_d
	vehicle/hour	pax/vehicle	pax/hour	pax/vehicle		seconds /vehicle	seconds/pax (/vehicle)	seconds/vehicle	seconds/vehicle	seconds/hour		pax/second
A	15	60	900	6	large, steps to board	12	3	18	30	450	12.5%	2.00
B	20	50	1000	0	medium, at level board	10	1	0	10	200	5.6%	5.00
C	18	40	720	10	medium, steps to board	10	3	30	40	720	20.0%	1.00
D	22	82	1804	3	large, steps to board	12	3	9	21	462	12.8%	3.90
E	5	90	450	16	large, steps to board	12	3	48	60	300	8.3%	1.50
F	25	20	500	0	small	4	1	0	4	100	2.8%	5.00
G	8	40	320	2	medium, steps to board	10	3	6	16	128	3.6%	2.50
H	23	55	1265	2	medium, at level board	10	1	2	12	276	7.7%	4.58
I	8	70	560	9	large, steps to board	12	3	27	39	312	8.7%	1.79
J	15	82	1230	8	large, steps to board	12	3	24	36	540	15.0%	2.28
K	10	48	480	0	medium, at level board	10	1	0	10	100	2.8%	4.80
L	6	59	354	13	large, steps to board	12	3	39	51	306	8.5%	1.16
M	4	58	232	1	large, steps to board	12	3	3	15	60	1.7%	3.87
TOTAL	179		9815							3954	109.8%	

In Table 6.20 the fixed dwell time (or "dead time") per bus is varied in a very simple way: either the bus is a large bus with a time of 12 seconds, it is a smaller bus with a time of 10 seconds, or there is one very small bus with a time of four seconds. The projected boarding and alighting time per bus route also only varies based on the vehicle type. For those new BRT-type buses with at-level boarding and three or four wide doors, one should estimate that the boarding and alighting time per customer will be one second, while for typical older buses one should assume the boarding or alighting time per passenger will be three seconds. These are reasonable values. The boarding and alighting passenger volumes are collected from the boarding and alighting survey for the bottleneck station. By adding the fixed dwell time (T_0) to the boarding and alighting time per route ($T_b + T_a$), the total dwell time per bus (T_d) can be calculated and is shown in the table above.

Using the results of the occupancy survey, one can now define a new variable, Pax(i). This refers to the average occupancy on each bus within a single route "i," in the peak hour passing the station most likely to face a bottleneck. With this, a "priority index" can be calculated in order to determine which routes to include first:

Eq. 6.34

$$\text{Priority}(i) = \frac{\text{Pax}(i)}{T_d(i)}$$

Where:

- $\text{Priority}(i)$: Priority index of route "i"; Passengers per second of dwell time on route "i" at the bottleneck station;
- $\text{Pax}(i)$: Average occupancy of each bus on route "i" as the bus passes the station;
- $T_d(i)$: Total dwell time in seconds of each bus on route "i".

In other words, priority should be given to those bus routes where the most passengers are able to benefit from the busway for each second used at the bottleneck station. Bus routes should be listed in descending order of this priority index, so that routes with more customers per second of dwell time consumed at the bottleneck station are included first, and so on. In Table 6.21, the routes are ranked based on the priority index listed in the column labeled "Priority index."

Table 6.21. Ranking of Routes for Route Choice

Ranking for route shifting onto corridor selection														
Route values					Accumulated values on station after route inclusion					Travel times				
Route	Frequency (surveyed or planned)	Customers of route i passing through station	Bus station use required by route	Priority index (passangers in the system per second of station use)	Frequency inside the busway	Customers inside the busway	Station saturation	Average queue delay at the station (for all vehicles using the station = vehicles shifted onto the busway)		Travel Time inside busway without congestion	Travel Time inside busway with station queue delay	TT outside	TT savings (to routes included in the corridor)	Aggreagated Travel Time savings to customers inside busway (person-hours saved, during one hour of operation)
i	F_i	Load_i = O_i * F_i	x_i = T_d * F_i /3600	priority_i = Load_i / T_d	Sum (F_i)	Load_inside = Sum (O_i * F_i)	x_station = Sum (x_i)	Tq_station = 0.7 * x_station^2 / [(1 - x_station) * Sum(F_i)]		TT _inside_no_cong = L_corridor / V_inside_no_cong	TT_inside = TT_inside_no_cong + Tq_station * N_station	TT_outside = L_corridor / V_outside	TT savings = TT_outside - TT_inside	ATT_savings = TT_savings * Load_inside
unit-->	vehicle/hour	pax/hour		pax/second	vehicle/hour	pax/hour		hour	second	hour	hour	hour	hour	pax-hour (/hour of operation)
B	20	1000	5.6%	5.00	20	1000	0.056	0.00011	0.41	0.20	0.20114	0.417	0.216	**216**
F	25	500	2.8%	5.00	45	1500	0.083	0.00012	0.42	0.20	0.20118	0.417	0.215	**323**
K	10	480	2.8%	4.80	55	1980	0.111	0.00018	0.64	0.20	0.20177	0.417	0.215	**426**
H	23	1265	7.7%	4.58	78	3245	0.188	0.00039	1.40	0.20	0.20390	0.417	0.213	**690**
D	22	1804	12.8%	3.90	100	5049	0.316	0.00102	3.7	0.20	0.21023	0.417	0.206	**1042**
M	4	232	1.7%	3.87	104	5281	0.333	0.00112	4.0	0.20	0.21117	0.417	0.205	**1085**
G	8	320	3.6%	2.50	112	5601	0.368	0.00134	4.8	0.20	0.21342	0.417	0.203	**1138**
J	15	1230	15.0%	2.28	127	6831	0.518	0.00307	11.1	0.20	0.23074	0.417	0.186	**1270**
A	15	900	12.5%	2.00	142	7731	0.643	0.00572	20.6	0.20	0.25720	0.417	0.159	**1233**
I	8	560	8.7%	1.79	150	8291	0.730	0.00921	33.2	0.20	0.29211	0.417	0.125	**1033**
E	5	450	8.3%	1.50	155	8741	0.813	0.01600	57.6	0.20	0.36004	0.417	0.057	**495**
L	6	354	8.5%	1.16	161	9095	0.898	0.03451	124.2	0.20	0.54512	0.417	-0.128	**-1168**
C	18	720	20.0%	1.00	179	9815	1.098	---	---	0.20	---	0.417	---	**---**

Each row in Table 6.21 represents a new route to be included in the BRT infrastructure. Starting with the empty busway, the last column shows the benefit in customers-hours (during one hour of operation) for including the route and all routes in rows above. After route "j," the row in blue, overall benefits start to decrease, so no more routes should be included.

Now one can proceed with the methodology used in Scenario I, noting some differences. One should begin by calculating saturation. In this case, the dwell times should still be added up per route, but since dwell times vary from route to route, one cannot simply multiply one dwell time by total frequency inside the busway. Instead, one should multiply dwell time per route by frequency per route and then perform the full summation. So, in this case, the saturation formula should be written as:

Eq. 6.35 $x = \sum_{\text{route-inside}} (T_{di} * F_i)/3600$

Where:

- x: Saturation at station;
- T_{di}: Total dwell time at station for route "i" in seconds;
- F_i: Frequency of route "i" in vehicles/hour.

In Table 6.21, station saturation (x) is recalculated each time a new route is added. So saturation when only Route B is part of the BRT service plan, is the number of seconds of an hour (the peak hour) that Route B consumes in total dwell time ($= (T_0 * \text{Freq})/3600 = 10 * 20/3600 = 0.056$), meaning that Route B uses 5.6 percent of available station time in an hour.

If Route F is added, the BRT service plan includes Routes B and F. The station saturation that is contributed by Route F (calculated in the same manner as above) is simply added to the saturation contributed by Route B, or in this case 8.3 percent, and so on.

As is discussed in Chapter 7: Capacity and Speed, a busway starts to saturate when $x = 0.4$, so routes where $x > 0.4$ should probably be excluded, pending further analysis.

The average queue time (average for all buses using the station) is calculated using the same formula from Scenario I (Eq. 6.30a):

Eq. 6.30a

$$T_q = \frac{0.7 * x^2}{1 - x} \frac{1}{F_{\text{inside}}}$$

Where:

Where:

- T_q: One vehicle queueing time at each station;
- x: Saturation of the station;
- F_{inside}: Number of buses per hour inside the busway;

So going back to including only Route B, the queuing delay is simply:

$$T_q = \frac{0.7 * 0.056^2}{(1-0.056)} * \frac{1}{20} = 0.00114\text{hours} = 0.4\text{seconds}$$

For this low frequency, 20 vehicles/hour, the average delay is less than 0.5 seconds, virtually no delay; as we add more vehicles this increases visibly.

For a more refined analysis, the additional time savings and losses of shifting a route is done per customer. The final piece of information that is needed in order to determine benefits for customers is the customer load passing the station. Load is calculated by multiplying the frequency times the observed customer occupancy per bus on the link approaching the bottleneck station. In the case of including only Route B, the load is 1,000. In the case where both Routes B and F are included in the BRT service, the load is the load for both Route B and Route F, or 1,000 + 500 = 1,500. Load is the sum of all occupancies on all routes included in the BRT infrastructure.

Eq. 6.36

$$\text{Load}_{\text{inside}} = \sum_{\text{routes-inside}} (O_{\text{route } i} * F_{\text{route } i})$$

Where:

- $\text{Load}_{\text{inside}}$: Customer load inside the BRT infrastructure;
- routes-inside: Number of routes inside the busway;
- $O_{\text{route } i}$: Occupancy on route i (inside the busway);
- $F_{\text{route } i}$: Frequency of route i (inside the busway).

We then calculate the total aggregated time savings for including each additional route, using the same benefit formula from Scenario I, as the calculus is cumulative, i.e., started from the reference situation where there are no routes inside the busway, there is no time loss to be computed due to the addition of the new route. The time savings must be multiplied by the passenger load instead of the vehicles to determine actual benefits to passengers, by using Equations 6.24a, 6.24c, and a variant of 6.24 (6.30 below):

Eq. 6.24a

$$TT_{\text{outside}} = \frac{L_{\text{corridor}}}{V_{\text{outside}}}$$

Eq. 6.24c

$$TT_{\text{inside}} = \frac{L_{\text{corridor}}}{V_{\text{inside-no-congestion}}} + T_q * N_{\text{stations}}$$

Eq. 6.37

$$ATT_{\text{savings}} = (TT_{\text{outside}} - T_{\text{Tinside}}) * \text{Load}_{\text{inside}}$$

Where:

- ATT_{savings}: Aggregated Travel Time savings for including selected routes in the BRT infrastructure;
- $\text{Load}_{\text{inside}}$: Customer load inside the BRT infrastructure;
- TT_{inside}: Travel time per bus inside the busway;
- TT_{outside}: Travel time per bus outside the busway;
- L_{corridor}: Length of the corridor;
- V_{outside}: Velocity outside the busway.
- $V_{\text{inside-no-congestion}}$: Velocity inside the busway without delay at stations;

- T_q: Average delay for each vehicle at a single station due to queuing;
- N_{stations}: Number of stations along the busway.

We do not need, in fact, to look at the aggregate travel time outside the corridor to determine which routes must be included. Aggregated travel time savings alone can answer for the utility of the inclusion of each additional route, and the point where the benefits are highest should be selected. In this case, benefits reach a maximum in the scenario where the following routes are included in the BRT services plan: B, F, K, H, D, M, G, J, and Routes A, I, E, L, and C are left to operate in mixed traffic. The result is almost the same as simply cutting off new routes when the saturation level reaches 0.4, except one more route is added.

6.5.3.3 Scenario III: Dwell Time and Occupancies Vary from One Bus Stop to the Next

In this example, it is assumed that different bus routes are causing the saturation problem at different stations, and multiple stations face bottlenecks. This is the most typical of real-world situations. In this case, there may be more than one bottleneck station, and the bus routes causing the bottleneck might vary by station. This scenario attempts to include all bus routes that need to use the infrastructure based on their rankings and, like the previous scenarios, leaves out those routes for which the cost of including them is greater than the benefit.

Considering a situation of 13 routes as the previous example, there are 8,191 possible combinations of routes to include inside the busway, and one could write a program to try them all to find which one yields the maximum aggregated travel time savings. If the number of routes doubles (26 routes), the number of possibilities increases to 67 million, which can still be tested in a feasible computational time. For 30 routes there are more than 1 billion combinations and for 40 routes, there are 1 trillion combinations, which computer brute force certainly cannot test.

For determining an optimal solution in this case, one should use the simplified methodology presented here, which alone is likely to yield the ideal result or a limited and manageable number of alternatives. This is mostly because the demand profile from one route to another is usually not completely random. High levels of vehicle occupation and high dwell times are often clustered in the same areas and at the same stops across many routes.

Here is a new example to demonstrate this methodology. Let's say the corridor has three BRT stations (X, Y, and Z), and four potential bus routes (A, B, C, and D). The average dwell time and average occupancy on each route vary between stations.

1. For each station, make a table of bus routes including average occupancy and dwell time, and calculate the priority index, Priority (station), using Equation 6.26 from Scenario II. Using the new example, one will have three tables:

Table 6.22. Route Characteristics at Station W

Route	Dwell time	Occupancy	PriorityiY
	TdiW	OiW	= OiY/ TdiW
	seconds/bus	pax/bus	pax/second
A	10	43	4.3
B	6	20	3.3
C	10	48	4.8
D	12	55	4.6

Table 6.23. Route Characteristics at Station Y

Route	Dwell time	Occupancy	PriorityiW
	TdiY	OiY	= OiY/ TdiY
	seconds/bus	pax/bus	Pax/second
A	10	35	3.5
B	9	20	2.2
C	8	30	3.8
D	12	40	3.3

Table 6.24. Route Characteristics at Station Z

Route	Dwell time	Occupancy	PriorityiY
	TdiZ	OiZ	= OiY/ TdiZ
	seconds/bus	pax/bus	pax/second
A	15	55	3.7
B	11	33	3.0
C	7	22	3.1
D	11	30	2.7

2. Determine the best priority order by averaging priority (station) for each route.

Table 6.25. Average Priority across Stations W, Y, Z

Route	Average Priority
	= (OiY + OiW + OiZ)/3
	pax/second
A	3.8
B	2.9
C	3.9
D	3.5

And then reorder the routes in descending order based on the average priorities, one table per station.

Table 6.26. Routes Ordered by Average Priority

Route	Average Priority
	= (OiY + OiW + OiZ)/3
	pax/second
C	3.9
A	3.8
D	3.5
B	2.9

3. Maintaining the priority order obtained above, add routes to the system as in Scenario II and obtain saturation and queue time per station, travel time inside the corridor, and aggregated time savings.

4. For each station, assume corridor length as the distance (or half the distance) to the previous and next station and real observed speed outside the corridor to determine where the total aggregate travel time savings for that section reaches its minimum. Look in greater detail at the levels of saturation at critical stations, and if they are far from the individual optimum using the average priority, consider changing the route priority from the average route priority to something that more closely optimizes the route priority around the bottleneck station.
5. Re-create the tables by station and see if the change results in a higher total benefit (sum of benefit of all stations calculated as in Scenario II): if yes, make the change; if not, try another.

These steps essentially replicate in a crude way what linear programming would do in a systematic way, and if the planner has data, time, and a deep understanding of these formulas, she or he can put all equations and restrictions into a system and look for an optimal solution.

6.5.3.4 Conclusion of BRT Route Inclusion

In conclusion, when designing BRT services for a BRT corridor with constrained capacity, the inclusion of routes into BRT services should be based on ensuring that the aggregated travel time gains that accrue to the last route included in the BRT system outweigh the losses that its inclusion imposes on the other routes already included in the BRT system. This loss results from the additional bus route to the BRT system slowing down the speeds of the vehicles already inside the system.

Further, the frequency and amount of overlap with the BRT corridor should be taken into consideration. Additionally, in order to help make decisions about which routes should be included in a new BRT service, a “priority” index could be created to measure the following: total customers on board the bus as it approaches the bottleneck stations divided by the total dwell time that that bus route uses at the bottleneck stations.

6.6 Direct Services, Trunk-and-Feeder Services, or Hybrids

> *“Paths cross all the time in this world of ours, sometimes in the strangest places.”*
>
> — Stephen King, writer, 1947–

When designing new services for a BRT system, the project team must decide which preexisting bus routes that continue beyond the BRT corridor should be incorporated into the new BRT service plan as “direct” services that enter and exit the BRT corridor, and which should be split into trunk routes operating inside the BRT infrastructure and feeder routes operating in mixed traffic and “feeding” the trunk stations. Whether and when to do this has been the subject of debate among BRT service planners. This section provides some basic guidance on how to make this determination in specific cases.

In general, most customers would prefer to take a bus directly from where their trip begins to where it ends. New BRT infrastructure on one corridor is not going to fundamentally change people’s trip origins and destinations in the short term. The new BRT infrastructure is likely to be built on a corridor with multiple preexisting public transport services that not only run up and down the corridor, but also continue beyond the corridor. Chances are that many people will not have destinations within walking distance of the new BRT stations, so if the preexisting services are discontinued, and only one BRT trunk service is running up and down the BRT infrastructure, many customers will be forced to use feeder services and transfer to trunk in stations along the corridor or at larger terminals. In the worst case, this transfer delay may be greater than the time benefit of using the BRT system.

The most important differences in the costs and benefits of direct services versus trunk-and-feeder services are as follows (listed here and described in detail below):

- Fleet requirements: When demand is peaked, as is generally the case, more fleet is required for trunk-and-feeder services than for direct services. When demand is flat, fleet requirements are basically equivalent;
- Vehicle sizes: When the trunk portion of the route is longer than the feeder portion, and many routes share the trunk corridor, larger vehicles can be used on the trunk routes, providing a cost savings for trunk-and-feeder services over direct services;
- Transfer costs: The greater the delay caused by the introduction of the new transfer, the greater the additional cost of trunk-and-feeder services, including:
  - Running time;
  - Boarding and alighting delay;
  - Suboptimal terminal location;
  - Suboptimal terminal design on walking time;
  - Land acquisition and terminal construction costs.
- Station saturation: The greater the risk of trunk corridor station platform saturation, the greater the benefit of trunk-and-feeder services.

This section systematically analyzes these key factors. Factors that did not vary significantly between trunk-and-feeder and direct service modes were not further considered. For instance, while some claim to prefer trunk-and-feeder systems to reduce irregularity of service inside the BRT trunk corridor, there is little empirical evidence to suggest any significant overall system-wide benefit of this. Having irregular arrivals of feeder buses at transfer terminals where conditions can become severely overcrowded, as frequently happens in Bogotá's TransMilenio, is as problematic as having irregular direct services with a dispersed impact along the BRT trunk corridor.

The following sections provide some formulas based on the above criteria that should assist in making decisions about which bus routes to retain as direct services and which to cut into trunk-and-feeder services. As there are many variables to consider, alternatives should ideally be tested using a public transport demand model, and this should be complemented by an analysis of saturation and delays of each proposal at critical points such as at stations and signals.

6.6.1 Fleet Requirements for Direct Versus Trunk-and-Feeder Services

All other things being equal, trunk-and-feeder systems tend to require larger fleets than direct service systems, and the amount of extra fleet needed will vary based in large part on the degree to which the demand is concentrated in peak periods. This subsection explains the reasons for this effect, and uses the method of calculating fleet requirements in specific conditions.

As was discussed above in Section 6.4, the fleet size per route is generally determined by the fleet required to satisfy the maximum load that accumulates on the critical link during the course of the route cycle time during the peak period (Eq. 6.18: $\text{Fleet}_{\text{route}} = \frac{\text{MaxLoad}_{\text{route}}}{\text{VSize}*\text{LoadFactor}}$). Below, a series of scenarios illustrate the point, each with more complicated assumptions.

First, the fleet requirements for direct services with uniform demand throughout the day will be discussed. Then, calculating the fleet if demand varies between peak and off peak will be reviewed. Finally, some of the direct routes are split into trunk-and-feeder routes using the principles from the previous scenarios and fleet needs are compared between direct services and trunk-and-feeder services. In order to do this, one should have a BRT corridor with services that look like the diagram in Figure 6.41.

We make the following additional assumptions:

- *A* One should have already determined that the bus capacity (VSize), for the examples being considered have a design load factor of 85 percent, so in these examples the bus capacity is 60 passengers, though the real BRT vehicle capacity is 70 passengers;
- *B* All the bus routes operate on full BRT infrastructure between Downtown and the Terminal (as in diagram Figure 6.41), and all services operate in mixed traffic beyond the Terminal;
- *C* There is no overlap of routes until they reach the common point, Terminal;
- *D* The critical link with the maximum aggregate load (i.e., the load for all routes combined) occurs somewhere near the Terminal and continues at a similar level to Downtown;
- *E* The peak hour, in the cases where it exists, occurs earlier in the day on the link before the Terminal and later between the Terminal and Downtown.

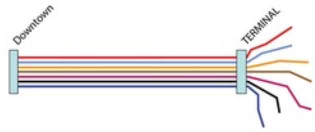

Figure 6.41. Service pattern used for fleet calculations in Scenarios 1–3 below. Image *ITDP.*

6.6.1.1 Comparative Fleet Advantages under Flat Demand with Uniform Routes

In this situation, two service patterns are compared:

1. *Direct Services*: A service pattern where multiple bus routes run in mixed traffic on local streets and then continue onto the BRT corridor (Figure 6.42).
2. *Trunk-and-Feeder Services*: A service pattern where multiple bus routes run in mixed traffic on local streets and terminate at a single terminal. Another bus route with higher frequency operates up and down the BRT corridor, and customers travelling between one and the other must transfer.

When designing a BRT system, normally one could assume a reasonable BRT speed to be the equivalent of the speed of a vehicle operating during off-peak conditions, or one could assume a Gold Standard BRT system speed will be roughly 20 kph in a downtown area and about 25 kph on a major urban arterial. For this analysis, the cycle time (TC) of a direct service route will be the time spent on the trunk (at off-peak speeds) plus the time spent on the mixed traffic portion of the route at existing peak-hour mixed traffic speeds. For the trunk-and-feeder alternative, the TC of the trunk route will just be the time spent on the trunk portion of the route at off-peak speeds, and the feeder portion of the route will be the feeder portion of the route at existing peak-hour mixed traffic speeds. Therefore, one should define three types of TCs:

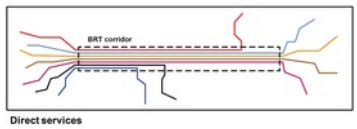

Figure 6.42. Service Pattern A—Direct Services: A service pattern where multiple bus routes run in mixed traffic on local streets and then continue onto the BRT corridor. *ITDP.*

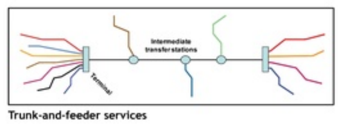

Figure 6.43. Service Pattern B—Trunk-and-Feeder Services: A service pattern where multiple bus routes run in mixed traffic on local streets and terminate at a single terminal. Another bus route with higher frequency operates up and down the BRT corridor, and customers travelling between one and the other must transfer. *ITDP.*

Eq. 6.38

$$TC_{\text{Trunk}} = (L_{\text{Trunk}} * V_{\text{Trunk Outbound}}) + (L_{\text{Trunk}} * V_{\text{Trunk Inbound}})$$

Where:

- TC_{Trunk}: Cycle time in hours for a vehicle to complete one circuit of the trunk;
- L_{Trunk}: Length of the trunk;
- $V_{\text{Trunk Outbound}}$: Velocity on the outbound trunk;
- $V_{\text{Trunk Inbound}}$: Velocity on the inbound trunk.

Eq. 6.39

$$TC_{\text{Feeders}} = L_{\text{Feeders}} * V_{\text{Feeders Outbound}} + L_{\text{Feeders}} * V_{\text{Feeders Inbound}}$$

Where:

- TC_{Feeders}: Cycle time in hours for a vehicle to complete one circuit of the feeders;
- L_{Feeders}: Length of the feeders;
- $V_{\text{Feeders Outbound}}$: Velocity on the outbound feeder;
- $V_{\text{Feeders Inbound}}$: Velocity on the inbound feeder.

For our analysis, it is assumed that the cycle time for the trunk routes plus the cycle time for the feeder routes is as short as possible, being equivalent to the cycle time for the direct service routes or:

Eq. 6.40

$$TC_{\text{direct}} = TC_{\text{trunk}} + TC_{\text{feeder}}$$

Where:

- TC_{Direct}: Cycle time in hours for a vehicle to complete one circuit of the trunk-and-feeder services;
- TC_{Trunk}: Cycle time in hours for a vehicle to complete one circuit of the trunk service;
- TC_{Feeder}: Cycle time in hours for a vehicle to complete one circuit of the feeder service;

Under these conditions, the benefit of a direct service will be the difference in the fleet requirements between Service Plan A and Service Plan B:

Eq. 6.41

$$\text{Fleet}_{\text{benefit direct}} = \text{Fleet}_{\text{trunk}} + \text{Fleet}_{\text{feeder}} - \text{Fleet}_{\text{direct}}$$

Where:

- $\text{Fleet}_{\text{benefit direct}}$: Benefit of a direct service in terms of the fleet;
- $\text{Fleet}_{\text{trunk}}$: Fleet requirement for the trunk service;
- $\text{Fleet}_{\text{feeder}}$: Fleet requirement for the feeder service;
- $\text{Fleet}_{\text{direct}}$: Fleet requirement for the direct service.

Recall Equation 6.18 from Section 6.4, which shows that the fleet size is determined by the maximum load of passengers that accumulates over the course of the cycle time for a given bus size.

Equation 6.18 applied:

$$\text{Fleet}_{\text{direct}} = \frac{\text{MaxLoadperCycle}_{\text{direct}}}{\text{VSize} * \text{LoadFactor}}$$
$$\text{Fleet}_{\text{trunk}} = \frac{\text{MaxLoadperCycle}_{\text{trunk}}}{\text{VSize} * \text{LoadFactor}}$$
$$\text{Fleet}_{\text{feeder}} = \frac{\text{MaxLoadperCycle}_{\text{feeder}}}{\text{VSize} * \text{LoadFactor}}$$

Where:

- $\text{Fleet}_{\text{trunk}}$: Fleet requirement for the trunk service;
- $\text{Fleet}_{\text{Feeder}}$: Fleet requirement for the feeder service;
- $\text{Fleet}_{\text{direct}}$: Fleet requirement for the direct service.
- $\text{MaxLoadperCycle}_{\text{trunk}}$: Maximum load on the trunk service for one cycle time;
- $\text{MaxLoadperCycle}_{\text{feeder}}$: Maximum load on the feeder service for one cycle time;
- $\text{MaxLoadperCycle}_{\text{direct}}$: Maximum load on the direct service for one cycle time;

- VSize: Vehicle capacity;
- LoadFactor: Design load factor (usually 0.85), which is the same for all routes.

The main assumption of this scenario, that the demand is uniform throughout the day, implies that the maximum load in the critical link (MaxLoad) is equal at any time. So the maximum load considered per cycle time (MaxLoadperCycle) for any given cycle time would be equal to the sum of two “maximum load per cycle” of smaller cycles times that add up to the same time, or, starting from Eq. 6.6a.

Eq. 6.6a

$$\text{MaxLoadperCycle} = \text{MaxLoad} * TC$$

$$\text{MaxLoadperCycle}_{T1} = \text{MaxLoad} * T1$$

$$\text{MaxLoadperCycle}_{T2} = \text{MaxLoad} * T2$$

$$\text{MaxLoadperCycle}_{T1+T2} = \text{MaxLoad} * (T1 + T2)$$

Eq. 6.42

$$\text{MaxLoadperCycle}_(T1 + T2) = \text{MaxLoadperCycle}T1 + \text{MaxLoadperCycle}_T2$$

Where:

- $\text{MaxLoadperCycle}_(T1 + T2)$: Maximum load considered for the sum of cycle times 1 and 2;
- $\text{MaxLoadperCycle}_T1$: Maximum load considered for cycle time 1;
- $\text{MaxLoadperCycle}_T2$: Maximum load considered for cycle time 2.

Therefore, as long as $TC_{\text{direct}} = TC_{\text{trunk}} + TC_{\text{feeder}}$ the benefit of direct service is zero, as we show below:

$$\text{Fleet}_{\text{benefitdirect}} = (\text{Fleet}_{\text{trunk}} + \text{Fleet}_{\text{feeder}}) - \text{Fleet}_{\text{direct}}$$
$$= \left(\frac{\text{MaxLoadperCycle}_{\text{trunk}}}{\text{VSize} * \text{LoadFactor}} + \frac{\text{MaxLoadperCycle}_{\text{feeder}}}{\text{VSize} * \text{LoadFactor}}\right) - \frac{\text{MaxLoadperCycle}_{\text{direct}}}{\text{VSize} * \text{LoadFactor}}$$
$$= \frac{\text{MaxLoadperCycle}_{\text{trunk}} + \text{MaxLoadperCycle}_{\text{feeder}} - \text{MaxLoadperCycle}_{\text{direct}}}{\text{VSize} * \text{LoadFactor}}$$
$$= \frac{\text{MaxLoadperCycle}_{\text{trunk}} + \text{MaxLoadperCycle}_{\text{feeder}} - \text{MaxLoadperCycle}_{\text{trunk+feeder}}}{\text{VSize} * \text{LoadFactor}}$$
$$= \frac{\text{MaxLoadperCycle}_{\text{trunk}} + \text{MaxLoadperCycle}_{\text{feeder}} - (\text{MaxLoadperCycle}_{\text{trunk}} + \text{MaxLoadperCycle}_{\text{feeder}})}{\text{VSize} * \text{LoadFactor}}$$
$$= 0$$

As an example we use a cycle time (TC) on the trunk of one hour, as well as a cycle time on the feeders in mixed traffic of one hour. So:

$$TC_{\text{trunk}} = 1\text{hour}$$

$$TC_{\text{feeder}} = 1\text{hour}$$

$$TC_{\text{direct}} = 2\text{hour}$$

This example assumes that the optimal vehicle capacity was already determined (see previous introduction subsection) to be sixty passengers.

The MaxLoadperCycle for two hours is precisely double the maximum load for a cycle time of one hour, or:

$$\text{MaxLoadperCycle}_{\text{2 hours}} = 2 * \text{MaxLoadperCycle}_{\text{1 hour}}$$

In this case, one should assume that MaxLoad $= 225$pax/hour, and one knows that demand is flat throughout the day, so the PHtoCC $= 0$, therefore:

$$\text{MaxLoadperCycle}_{\text{direct}} = 225 * 2 = 450$$

And the fleet required for the trunk-and-feeder scenario is:

$$\frac{\text{Fleet}_{\text{direct}} = 450}{60 = 7.5(ROUNDUP) = 8}$$

In the trunk-and-feeder scenario,

$$\text{MaxLoadperCycle}_{\text{trunk}} = \text{MaxLoadperCycle}_{\text{feeder}} = 225 * 2 = 450$$

$$\frac{\text{Fleet}_{\text{trunk}}=225}{60=3.75(ROUNDUP)=4} \; \frac{\text{Fleet}_{\text{feeder}}=225}{60=3.75(ROUNDUP)=4} \; \text{Fleet}_{\text{direct benefit}} = (4+4) - 8 = 0$$

In this case, the fleet needed for the direct service scenario is the same as the fleet needed for the trunk-and-feeder service option. If there were a rounding error, the trunk-and-feeder option may require a slightly larger fleet due to rounding, but the additional fleet is not that significant.

6.6.1.2 Comparative Fleet Advantages under Peaked Demand with Uniform Routes

If the demand is peaked, but the routes remain uniform, the fleet requirements change, and direct services have a distinct advantage over trunk-and-feeder services. The advantage is proportional to double the peak hour to cycle correction factor (PHtoCC).

Remembering that and (Eq. 6.6b) the fleet benefit for using a direct route will be given by:

Eq. 6.43

$$\text{Fleet}_{\text{benefitdirect}} = (\text{Fleet}_{\text{trunk}} + \text{Fleet}_{\text{feeder}}) - \text{Fleet}_{\text{direct}}$$

$$= \frac{\text{MaxLoadperCycle}_{\text{trunk}} + \text{MaxLoadperCycle}_{\text{feeder}} - (\text{MaxLoadperCycle}_{\text{trunk}} + \text{MaxLoadperCycle}_{\text{feeder}})}{\text{VSize} * \text{LoadFactor}}$$

$$= \frac{\text{MaxLoad} * TC_{\text{trunk}} * [1 - \text{PHtoCC} * (\text{TC}_{\text{trunk}} - 1)] + \text{MaxLoad} * TC_{\text{feeder}} * [1 - \text{PHtoCC} * (\text{TC}_{\text{feeder}} - 1)]}{\text{VSize} * \text{LoadFactor}}$$

$$- \frac{\text{MaxLoad} * (TC_{\text{trunk}} + TC_{\text{feeder}}) * [1 - \text{PHtoCC} * ((TC_{\text{trunk}} + TC_{\text{feeder}}) - 1)]}{\text{VSize} * \text{LoadFactor}}$$

$$= \frac{\text{MaxLoad} * TC_{\text{trunk}} * [1 - \text{PHtoCC} * (\text{TC}_{\text{trunk}} - 1)] + \text{MaxLoad} * TC_{\text{feeder}} * [1 - \text{PHtoCC} * (\text{TC}_{\text{feeder}} - 1)]}{\text{VSize} * \text{LoadFactor}}$$

$$- \frac{\text{MaxLoad} * TC_{\text{trunk}} * [1 - \text{PHtoCC} * ((TC_{\text{trunk}} + TC_{\text{feeder}}) - 1)]}{\text{VSize} * \text{LoadFactor}} - \frac{\text{MaxLoad} * TC_{\text{feeder}} * [1 - \text{PHtoCC} * ((TC_{\text{trunk}} + TC_{\text{feeder}}) - 1)]}{\text{VSize} * \text{LoadFactor}}$$

$$= \frac{\text{MaxLoad} * TC_{\text{trunk}} * \{[1 - \text{PHtoCC} * (\text{TC}_{\text{trunk}} - 1)] - [1 - \text{PHtoCC} * ((TC_{\text{trunk}} + TC_{\text{feeder}}) - 1)]\}}{\text{VSize} * \text{LoadFactor}} + \frac{\text{MaxLoad} * TC_{\text{feeder}} * \{[1 - \text{PHtoCC} * (\text{TC}_{\text{feeder}} - 1)] - [1 - \text{PHtoCC} * ((TC_{\text{tru}}}{\text{VSize} * \text{LoadFactor}}$$

$$= \frac{\text{MaxLoad} * TC_{\text{trunk}} * \{[1 - \text{PHtoCC} * \text{TC}_{\text{trunk}} + \text{PHtoCC}] - [1 - \text{PHtoCC} * TC_{\text{trunk}} - \text{PHtoCC} * TC_{\text{feeder}} + \text{PHtoCC}]\}}{\text{VSize} * \text{LoadFactor}}$$

$$+ \frac{\text{MaxLoad} * TC_{\text{feeder}} * \{[1 - \text{PHtoCC} * \text{TC}_{\text{feeder}} + \text{PHtoCC}] - [1 - \text{PHtoCC} * TC_{\text{trunk}} - \text{PHtoCC} * TC_{\text{feeder}} + \text{PHtoCC}]\}}{\text{VSize} * \text{LoadFactor}}$$

$$= \frac{\text{MaxLoad} * TC_{\text{trunk}} * \{TC_{\text{feeder}} + \text{PHtoCC}\}}{\text{VSize} * \text{LoadFactor}} + \frac{\text{MaxLoad} * TC_{\text{feeder}} * \{TC_{\text{trunk}} + \text{PHtoCC}\}}{\text{VSize} * \text{LoadFactor}}$$

$$= 2 * \frac{\text{MaxLoad} * TC_{\text{trunk}} * TC_{\text{feeder}} * \text{PHtoCC}}{\text{VSize} * \text{LoadFactor}}$$

Where

- PHtoCC: Nonnegative correction factor, the calibration of which is based on survey data, is discussed in Box 6.2. The usual value is near 0.1;
  - If TC is larger than one hour: correction $1 - \text{PHtoCC} * (\text{TC} - 1)$ will result smaller than one;
  - If TC is smaller than one hour: correction $1 - \text{PHtoCC} * (\text{TC} - 1)$ will result larger than one;
  - If TC is equal one hour: correction $1 - \text{PHtoCC} * (\text{TC} - 1)$ will result in one;
  - If PHtoCC is equal zero, there will be no correction, and the formula is equal to the previous formula.
- MaxLoad: Maximum hourly load on the critical link;

- TC: Cycle time in hours.
- TC_{Direct}: Cycle time in hours for a vehicle to complete one circuit of the trunk-and-feeder services;
- TC_{Trunk}: Cycle time in hours for a vehicle to complete one circuit of the trunk service;
- TC_{Feeder}: Cycle time in hours for a vehicle to complete one circuit of the feeder service;
- $Fleet_{\text{trunk}}$: Fleet requirement for the trunk service;
- $VSize$: Vehicle capacity;
- $LoadFactor$: Design load factor (usually 0.85), which is the same for all routes.

As an example, we keep the same assumptions from the previous case, but consider a peaked demand of 265 where the correction factor is given by 0.15 (see Box 6.2 How to determine correction factor from hour to cycle time ($PHtoCC$) based on load observations):

$\text{MaxLoadperCycle}_{\text{direct}} = \text{MaxLoad} * (TC_{\text{direct}} * (1 - \text{PHtoCC} * (\text{TC}_{\text{direct}} - 1))) = 265 * 2 * (1 - 0.15 * 2 - 1))) = 450$

$\text{MaxLoadperCycle}_{\text{feeder}} = \text{MaxLoadperCycle}_{\text{trunk}} = \text{MaxLoad} * (TC_{\text{feeder}} * (1 - \text{PHtoCC} * (\text{TC}_{\text{feeder}} - 1))) = 265 * 1 * (1 - 0.15 * 1 - 1))) = 265$

In the case of the direct service option,

$$\text{Fleet}_{\text{direct}} = \frac{\text{MaxLoadperCycle}_{\text{direct}}}{\text{VSize} * \text{LoadFactor}} = \frac{450}{60} = 7.5(ROUNDUP) = 8$$

In the case of the trunk-and-feeder option:

$$\text{Fleet}_{\text{trunk}} = \frac{\text{MaxLoadperCycle}_{\text{trunk}}}{\text{VSize} * \text{LoadFactor}} = \frac{265}{60} = 4.417(ROUNDUP) = 5$$

$$\text{Fleet}_{\text{feeder}} = \frac{\text{MaxLoadperCycle}_{\text{feeder}}}{\text{VSize} * \text{LoadFactor}} = \frac{265}{60} = 4.417(ROUNDUP) = 5$$

So:

$$\text{Fleet}_{\text{directbenefit}} = (\text{Fleet}_{\text{trunk}} + \text{Fleet}_{\text{feeder}}) – \text{Fleet}_{\text{direct}} = (5 + 5) – 8 = 2\text{vehicles}$$

We save two vehicles by using direct services over a trunk-and-feeder service plan on this route. One way to think about this is that the peak demand in the mixed traffic section of the routes occurs earlier in the day, so the same vehicles in a direct services service plan needed to serve the peak-hour demand on the mixed traffic “feeder” portion of the route can continue past the terminal and serve the peak-hour demand, occurring slightly later, on the trunk. With the trunk-and-feeder service plan, buses need to serve the peak demand on the feeder routes at close to the same time as on the trunk. So, while it is peak time for the feeders, the trunk vehicles are waiting, and then, as the peak demand shifts toward the trunk, some of the feeder vehicles will be unused. A direct services service plan therefore uses a smaller fleet because it optimizes the fleet by serving the demand as it moves through the corridor.

In this example, the benefit was evaluated for just one route. If one does the analysis for ten equivalent routes, and all have the same TC, the difference in fleet would be multiplied by ten, and the difference becomes significant.

6.6.2 Vehicle Size Optimization Benefits for Trunk-and-Feeder versus Direct Services

The main advantage of a trunk-and-feeder service is that the demand on the feeder routes, which in isolation would be served by small vehicles with high operating costs per customer, can be combined on the trunk portion of the route, so that customers from multiple feeder routes can all use a much larger trunk vehicle. Because large vehicles at high occupancy levels have lower operating costs per customer than smaller vehicles, there is a benefit of lower vehicle operating costs with trunk-and-feeder services in appropriate conditions. This section identifies easy ways of spotting what those conditions are, to conclude the following:

The greater the number of routes being combined into a trunk route, and the greater the proportion of the total trip that is taken up by the trunk portion of the trip, the greater the benefit.

Applying the formulas presented before, the benefits of optimal fleet size can be compared under different service plan alternatives as applied to some typical conditions. In both scenarios simplified examples are first introduced to illustrate general principles, and then the general formulas are applied to more real-world situations.

6.6.2.1 Vehicle size optimization with several similar feeder routes:

In this example, one looks at the benefits of trunk-and-feeder systems from using bigger vehicles on the trunk portion of the route for BRT projects where the following conditions apply:

- *A* All routes have similar demand;
- *B* All routes extend beyond the trunk corridor for a similar distance and at similar speeds, and all routes leave the trunk corridor at roughly the same place;
- *C* The peak-hour load ($MaxLoad$) for the trunk is similar to the peak-hour load for all of the combined feeders;
- *D* No transfer time is required to get from the feeder vehicle to the trunk vehicle, just waiting time;
- *E* No extra time is required for vehicles to pull off the BRT trunk corridor and enter a transfer terminal;
- *F* There is no peak in the demand (i.e., PHtoCC $= 0$). In other words, demand is constant throughout the day, such that the effect of the peak factor on the overall fleet size does not apply.

  The following is assumed:
- There are five routes that have the same itineraries on the BRT corridor, with the same characteristics, N_{routes}: number of routes $= 5$;
- The cycle time on the part of the service that overlaps the BRT trunk infrastructure is assumed to be two hours. $TC_{\text{trunk}} = 2$;
- The cycle time on the part of the service that operates in mixed traffic beyond the trunk corridor is 0.6 hours; $TC_{\text{feeder}} = 0.6$;
- Other variables determinant to the optimal bus size and waiting costs are equal for all routes, in the two alternatives (direct service and trunk-and-feeder service):
  - Bus FixedCost = US$30/per bus-hour;
  - Renovation factor = 1.5;
  - (Frequency) Irregularity = 0.3;
  - Waiting cost per passenger = US$12/hour;
  - Design Load Factor = 0.85.

We also assume that the total fixed operating costs are simply the sum of the fixed operating cost per vehicle times the fleet (i.e., no other fixed costs are being considered), or:

Eq. 6.9:

$$\text{RouteFixedCost} = \text{BusFixedCost} * \text{Fleet}_{\text{route}}$$

Where:

- RouteFixedCost: Total fixed operational cost for the route;
- BusFixedCost: Fixed operating costs per vehicle;
- $\text{Fleet}_{\text{route}}$: Number of buses needed to operate the route.

It is also assumed that the maximum load on the trunk route is the same as the number of routes times the maximum load of each route combined; for each route we will assume a MaxLoad of a hundred passengers per hour:

Eq. 6.44

$$\text{MaxLoad}_{\text{trunk}} = N_{\text{routes}} * \text{MaxLoad}_{\text{iroute}}$$

Where:

- $\text{MaxLoad}_{\text{trunk}}$: MaxLoadtrunk = Maximum hourly load on the trunk;
- N_{routes}: Number of routes;
- $\text{MaxLoad}_{\text{iroute}}$: Maximum hourly load on the "i" route.

As was explained earlier, the optimal vehicle size depends on the point where the combined value of people's time waiting (which is lower with higher frequency and smaller vehicles) and the total fixed costs (which are lower with larger vehicles) are minimized, as laid out by Equation 6.16. We therefore need two more variables:

$$\text{VSize}_{\text{optimum}} * \text{LoadFactor} = \sqrt{\frac{\text{BusFixedCost} * \text{MaxLoadperCycle}_{\text{route}}}{\text{Ren}_{\text{route}} * \text{Costwait} * 0.5(1 + Irr_{\text{route}})}}$$

For this case, where demand is flat ($\text{MaxLoadperCycle} = \text{MaxLoad}_{\text{route}} * TC$), this means:

$$\text{VSize}_{\text{optimum}} * \text{LoadFactor} = \sqrt{\frac{\text{BusFixedCost} * \text{MaxLoad}_{\text{route}} * TC}{\text{Ren}_{\text{route}} * \text{Costwait} * 0.5(1 + Irr_{\text{route}})}}$$

To determine whether, in this scenario, the direct service option or the trunk-and-feeder service option is better, the total waiting and fixed costs of the two scenarios (given by Equations 6.12 and 6.13 below) need to be compared. Equations 6.12 and 6.15:

$$\text{WaitCost}_{\text{route}} = \text{Ren}_{\text{route}} * \text{Cost}_{\text{wait}} * 0.5 * (1 + Irr_{\text{route}}) * \text{LoadFactor} * \text{VSize}$$

$$\text{FixedCost}_{\text{route}} = \frac{\text{BusFixedCost} * \text{MaxLoadperCycle}_{\text{route}}}{\text{VSize}_{\text{route}} * \text{LoadFactor}}$$

For the formulas above:

- $\text{WaitCost}_{\text{route}}$: Total waiting time cost generated to the route users (in \$);;
- $\text{VSize}_{\text{route}}$: Vehicle serving the route capacity;
- LoadFactor: Design load factor (usually 0.85).
- $\text{MaxLoadperCycle}_{\text{route}}$: Maximum demand across the critical segment of the route that will accumulate for the duration of one cycle during the busiest moment of the typical day (see Subsection 6.3.13);
- MaxLoad: Maximum demand across the critical segment of the route;
- TC:Cycle time of the route;
- $\text{FixedCost}_{\text{route}}$: Total fixed operating cost for the route (in US\$/hour) (= WaitCostRoute when VSize is optimum)

- $\text{Ren}_{\text{route}}$: Renovation factor of the route;
- Costwait Average user waiting cost ($/time);
- Irrroute: Irregularity index of the route; measure of the variance between the actual headways and the scheduled headways (usually near 0.3, see Section 6.3.9);

  Direct services:

$$\text{VSize}_{\text{opt-direct}} * \text{LoadFactor} = \sqrt{\frac{\text{BusFixedCost} * \text{MaxLoad}_{\text{direct}} * TC}{\text{Ren}_{\text{route}} * \text{Costwait} * 0.5(1 + Irr_{\text{direct}})}}$$

$$\text{VSize}_{\text{opt-direct}} * 0.85 = \sqrt{\frac{30 * 100 * 2.6}{1.5 * 12 * 0.5(1 + 0.3)}} = 25.82$$

$$\text{VSize}_{\text{opt-direct}} = 30$$

Trunk-and-feeder option

$$\text{VSize}_{\text{opt-trunk}} * \text{LoadFactor} = \sqrt{\frac{\text{BusFixedCost} * \text{MaxLoad}_{\text{trunk}} * TC}{\text{Ren}_{\text{route}} * \text{Costwait} * 0.5(1 + Irr_{\text{trunk}})}}$$

$$\text{VSize}_{\text{opt-trunk}} * 0.85 = \sqrt{\frac{30 * 500 * 2.0}{1.5 * 12 * 0.5(1 + 0.3)}} = 50.64$$

$$\text{VSize}_{\text{opt-trunk}} = 60$$

$$\text{VSize}_{\text{opt-feeder}} * \text{LoadFactor} = \sqrt{\frac{\text{BusFixedCost} * \text{MaxLoad}_{\text{feeder}} * TC}{\text{Ren}_{\text{route}} * \text{Costwait} * 0.5(1 + Irr_{\text{feeder}})}}$$

$$\text{VSize}_{\text{opt-feeder}} * 0.85 = \sqrt{\frac{30 * 100 * 0.6}{1.5 * 12 * 0.5(1 + 0.3)}} = 12.40$$

$$\text{VSize}_{\text{opt-direct}} = 15$$

The comparative cost of the two scenarios can now be calculated for both alternatives; when the vehicle size is optimal, the total cost of waiting is equal to the total fixed costs (see Section 6.4.3); as such, it is enough to double either one:

$$\text{WaitCost}_{\text{direct}} = \text{Ren}_{\text{route}} * \text{Cost}_{\text{wait}} * 0.5 * (1 + Irr_{\text{direct}}) * \text{LoadFactor} * \text{VSize}_{\text{direct}}$$

$$\text{WaitCost}_{\text{direct}} = 1.5 * 12 * 0.5 * (1 + 0.3) * 0.85 * 30 = 298.35\$$$

As there are 5 direct routes, the wait cost plus the fixed costs for this alternative is 10 times the wait cost, i.e., US$2,983.50.

$$\text{WaitCost}_{\text{trunk}} = \text{Ren}_{\text{route}} * \text{Cost}_{\text{wait}} * 0.5 * (1 + Irr_{\text{trunk}}) * \text{LoadFactor} * \text{VSize}_{\text{trunk}}$$

$$\text{WaitCost}_{\text{trunk}} = 1.5 * 12 * 0.5 * (1 + 0.3) * 0.85 * 60 = 596.70\$$$

$$\text{WaitCost}_{\text{feeder}} = \text{Ren}_{\text{route}} * \text{Cost}_{\text{wait}} * 0.5 * (1 + Irr_{\text{feeder}}) * \text{LoadFactor} * \text{VSize}_{\text{feeder}}$$

$$\text{WaitCost}_{\text{feeder}} = 1.5 * 12 * 0.5 * (1 + 0.3) * 0.85 * 15 = 149.17\$$$

As there are five feeder routes, the wait cost plus the fixed costs for the trunk-and-feeder alternative is 10 times the feeder wait cost plus two times the trunk wait cost, i.e., US$2,685.15 US$ (1,491.75 + 1,193,40).

In this example, the trunk-and-feeder system yields about a 13 percent benefit in total costs over the direct service alternative. This is entirely due to the savings made possible by the returns to scale from using larger vehicles.

Box 6.3. Estimating the range of benefit from vehicle size optimization due to trunk-and-feeder operations

If one runs several scenarios, one finds that there is a pattern to the conditions in which there will be benefits from fleet optimization from a trunk-and-feeder system over a direct service system.

It turns out that two parameters determine the degree of benefit likely to happen from conversion of a direct service into a trunk-and-feeder service purely from the perspective of the vehicle size optimization: cycle times for each part of the service. So one must consider the proportion of time spent on the feeder portion of the route vis-à-vis the time spent on the trunk portion of the route (Fpr) as follows:

$$F_p r = \frac{TC_{\text{feeder}}}{TC_{\text{trunk}}}$$

Eq. 6.45

$$TC_{\text{feeder}} = F_p r * TC_{\text{trunk}}$$

Where:

- $F_p r$: Proportion of time spent on the feeder portion of the route vis-à-vis the time spent on the trunk portion of the route;
- TC_{Trunk}: Cycle time in hours for a vehicle to complete one circuit of the trunk service;
- TC_{Feeder}: Cycle time in hours for a vehicle to complete one circuit of the feeder service.

After some reformulation where only Nroute and Fpr determine the outcome, it turns out that, if the assumptions for this section hold, trunk-and-feeder services will yield benefits in a condition where:

Eq. 6.46

$$F_p r < \frac{(N_{\text{route}} - 1)^2}{4 * N_{\text{route}}}$$

Where:

- $F_p r$: Proportion of time spent on the feeder portion of the route vis-à-vis the time spent on the trunk portion of the route;
- N_{route}: Number of routes being combined into the same trunk part of the service.

In other words, with just the number of feeder routes and their cycle time as a proportion of the trunk, one can already have a reasonable sense of the degree of benefit from shifting to a trunk–feeder system (if one ignores all the other costs and benefits associated with trunk-and-feeder services versus direct services).

In this ideal case, there will be a generalized cost reduction from shifting from a direct service to a trunk-and-feeder service. This is shown in the next figure. The line below shows the slope ofi $F_{pr} = \frac{(N-1)^2}{(4 * N_{\text{route}})}$

For any combination above the line there is no benefit, and for any combination below the line there is a benefit to shifting to trunk-and-feeder under these conditions.

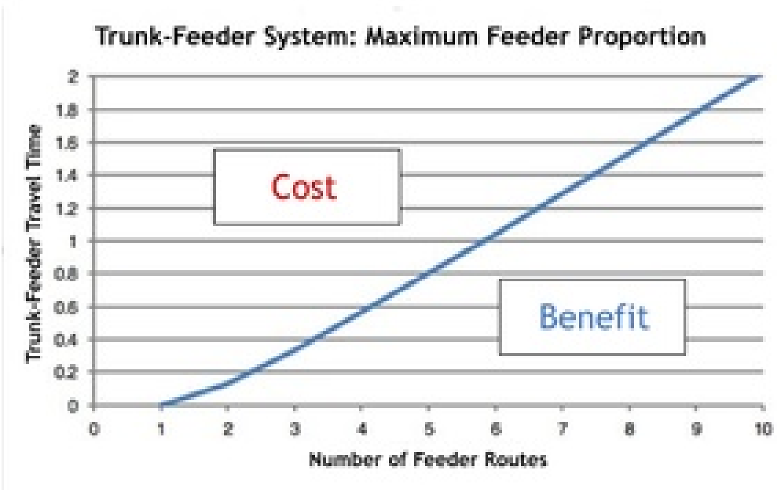

Figure 6.44. Conditions under which benefits can be accrued from vehicle size optimization in a trunk-and-feeder system: The blue line above shows the points at which the benefits and costs of direct services and trunk-and-feeder services are equal, determined by two variables: the proportion of the total trip time that takes place on the feeder route (y axis) and the total number of feeder routes that share the trunk demand (x axis). Image *Pedro Szász*.

If all the possible outcomes are plotted as different combinations of the number of routes ($N_{\text{route}} = n$ in the figure) and the feeder portion cycle time as a proportion of total cycle time F_pr. It would be found that the benefits fall in the ranges shown in Figure 6.45.

The yellow line, for instance, indicates that the maximum benefit for a system where the direct service originally had only three routes ($n = 3$), and the cycle time beyond the trunk is only 20 percent of the total cycle time ($Fpr = 0.1$).

The maximum total cost benefit is only 5 percent. In such circumstances, it will be nearly impossible to recover the other losses associated with trunk-and-feeder services from the benefits of optimizing the vehicle size.

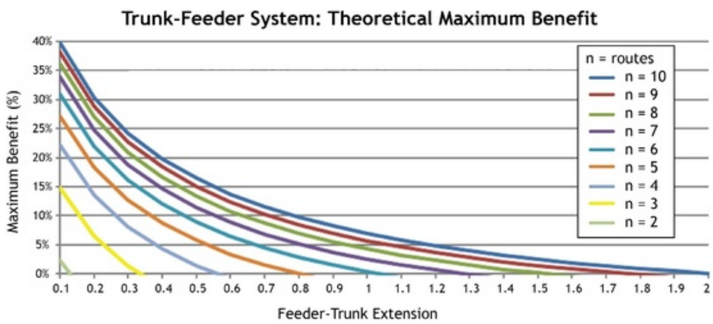

Figure 6.45. Range of possible benefits from vehicle size optimization from for trunk-and-feeder systems, depending on the number of routes (each line) and the share of the total trip time accounted for by the feeder route (x axis). *Pedro Szász*.

This points to the fact that, if there are a lot of small direct service routes that overlap for a long distance with the trunk corridor, each route will have a relatively low demand and will optimally use small vehicles. If the small direct routes along the trunk route are turned into trunk-and-feeder services, customers on each low-demand route would share the use of a much larger vehicle, realizing returns to scale in the fixed cost of vehicles.

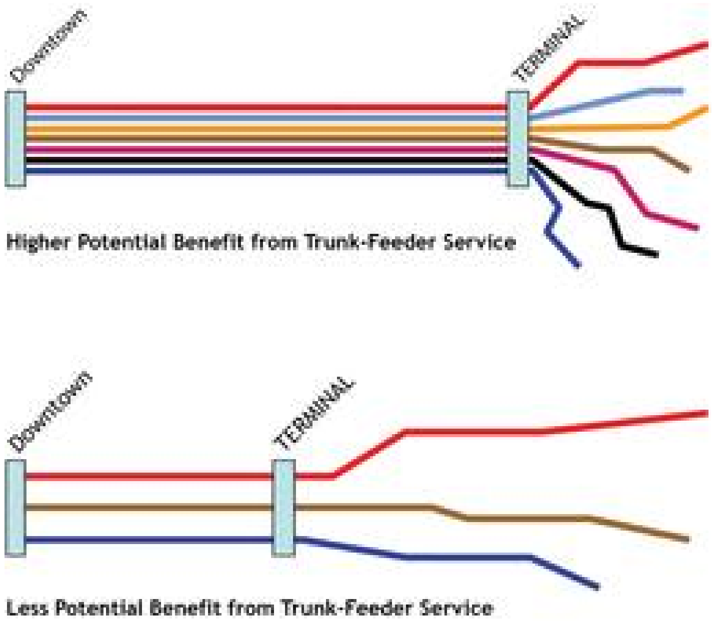

Figure 6.46. Visual comparison of situations that can yield more benefits from the shift from direct service to trunk-and-feeder services. *ITDP.*

If the number of routes is low, the demand will be split among a smaller number of routes, so the original routes will already be using larger buses. Further, if the routes share only a short section of the trunk, the distance available for larger vehicles to reap benefits would be smaller, so there would be less benefit.

The smaller services with low demand have the greater benefits from joining the trunk-and-feeder system to achieve returns to scale. As with any collective, the more people who join, and the longer they remain members, the greater the benefit.

In summary, a corridor that has a long trunk and short feeder extensions and more routes, rather than fewer sharing the total demand, the greater the chances that a trunk-and-feeder system will bring benefits.

6.6.2.2 Calculating the Benefits of a Trunk-and-Feeder System for Corridors with Multiple Routes of Different Characteristics

Usually, when planning a BRT system, most of the routes using a BRT corridor are different, and determining the benefits of a trunk-and-feeder operation in those conditions is complicated. This section outlines a methodology that will be applicable in some real-world conditions. In this scenario, to make things simpler, some of the same assumptions from the previous scenario still hold.

- *A* Trunk segment (and time) is the same for all routes.
- *B* No transfer time is required to get from the feeder vehicle to the trunk vehicle, just waiting time.
- *C* No extra time is required for vehicles to pull off the BRT trunk corridor and enter a transfer terminal.
- *D* PHtoCC = 0, there is no peak factor. In other words, it can be assumed that the demand is constant throughout the day, such that the effect of the peak factor index on the overall fleet size does not apply, so there is no fixed operating costs (Cf) disadvantage to converting to trunk-and-feeder services related to smaller fleet size.

However, in this case, each bus route is allowed to vary in the length that it overlaps the trunk corridor and in the cycle time.

In these conditions, one explores how to answer the following questions:

1. Knowing that shifting all routes from direct services to a trunk-and-feeder system yields benefits, will there still be benefits if only some of the routes are changed to trunk-and-feeder?
2. Is the maximum benefit obtained when all routes are converted to trunk-and-feeder, or when routes are selectively converted based on their demand profile?
3. How is the optimum case determined?

We approach these questions in a similar manner to the subsection: *Scenario II: Dwell Times and Demand Vary from Route-to-Route, and All Stations Are Similar*, to decide which routes should be included in the busway, by calculating the benefits generated by shifting successive routes to trunk-and-feeder service starting from the condition where all routes are direct services. In order to analyze the theoretical behavior, the exercise allows for every possible bus size. In real operation planning, one has to select among the existing bus capacities (accepting design load factors up to 0.9 also comes into play) and calculate fixed costs and waiting costs (no longer equal) based on the resulting number of buses.

Each route has two basic characteristics that vary in this example:

- Maximum Load for route "i" $= \text{MaxLoad}_i$;
- Cycle time on feeder part of route "i" $= TC_{i\text{-feeder}}$

With these two parameters, the following equations are obtained:

$\text{MaxLoadperCycle}_{i\text{-direct}} = \text{MaxLoad} * TC_i$;

$$\text{MaxLoadperCycle}_{i\text{-trunk}} = \text{MaxLoad} * TC_{i\text{-trunk}}$$

$$\text{MaxLoadperCycle}_{i\text{-feeder}} = \text{MaxLoad} * TC_{i\text{-feeder}}$$

Where:

- MaxLoad_i: Maximum hourly load for route "i" in the critical link;
- $\text{MaxLoadperCycle}_{i\text{-direct}}$: Maximum load (or the number of passenger places required) on the direct service per cycle time for route "i";
- $\text{MaxLoad}_{i\text{-trunk}}$: Maximum load (or the number of passenger places required) on the trunk part of service per trunk cycle time ($TC_{i\text{-trunk}}$) for route "i";
- $\text{MaxLoadperCycle}_{i\text{-feeder}}$: Maximum load (or the number of passenger places required) on the trunk part of service per trunk cycle time ($TC_{i\text{-feeder}}$) for route "i";
- TC_i: cycle time for route "i," could be also represented as TCi-direct;
- $TC_{i\text{-feeder}}$: Cycle time in hours for a vehicle to complete one circuit of the feeder part of route "i";
- $TC_{i\text{-trunk}}$: Cycle time in hours for a vehicle to complete one circuit of the trunk part of route "i."

This means that the feeder services should supply places during the peak hour to meet the maximum load on the critical link of the feeder route, which is assumed to be close to the terminal.

Our example considers eight routes as defined in Table 6.27 where the trunk part of all routes needs 1.3 hours and the assumption that $TC_{i\text{-direct}} = TC_{i\text{-trunk}} + TC_{i\text{-feeder}}$ is still valid.

Table 6.27. Example of Routes to Be Considered for Trunk-and-Feeder Service

Route	Cycle times			Maximum Load	Maximum Load per Cycle		
	As direct service	Trunk part (as trunk-feeder)	Feeder part (as trunk-feeder)		As direct service	Trunk part (as trunk-feeder)	Feeder part (as trunk-feeder)
i	TC_direct	TC_trunk	TC_feeder	MaxLoad	MaxLoadper Cycle_direct = MaxLoad * TC_direct	MaxLoadper Cycle_trunk = MaxLoad * TC_trunk	MaxLoadper Cycle_feeder = MaxLoad * TC_feeder
unit-->	hour	hour	hour	pax/hour	pax	pax	pax
A	1.8	1.3	0.5	400	720	520	200
B	2	1.3	0.7	200	400	260	140
C	3.3	1.3	2.0	100	330	130	200
D	1.9	1.3	0.6	500	950	650	300
E	1.7	1.3	0.4	800	1360	1040	320
F	1.5	1.3	0.2	400	600	520	80
G	2.3	1.3	1.0	800	1840	1040	800
H	5.3	1.3	4.0	2000	10600	2600	8000

Other variables that determine the optimal bus size and waiting costs are equal for all routes in the two alternatives (direct service and trunk-and-feeder service):

- BusFixedCost = US$30/per bus-hour;
- Renovation factor = 1.5;
- (Frequency) Irregularity = 0.3;
- Wait cost per passenger = US$12/hour;
- Design Load Factor = 0.85.

The equations are the same: Eq. 6.16a, Eq. 6.12, and Eq. 6.18 (taking into account the fixed operating costs per vehicle, BusFixedCost):

$$\text{VSize}_{\text{optimum}} * \text{LoadFactor} = \sqrt{\frac{\text{BusFixedCost} * \text{MaxLoad}_{\text{route}} * TC}{\text{Ren}_{\text{route}} * \text{Costwait} * 0.5(1 + Irr_{\text{route}})}}$$

$$\text{WaitCost}_{\text{route}} = \text{Ren}_{\text{route}} * \text{Cost}_{\text{wait}} * 0.5 * (1 + Irr_{\text{route}}) * \text{LoadFactor} * \text{VSize}$$

$$\text{FixedCost}_{\text{route}} = \frac{\text{BusFixedCost} * \text{MaxLoadperCycle}_{\text{route}}}{\text{VSize}_{\text{route}} * \text{LoadFactor}}$$

Where:

- $\text{VSize}_{\text{optimum}}$: Optimum vehicle size;
- LoadFactor: Design load factor (usually 0.85).
- BusFixedCost: Fixed operating costs per vehicle;
- $\text{WaitCost}_{\text{route}}$: Total waiting time cost generated to the route users (in $);;
- $\text{MaxLoad}_{\text{route}}$: Route demand on the critical link;
- TC:Cycle time of the route;
- $\text{Ren}_{\text{route}}$: Renovation factor of the route;
- $\text{Costwait}_{\text{route}}$ Average user waiting cost ($/time);
- Irrroute: Irregularity index of the route; measure of the variance between the actual headways and the scheduled headways (usually near 0.3, see Section 6.3.9);
- VSize: Vehicle capacity;
- $\text{FixedCost}_{\text{route}}$: Total fixed operating cost for the route (in US$/hour) (= WaitCostRoute when VSize is optimum)
- $\text{MaxLoadperCycle}_{\text{route}}$: Maximum demand across the critical segment of the route that will accumulate for the duration of one cycle during the busiest moment of the typical day (see Subsection 6.3.13);

In order to decide which should be changed, the routes should be situated in ascending order of places ($\text{MaxLoadperCycle}_{\text{feeder}}$) that each feeder route brings to the trunk service. Routes bringing fewer places to the trunk corridor will benefit more from being integrated into the trunk-and-feeder system, because these routes, in a direct service arrangement, will have the smallest vehicles.

Then the following should be calculated for each route:

- Optimal bus size and the sum of fixed plus waiting costs for operation as direct service;
- Optimal bus size and sum of fixed plus waiting costs for the feeder part of the route as if operated as trunk-and-feeder;

- Optimal bus size and sum of fixed plus waiting costs for the trunk assuming all routes classified as if operated as trunk-and-feeder.

With that, the overall benefits of fixed plus waiting costs of each alternative from splitting an additional route into separate feeder-and-trunk services can be calculated. The steps for the example are shown in Table 6.28.

Table 6.28. Route Selection to Shift from Direct to Trunk-and-Feeder Service

Ranking for route shifting from Direct to Trunk-and-feeder													
Route	**Maximum Load per Cycle**				Optimal Bus Size			Fixed + Wait Cost during peak-hour					
	As direct service	Trunk part (as trunk-feeder)	Feeder part (as trunk-feeder)	Accumulated for trunk service with the above	As direct service	Feeder part (as trunk-feeder)	Trunk (as trunk-feeder, for row and all routes above)	As direct service	Feeder part (as trunk-feeder)	Trunk part (as trunk-feeder for all routes above)	Accumulated direct (for all routes bellow)	Accumulated feeder (for this and all routes above)	**Direct (bellow) + Trunk-feeder (this and above) services**
i	MaxLoadper Cycle_direct = MaxLoad * TC_direct	MaxLoadper Cycle_trunk = MaxLoad * TC_trunk	MaxLoadper Cycle_feeder = MaxLoad * TC_feeder	Sum MaxLoadperCycle _trunk	Vsize_optimum_i-type * LoadFactor= SQRT { (BusFixedCost * MaxLoadperCycle_i-type) / (Ren * Cost_wait * 0.5 (1+Irr)) }			Cost_i-serv = 2 * Ren * Cost_wait * 0.5 (1+Irr)) * LoadFactor * Vsize_i-serv			Sum (Cost_i-direct)	Sum (Cost_i-feeder)	**Cost_i-trunk + Sum (Cost_i-feeder) + Sum (Cost_i-**
unit-->	pax	pax	pax	pax	pax	pax	pax	$/hour	$/hour	$/hour	$/hour	$/hour	**$/hour**
										0	11,355	**0**	**11,355**
F	600	520	80	520	39.22	14.32	36.51	918	335	854	10,437	335	**11,627**
B	400	260	140	780	32.03	18.95	44.72	749	443	1,046	9,688	778	**11,513**
C	330	130	200	910	29.09	22.65	48.30	681	530	1,130	9,007	1,308	**11,446**
A	720	520	200	1430	42.97	22.65	60.55	1,005	530	1,417	8,002	1,838	**11,257**
D	950	650	300	2080	49.35	27.74	73.03	1,155	649	1,709	6,847	2,487	**11,043**
E	1360	1040	320	3120	59.05	28.64	89.44	1,382	670	2,093	5,465	3,158	**10,716**
G	1840	1040	800	4160	68.69	45.29	103.28	1,607	1,060	2,417	3,858	4,217	**10,492**
H	10600	2600	8000	6760	164.86	143.22	131.66	3,858	3,351	3,081	0	7,569	**10,650**

On the table, one can now compare scenarios. The first column "F" is a scenario where only the former direct service Route "F" has been converted to a trunk route and a feeder route. Then it is assumed that the remainder of the service is direct. The cost of servicing the remainder of the demand in the corridor with direct services is calculated thus:

- Total cost of waiting and fixed operating costs on the remaining direct service routes equals total cost of all direct service routes less the route converted to trunk-and-feeder, or:

$$Cwf_{\text{remaining direct lines}} = Cwf_{\text{all routes direct}} - Cwf_{\text{direct route F}}$$
$$= 11,355–918 = 10,437$$

The total cost of a scenario where only Route F is converted to a trunk-and-feeder service, and all the remaining routes remain direct service routes, is just the cost of the trunk service, plus the cost of the feeder service, plus the cost of the remaining direct services, or:

$$Cwf_{\text{total Scenario F}} = 854 + 335 + 10,437 = 11,627$$

In the second scenario, row "B," both Route F and Route B are converted to a trunk-and-feeder services, and all the other routes remain direct services. All of the columns are calculated in the same manner.

Unlike the costs of the feeder routes and the direct service routes, which will not change depending on how many routes there are, the trunk route will have decreasing costs the more routes that join the trunk-and-feeder service, as the maximum load and hence the vehicle size will increase the more small routes that join. The trunk-and-feeder system, under this specific set of assumptions, becomes more efficient than the direct-service-only system once the three best routes for conversion (F, B, and A) are added to the trunk-and-feeder service, as the total costs of the direct-service-only scenario (11,355) are greater than the trunk-and-feeder with F, B, and A scenario (11,342). The benefits continue to accrue as more routes are converted to trunk-and-feeder until Route H is added. Route H is particularly unsuited to trunk-and-feeder operations, because it has a very high demand on its own; has a very high frequency on its own; uses a very large vehicle size on its own; and continues well beyond the trunk corridor for some distance. With these characteristics, it is a prime candidate for a route that should continue to function as a direct service.

Figure 6.47 is a graph of the overall cost structure of each alternative:

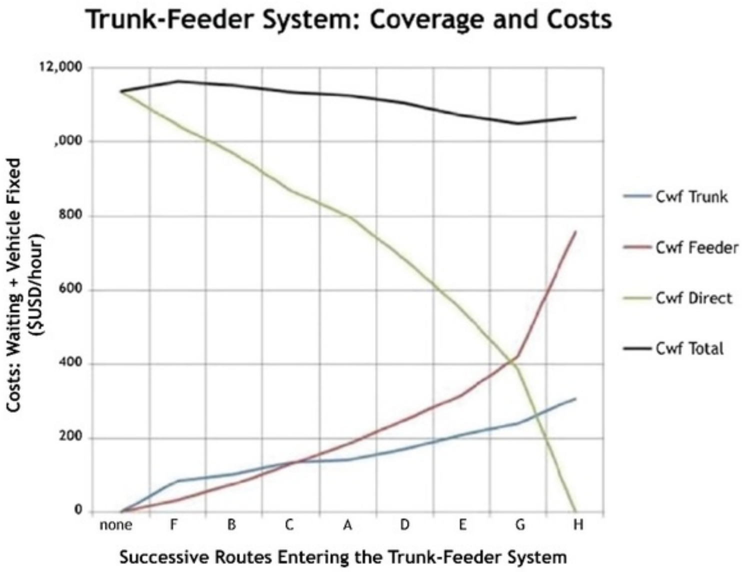

Figure 6.47. This is one possible set of cost curves that represents the total system costs as more preexisting direct service routes are converted to trunk-and-feeder routes, once all preexisting direct services are ranked based on the number of potential customers the feeder route brings to the trunk corridor. As more routes are converted to trunk-and-feeder, the cost of operating the trunk and the feeder routes increases, the cost of operating the remaining direct routes decreases, and the total system cost in this example continues to fall until the routes bringing the largest volume of customers to the trunk are converted, at which point total system costs increase. *Pedro Szász.*

So as expected trunk-and-feeder system costs are growing, and normal route costs are decreasing. Figure 6.48 shows just the total cost:

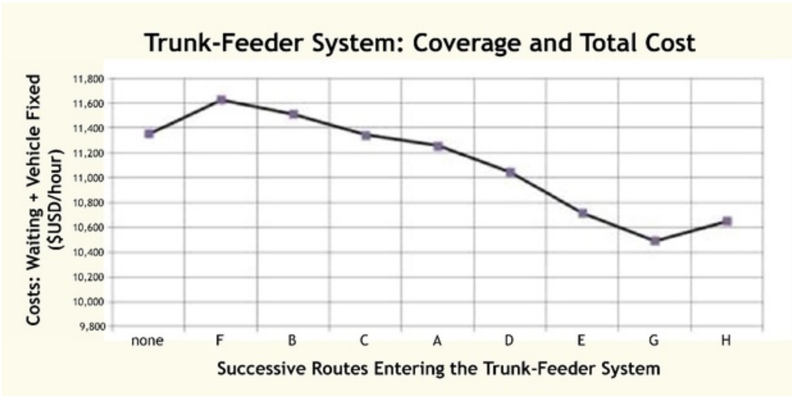

Figure 6.48. Close up of total system costs only from Figure 6.47. *Pedro Szász.*

Box 6.4. Exercise to demonstrate the effectiveness of a trunk-and-feeder system

Continuing with the same methodology from above, one finds that if the trunk route is very long and carries a lot of demand, the costs will continue to fall as more routes are converted to trunk-and-feeder.

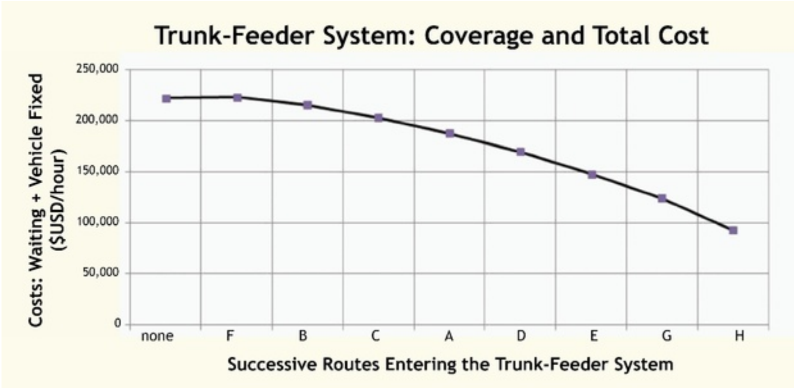

Figure 6.49. Likely total system cost curve if there are many feeder routes and the feeders only constitute a short portion of total trip time. Graph *Pedro Szász.*

Conversely, if the trunk portion of the total route is very short, and most of the customers are going well beyond the trunk corridor, converting more routes to trunk-and-feeder will only increase overall system costs.

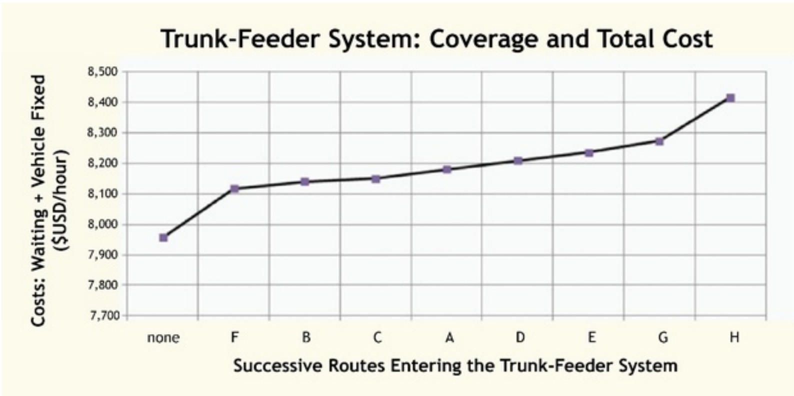

Figure 6.50. Likely total system cost curve if feeder route travel time is greater than trunk travel time. Graph *Pedro Szász.*

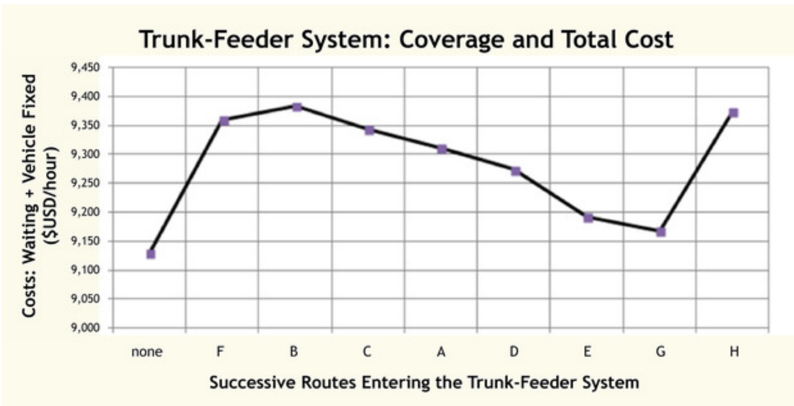

Figure 6.51. Likely cost curve if there are feeder routes of varying length but in general the time spent on the feeder route is long relative to the time spent on the trunk route. Graph *Pedro Szász.*

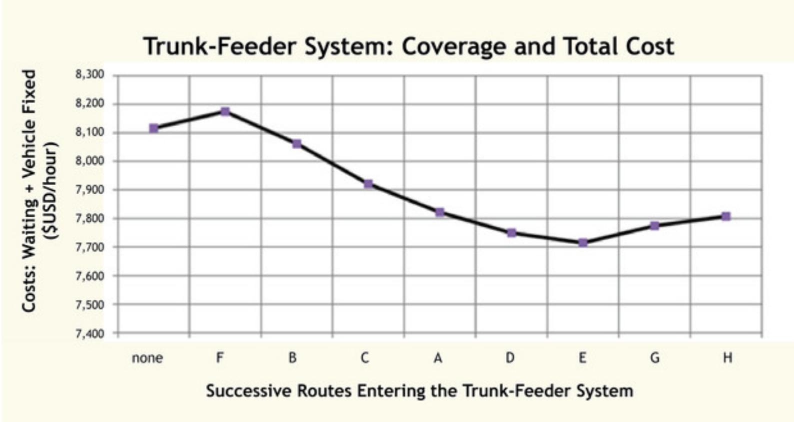

Figure 6.52. Likely cost curve for feeder routes of various travel times but where in general feeder route travel times are short relative to total travel time. *Pedro Szász.*

This exercise, while simplified from real-world conditions by a number of assumptions, demonstrates the general concept that the effectiveness of a trunk-and-feeder system depends on whether it makes sense for a critical mass of routes. Once it makes sense to convert a critical mass of routes to a trunk-and-feeder system, it becomes easier and easier to add more routes to the system profitably. Once trunk-and-feeder reaches critical mass, only very high volume routes continuing well beyond the trunk system are likely to still be profitably excluded from the trunk feeder system and retained as direct services. As such, there are mathematical reasons why there is a tendency toward systems with all direct services or all trunk-and-feeder services.

6.6.3 Transfer and Terminal Delay

Splitting an existing direct service route into a trunk route and a feeder route will add several types of additional delay relating to the new required transfer. First, if transfer facilities are not located in an optimal location, or if access to the facility is poorly designed, vehicles will have to go out of their way to make the transfer possible, described as "negative distances," increasing vehicle cycle times, and hence fleet requirements and operating costs. Second, transfers add significantly to customer travel times and discomfort since customers must walk from one bus route to the next. Avoiding transfer delays is often one of the main reasons discretionary riders elect not to use a system. Further, if transfers involve any form of physical hardship, such as stairs, tunnels, or exposure to rain, cold, or heat, then the system's acceptability is even more compromised.

Not all transfers are equal. On one extreme are transfers located far from the trunk corridor involving slow and circuitous detours for both trunk routes and feeder routes to reach the transfer station, and lengthy walks across intersections and other obstacles unprotected from rain and sun. At the other extreme there are transfers made directly on a trunk corridor where many feeder services converge, with excellent terminal design involving minimal vehicle diversion and a simple few meters to walk across a comfortable, safe, and weather-protected platform. The quality of the transfer depends largely on the infrastructure and route design.

When considering whether to implement a trunk-and-feeder service, a direct service, or some combination, it is critical to calculate the likely delays caused by the forced transfer under the specific conditions being proposed for the system.

6.6.3.1 Additional Passenger Delay Waiting for the Trunk Vehicle or Feeder Vehicle and Boarding and Alighting Again

When customers on a former direct service route now need to take a feeder vehicle and transfer at some point to a trunk vehicle, and this transfer point tends to be near where the bus route is at its maximum load, the maximum load of customers will now have to wait for the trunk vehicle in the morning and the feeder vehicle in the afternoon. These customers will face a waiting cost of half the headway of the trunk, or half the headway on their feeder route, depending on which direction they are going.

Since customers have to alight from the first vehicle and board a second one, there is an additional boarding and alighting delay per customer who needs to transfer. This additional delay will simply be the total boarding and alighting delay at the transfer station multiplied by the total number of transferring customers.

6.6.3.2 Extended Vehicle Running Time Due to Route Modifications Required by the Suboptimal Location of the Transfer Terminal

In all of the examples of trunk-and-feeder systems proposed in this section, all the routes pass a common point where they would diverge, so the location of a transfer terminal was simple and caused no additional travel time penalty. However, in most cases, the location of the terminal will serve some routes better than others. There will be some routes that will be pulled off their original route to reach a new common terminal point. In Figure 6.53, one of three vehicle routes is diverted from its original path because the terminal is not located where it originally departed the BRT corridor. This causes additional delay for all customers and additional operating time and cost for the vehicle operator. Some empirically observed ranges of additional minutes of running time on a route have been shown, but this will need to be measured on a route-by-route basis.

In addition, there is often no land readily available directly on the trunk corridor, so the terminal will need to be located where lower-cost land is available at some larger distance from the original trunk route. Terminals typically require a lot of land. In addition to accommodating other feeder services, terminals are places where vehicles turn around or park during off-peak periods (staging areas), and that requires space, too.

In most real-world cases, instead of placing a terminal at the natural convergence point of the existing bus routes, the terminal is located some blocks away on a piece of land owned by the municipality or that can be acquired otherwise at low cost. This adds two types of additional delay. It creates extra travel distance, possibly for both the trunk and the feeder vehicles, and it doubles the cycle time for vehicles traveling from the original corridor.

If the BRT trunk infrastructure is not extended all the way to the terminal, as is sometimes the case, the reduced speeds of the additional travel distance also need to be factored into the additional delay caused by the terminal being off corridor. Often, these access and egress roads around the terminal require complex new multiphase traffic signals, narrow, congested streets and other causes of slow speeds that did not affect the original direct service route that operated entirely on a major arterial.

As an example of this situation, in León, Guanajuato, Mexico, the terminal is 600 meters away from the main trunk corridor on Lopez Mateos Avenue (Figure 6.55). In addition to the delay due to the 600-meter diversion, the speeds on the terminal access road are lower than on the original arterial, and additional signal delay was introduced in order to provide turning access to enter and exit the terminal.

Another example is on Corridor 9 de Julho/Santo Amaro, in São Paulo, where the transfer terminal is 500 meters away from the natural connection point (Figure 6.56).

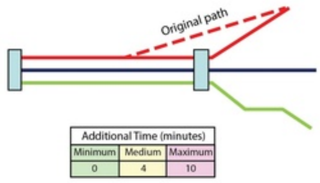

Figure 6.53. An illustration of why additional route kilometers would be added to a route if it were converted to a trunk-and-feeder route and the point where the new transfer takes place (a new transfer facility) is beyond the point where the original route diverged from the trunk route. Typical terminal observations of additional customer travel times are shown in the box. Image *Arthur Szász.*

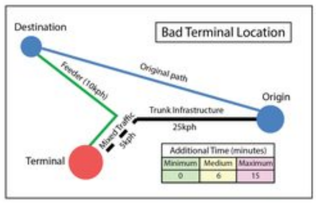

Figure 6.54. An illustration of additional route kilometers that are generated if a direct service is replaced by a trunk-and-feeder alternative where the point of transfer takes place at a facility off the BRT infrastructure. Typical terminal observations of additional customer travel times are shown in the box. Image *Arthur Szász.*

Figure 6.55. The addition of the trunk-and-feeder terminal in León, Guanajuato, Mexico, introduced considerable delay in travel times. Image *Arthur Szász.*

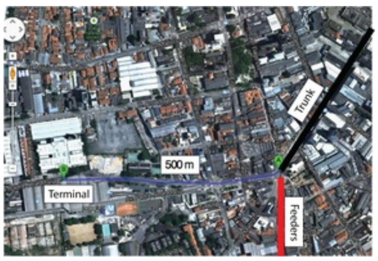

Figure 6.56. Trunk-and-feeder terminal Santo Amaro in São Paulo is poorly located and accesses are poorly designed, causing additional travel times. Image *Arthur Szász.*

6.6.3.3 Internal Circulation within the Transfer Terminal

The art of high-quality terminal design is not well known nor has it been systematized. In this planning guide, Chapters 25: Stations and 28: Multi-Modal Integration provide some very preliminary guidance, but optimizing a transfer terminal design is a critical area for further work.

Buses entering a transfer terminal often face significant delays caused by bus queues. Transfer terminals often include multiple platforms, as they are generally designed to accommodate multiple bus routes converging in one location. When poorly designed, there can be significant additional delays involved with vehicles entering the terminal and reaching their assigned platforms.

Transferring customers also face walks of varying distances and comfort depending on the quality of the terminal design. The best-designed trunk-and-feeder systems have feeder platforms immediately across from the trunk platforms, but not all terminals are so well designed. It is quite typical for a transfer terminal to require customers to needlessly climb up and down multiple stairways to reach their allotted boarding platform, when grade crossing would work just fine. If the terminal is large enough, it is of course impossible for all the feeder routes to be located immediately across the platform from a trunk platform, and the more feeder routes there are, the greater the likelihood that the customers will have to walk significant distances to reach their transfer route. Ideally, routes should be restructured and designed so that transfers can be made in several different stations, instead of concentrating all of them in just one location. Chapter 25: Stations and Chapter 28: Multi-Modal Integration also provide some preliminary guidelines for terminal design that can minimize this walking delay.

6.6.3.4 Range of Likely Delays from Empirical Observations

Taking into account all six forms of transfer delay described in the previous four items, Table 6.29 provides some typical ranges for each variable.

Table 6.29. Typical Ranges of Additional Terminal Delays

	Bus and passenger delay		
Description	minimum	average	maximum
	minutes		
Rerouting to Terminals	0	4	10
Bad Terminal Location	0	6	15
Internal and External Circulation	2	4	6
Additional Boarding & Alighting Delay	1	3	5
	Passenger delay only		
Walking inside terminal	0	2	6
Additional waiting due to transfer	2	4	6
Total time/ passenger: minutes	5	23	48
Equivalent time/passenger: minutes	7	31	66

Some variables affect both the bus operating cost and the waiting time of customers, and other variables only affect customer waiting times. If a terminal is located directly on a trunk corridor and at a natural point of divergence for the feeder routes, there could be zero delay for customers and operators due to bad terminal location, but at worst both operators and customers could face very significant delays. Internal and external circulation time for the bus at the terminal virtually always adds some delay. Additional boarding and alighting time due to the transfer delays both customers and vehicles in all cases within predictable ranges.

The additional walking times inside the terminal will vary depending on the quality of the terminal design, and the additional waiting time due to the transfer will vary with the frequency of the trunk service and the feeder service within somewhat predictable ranges.

The total time in minutes per customer adds up with these causes of delay. The "equivalent time" per customer multiplies walking time by three, because people generally do not like to walk, and it multiplies waiting time by two, because people generally do not like to wait. In other words, following standard cost-benefit analysis practice, these two types of delay are weighted based on customers' empirically observed willingness to pay to avoid these types of delay.

As a result of this transfer penalty, an average trunk-and-feeder system starts with a disadvantage of twenty-three minutes of customer travel time per route converted. These additional delays also translate into increased cycle time (TC), which directly translates into increased fleet needs and increased operating costs. When added to the extra fleet needed to compensate for the peak hour correction factor and extra fleet required at the terminal for scheduling adjustments in real-world conditions, it is typical for trunk feeder systems to require from 11 percent to 66 percent additional fleet. In most cases, these extra costs will total something in the range of 34 percent of an additional cost for the trunk-and-feeder service, while the benefits from the larger vehicle use are going to be generally in a similar range only when the trunk is very long relative to the feeder route, and there are many very small routes converging.

While the general benefits of many elements of BRT accrue primarily during the peak period, the time lost at terminals has an adverse impact on cycle times and customer travel times throughout the day. As a result, the benefits of a trunk-and-feeder BRT system exist mainly during peak hours. From a cost-benefit perspective, the terminal losses are rarely possible to recover from the benefits of being able to use larger vehicles on the trunk corridor.

In summary, an excellent terminal project, located directly on the BRT trunk corridor at a natural convergence point, is a necessary but insufficient precondition for achieving any benefit from the conversion from a direct service to a trunk-and-feeder service.

6.6.4 Avoiding Station and Platform Saturation

There are two additional factors to consider when deciding on whether to convert a direct service route to a trunk-and-feeder route: station saturation and platform saturation.

6.6.4.1 Avoiding Station Saturation

It may be the case that some existing bus routes using a planned BRT corridor operate with very small vehicles that are not compatible with BRT trunk infrastructure, usually because the roads they use are too narrow or in too deteriorated a condition for BRT vehicle operation. In this situation, including this route as a direct service on a BRT trunk corridor is likely to be ill advised. This is because providing a direct service for a minibus, for instance, is likely to more rapidly saturate the trunk corridor.

If the methodology is followed as suggested in subsection *Scenario II: Dwell Times and Demand Vary from Route-to-Route, and All Stations Are Similar*, where routes are included inside the BRT infrastructure based on a metric that gives priority to those bus routes where the customers using that route consume the least time at the bottleneck station, then it is likely that a route in which only minibuses can operate due to the operational conditions off the trunk route would be excluded because that type of bus would consume a lot of time at the bottleneck station.

In Section 6.5, it was assumed that such a route would operate in parallel to the BRT infrastructure in mixed traffic. However, such a solution has two disadvantages. The first is that the demand from the route is lost to the BRT system, and the second is that the mixed traffic lanes on the BRT corridor are more likely to face saturation. As such, in those conditions, it may be desirable to convert that direct service route into a trunk route and a feeder route.

The degree to which that specific route is likely to congest the bottleneck station can be calculated using the formulas provided in Chapter 7: Capacity and Speed on capacity and speed. The determination of whether the route should be simply cut, converted to a feeder, or allowed to continue to operate in the mixed traffic lanes will depend on the availability of land for a transfer location; the importance of the route to the level of demand on the trunk route; the level of congestion in the mixed traffic lanes; and the degree to which the trunk route can handle the additional demand without saturating the bottleneck station.

6.6.4.2 Avoiding Station Platform Saturation

Another possible reason to convert a direct service route to a trunk-and-feeder service is if there is a risk that the trunk station platforms would become overcrowded with waiting customers, though in this case the less drastic and more practical option would be simply to reconfigure the routes.

Lower frequency, direct service buses can cause more customers to have to wait on station platforms than high-frequency trunk services. For low-demand systems this does not cause any significant problem. However, at high levels of demand, the station platform can become overcrowded and become saturated.

As such, there are limitations to the number of direct routes that can operate on the same trunk bus stop unless stations can be sized to handle the required volumes of waiting customers. While external fare collection, at-level boarding, multiple and large doors, and large vehicles have increased station capacity markedly (the subject of the next chapter), these features have not made any progress in reducing the space consumed by waiting customers.

In order to show the difference, begin by calculating the average number of passengers waiting for one route ($Pwait_i$) by:

Eq. 6.47

$$P_{wi} = \frac{P_{bi}}{F_i} * \frac{(1 + Irr_i)}{2}$$

Where:

- P_{wi}: Passengers waiting for route i at given station (passengers/hour);
- P_{bi}: Boarding passengers in route i at given station (passengers/hour);
- F_i: Frequency of route “i” (vehicles/hour);
- Irr_i: Irregularity index of route i.

Then, the total number of passengers waiting at the station (Pwait) is given by:

Eq. 6.48

$$P_{wtotal} = \sum_i \frac{Pb_i}{F_i} * \frac{(1 + Irr_i)}{2}$$

Where i is all the routes that use the station.

In other words, the number of customers that are likely to end up waiting on a platform will be the sum total of all of the boarding passengers per route per hour at that station divided by the frequency and then multiplied by the risk of irregular arrival of the bus.

For example:

P_{bi}: 120 passengers/hour ;

F_i: 6 vehicles/hour;

Irr_i: 0.3 .

$$P_{wi} = \frac{\frac{120}{6} * (1 + 0.3)}{2} = 13$$

It might be expected that at any given time there would be 13 passengers accumulating for boarding in route i.

If there are 20 similar direct routes using the same sub-stop, there will be on average 13 passengers at that bus stop for each route at any given time.

So,:

$$P_{w\ \text{direct}} = P_{w\ \text{total}} = 20 * 13 = 260$$

There will be 260 passengers on the station platform at any given time.

To accommodate these passengers, normally one would want at least one square meter for every 2 passengers waiting. Also consider usable platform width minus 1 meter (0.5 m “buffer” on both sides), minus 1 meter for circulation space for up to 2,000 passengers per hour (1 meter of width is required per 2,000 circulating passengers per hour) to be the usable waiting space. Usually the length of the docking bay is considered the usable length.

Therefore, to accommodate just the waiting area for 260 passengers, and assuming circulating passengers are less than 2,000 per hour, one would need 260/2 = 130 square meters, or a platform 6 meters wide and 33 meters long, or 7 meters wide and 26 meters long, or 9 meters wide and 22 meters long, and so on.

If these 20 direct services routes (120 buses) were converted into just one trunk route with a frequency of 60 articulated buses per hour (cutting the frequency in half by doubling the size of the buses), the number of boarding passengers per hour into the one trunk route would be:

$$P_{bi} = 120 * 20 = 2400$$

And the average number of waiting passengers at each trunk station will be:

$$P_{w\ \text{trunk}} = P_{w\ \text{total}} = \frac{\frac{2400}{60} * (1 + 0.3)}{2} = 26\text{passengers}$$

As people can take the first bus that comes along, fewer passengers accumulate on the platform waiting for their bus. In this scenario, trunk-and-feeder reduces the number of passengers waiting on each platform by 90 percent (from 260 to just 26) due to the frequency and size of the vehicles. Thus, the station platform only needs to be 13 meters long and 4 meters wide to comfortably accommodate the waiting passengers. Indeed, this is the more common situation, where the station length is determined not by the number of waiting passengers, but by consideration of the BRT station saturation from stopping buses, since the platform length required for 60 large buses per hour will be at least 40 meters. If there is limited space along the trunk route and sufficient space at the terminals, there will be some advantage to relocating these waiting passengers from a congested trunk platform to a transfer terminal.

When designing BRT stations, calculate the expected density of waiting customers based on the proposed service plan, and ensure that the length and width is adequate to serve both vehicle movements and waiting customer requirements. As the Guangzhou BRT is the highest capacity direct service BRT system in the world, it is worth looking at the station-sizing ramifications of its direct service in Figure 6.57.

In Guangzhou, the design parameter was to provide for two passengers per square meter. Each docking bay has 5 meters of platform width, of which 2.5 is usable for a waiting area, and each waiting area per docking bay is 20 meters long. As such, each waiting area per bus is $20\text{m} * 2.5\text{m} = 50\text{m}^2$. With eight docking bays, the station can support up to 100 passengers per docking bay, and 800 passengers in total.

It was not easy, however, to convince the authorities to allocate 5 meters of road right-of-way to the station platform, although 5 meters is the average. A station narrower than 4 meters is not recommended for a bidirectional station. In very space-constrained locations, a small station with just 3 meters of width and 20 meters in length can only support around 60 passengers per hour.

Figure 6.57. On the Guangzhou BRT, the highest capacity direct service BRT system in the world, there are stations with up to four sub-stops and twelve docking bays (two to three docking bays per sub stop) per direction. Image *Bing Maps*.

Figure 6.58. With only direct services in the Guangzhou BRT System, Shidajida station has four sub-stops and was designed with ample platforms and customer waiting space. Image *Karl Fjellstrom, Far East BRT*.

6.6.5 Conclusion: When to Consider Converting Direct Services to Trunk-and-Feeder Services

The large number of variables to consider when deciding whether to split existing direct services into trunk-and-feeder services makes it difficult to provide a single unified formula for making such a determination. Commercial public transport simulation software is not equipped to handle the sorts of multivariate analyses presented here either. The number of possible alternative service plan scenarios to test is so great that service planners need to follow some basic rules of thumb to create a set of scenarios for testing with a public transport demand model. As such, most of these decisions will need to continue to rely on good judgment assisted with the basic approaches and tools provided, aided by public transport software models only after many of the critical decisions have already been made.

The following provides a brief summary of these rules, based on the preceding discussions.

- Trunk-and-feeder systems require additional fleet due to the peaked nature of demand.

Trunk-and-feeder systems require larger fleets to accommodate the same number of customers. The more peaked the demand, the more additional fleet that the trunk- and-feeder service will require. In normal operating conditions, real-world observations indicate that the additional fleet required to convert a direct service into a trunk-and-feeder service will be in the range of 11 to 15 percent. If demand is heavily peaked, slightly more vehicles may be needed. If demand is less peaked, slightly fewer additional vehicles will be required.

- Trunk-and-feeder systems allow the use of larger buses with lower operating costs per customer on trunk routes, assuming high occupancy levels.

The main benefit of the trunk-and-feeder system is the ability to use larger buses with lower operating costs per customer along high-volume trunk corridors. By consolidating the demand from a number of lower demand direct service routes, a trunk BRT might be able to operate very large articulated or even bi-articulated buses along the trunk corridor, allowing for potential operating cost savings. This savings is likely to be in the 15 to 30 percent range if the trunk portion of the route is long relative to the feeder portion (say, the length of most of the feeder routes are considerably less than 50 percent of the length of the trunk corridor), and a large number of direct service routes (say, greater than five) originally shared the demand along the trunk corridor.

- Trunk-and-feeder systems impose additional costs related to the required additional transfers.

Trunk-and-feeder systems impose a lot of additional costs on BRT services related to the need for an additional transfer. These additional costs manifest themselves during the peak hour as well as throughout the day.

First, if it is not possible to locate the transfer terminal very near to the trunk corridor at a natural point of route divergence, the buses and their customers will need to go out of their way to get to the transfer terminal. This directly increases both customer travel time and cost and vehicle operating time and cost.

Circulation within and around the terminal also tends to cause delays. Poor circulation might involve problems with buses approaching and operating within the terminal, or it might involve the way customers move within the terminal. Poor terminal design is common in public transport system design, and the number of skilled terminal designers is limited.

This transfer terminal-related delay is likely to add between 11 and 66 percent to the fleet required in a trunk-and-feeder service plan. In addition, in a well-designed terminal, customers could face five-minute delays, and in a badly designed terminal, an additional 48 minutes per transferring customer has been observed.

Transfer terminals also tend to have large construction costs and may require land acquisition and resettlement. Once constructed, the transfer terminals need personnel to manage, operate, clean, and maintain them, adding to operating costs.

- Trunk-and-feeder systems can mitigate against station saturation and station platform saturation.

If some bus routes cannot easily use buses that are fully compatible with BRT trunk infrastructure (such as minibus routes operating on narrow, poorly maintained roads), incorporating them into the trunk corridor as direct service routes will increase the risk that the trunk corridor stations will become saturated. It may be better to turn such routes into feeder routes.

Direct services also require customers on the trunk corridor to wait longer for their bus than trunk services. This results in more customers accumulating inside the station waiting for their buses. Trunk-and-feeder services will reduce the number of accumulating customers waiting for their buses, because more customers can take more of the routes operating on the trunk. This problem is more likely to manifest itself in high-demand systems.

The conditions under which the conversion of direct services to trunk-and-feeder services will bring overall benefits are fairly limited. Until recently, trunk-and-feeder systems were proliferating in conditions inappropriate to their use, and direct service options were being neglected. This can probably be attributed to the similarity of trunk-and-feeder services to rail services, and the application of service plans developed in Gold Standard systems like Bogotá to cities with different conditions, where trunk-and-feeder operations may make less sense. In the future, with more full-featured direct service and hybrid (i.e., Direct + Trunk-and-Feeder) BRT systems coming into existence, such as the new system in Lanzhou, Yichang, and other cities, more real-world data will become available for comparison of the relative merits of the two basic service planning approaches.

6.7 Deciding on Stop Elimination and Express Services

> *"If you want a happy ending that depends, of course, on where you stop your story."*
>
> — Orson Welles, actor, director, producer, and writer, 1915–1985

This section addresses the question of whether a new BRT service should retain the same stations as preexisting services, and whether limited-stop services should be created. Creating limited-stop services is done by means of selecting a proportion of the trips on an existing service and changing the programming to skip stops at certain stations: the unchanged service will be referred as the local service and the other one or more as a limited-stop service (or express service).

While eliminating stops from the system increases the walking time required by some customers to reach a stop, it also increases the average BRT vehicle speed (or "commercial speed") by removing the fixed dwell times at the station. Fixed dwell time (T0 or dead time) is the time associated with the bus pulling up to the station, docking, opening and closing its doors, and pulling out of the station.

In this chapter, the impact of stop removal on variable dwell time is not considered, as it is assumed there will not be much change with the elimination of stops, as the ridership will just redistribute among the remaining stations.

Including limited-stop service or services has a variety of impacts. The main advantages of limited-stop and express services are:

- Fixed dwell time is eliminated on the express routes so customers whose origins and destinations lie on the limited-stop route will benefit. This is discussed in this section;

- On high-demand corridors, by dividing a route into local and limited stop, the frequency per route is reduced, but also the irregularity of arrivals. This is also treated in this section;
- By increasing overall system speed, overall system capacity can be increased. This is covered in Chapter 7: Capacity and Speed.

However, these services also introduce some costs:

- Customer waiting times on local routes increase, as the frequency on the original route is reduced;
- Vehicles must be able to pass one another at stations.

Adding additional services must balance the benefits of removing fixed dwell time with the costs of adding customer waiting time, and the costs of deteriorated mixed traffic level of service resulting from the need to introduce passing lanes at all stations skipped by limited-stop services.

This section provides guidance to service planners to make decisions about which stations to eliminate or add when introducing a BRT system. The first subsection provides a basic methodology for deciding when to eliminate a station. It is a simple cost-benefit equation that compares the additional walking time to the reduction in fixed dwell time and provides some simple rules of thumb.

The remainder of the section assumes that the local service will be retained, but that additional limited-stop services will be created. In all these examples, walking time is no longer an issue, as the local service is retained, but at a lower frequency. Rather, it is an issue of balancing the waiting time associated with reduced frequencies per route and with the increased bus speeds. It is also a matter of optimizing frequencies to reduce the irregularity of service.

Normally, service planners will look at the demand profile of the corridor (an internal O/D to the system that also provides the number of customers on board at each link), and using a simulation model, will run alternative scenarios to test its benefits and its costs (operation and travel times). Service planners generally do not try an infinite number of possible alternatives; they use certain basic approaches to determine which scenarios are likely to perform the best, and limit themselves to a reasonable number of scenarios. This chapter is aimed at making more transparent the basic thinking that service planners use when defining scenarios to test using their simulation models.

6.7.1 Station Spacing and Station Elimination

When deciding whether to eliminate or add stations, it is necessary to determine what constitutes optimal spacing. If stations are spaced very far apart in the manner of a metro system, it is possible to reach very high vehicle speeds and system capacities. However, the disadvantage of such an approach is the additional time customers must spend to reach the nearest station. Therefore, BRT station spacing should try to strike an optimal balance between convenience for walking trips to popular destinations, and convenience for customers in the form of higher speed and capacity.

If the origins of customer trips are randomly distributed along a BRT corridor, a standard optimal distance between stations can be calculated. In most contexts, it ends up being between 450 meters and 500 meters, or roughly a quarter mile.

In Figure 6.59 the optimum station spacing distance is where the total travel time (blue line) is minimized. From the figure, this point occurs in the range of a station separation of 400 meters to 500 meters.

The following formulas can be used to calculate the optimal distance between stations, where the total walking cost and travel cost is minimized, or where:

Eq. 6.49

$$\text{Distance}_{\text{optimum}} = MIN(C_{\text{walk}} + C_{\text{travel}})$$

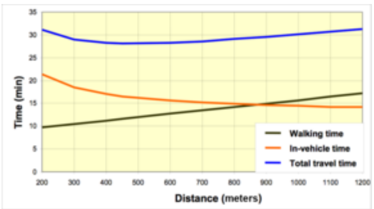

Figure 6.59. Optimizing total travel time as a function of station separation, this graph illustrates the trade-off faced by customers for increasing distances between station stops. As station stop distances increase, in-vehicle time falls as BRT vehicle speeds increase, but walking times also increase. Total travel time in a typical urbanized corridor tends to become minimal with stop distances around 450 meters. Image *Arthur Szász*.

Where:

- $Distance_{optimum}$: Optimal distance between stations;
- C_{walk} : Walking cost;
- C_{travel} : Travel cost.

Table 6.30 provides an example comparing general travel times for varying station spacings (from 210 meters to 500 meters) for an average customer trip. In this example, the average customer trip on a corridor is 4.35 kilometers. The trade-off between additional walking distances due to fewer stations and time spent waiting at stations due to more stations is compared on a per customer basis.

Table 6.30. Comparison of General Travel Times for Varying Station Spacings

Walk + Wait times at varying station spacings				
Bus Stop Spacing (km)	0.21	0.31	0.4	0.5
Average passenger trip length (km)	4.35	4.35	4.35	4.35
Time spent on-board waiting at bus stops				
Avg # bus stops/passenger trip (all stops)	21	14	11	9
Dwell time per bus stop (s)	25	25	25	25
Total time at bus stops (s)	518	351	272	218
Walking Time				
Average walking distance to station (one-quarter distance between stations) (m)	52.5	77.5	100	125
Walking speed (m/s)	1.3	1.3	1.3	1.3
Time walking to bus stop (s)	40	60	77	96
Time walking from bus stop (s)	40	60	77	96
Total walking time (to + from) (s)	81	119	154	192
Walking weight factor (burden of walking)	2	2	2	2
Total walking time, with weight (s)	154	231	308	385
Total walking + wait time (s)	679	572	558	580

In Table 6.30, the average number of stations per customer trip on the corridor is derived by dividing the average trip length by the average distance between stations. This is then multiplied by the average fixed dwell time per station to get the average delay per customer from the selected station distance.

It is then assumed that each customer walks on average one-quarter of the distance between stations at a walking speed of 1.3 meters per second. Boarding customers then have to walk to the station, and alighting customers have to walk from the station. This combined walking time then should be weighted by a factor of two, because most people dislike walking more than they dislike sitting on a moving bus. When these are compared for different stopping distances, the minimum total cost of walking and transiting customers occurs at an optimal distance of around .4 or .45 kilometers between stations. This turns out to be the optimal spacing when demand along a corridor is relatively uniform.

The BRT Standard gives 2 points for a system where the average stopping distance between stations is 0.3 kilometers and 0.8 kilometers (or between 0.2 miles and 0.5 miles), with 450 being a typical appropriate distance between stations. Note, however, that in high-capacity systems with large stations, BRT stations may cover an area around 100–250 meters long, and in this case a more reasonable station spacing is around 600 meters.

Of course, this calculation has been made per customer, rather than for customers in aggregate. Where there are large volumes of boarding and alighting customers, more frequent stations will be optimal, because more people will be affected by the long walking times than will benefit from the faster vehicle speeds. In areas with very few boarding and alighting customers, greater distances between stations will be optimal, because fewer people will benefit from the shorter walking distances, and more will benefit from the faster vehicle speeds. For this reason, it is fairly typical to have stations spaced at a greater distance apart farther from the city center, where demand is lower, and closer together downtown, where both demand and the density of trip attractors or generators are higher. Figure 6.59 visually summarizes the trade-off between walking times and BRT travel times in relation to the distance between stations.

Further, the optimal distance is not a constant, but will vary depending on a number of factors, including: the average trip length (assumed to be 4.35 kilometers in the table above), the average walking speed (used 1.2 m/s as a design speed to accommodate the range of walking speeds, but this can vary from city to city), the weight that people attribute to walking and urban density. In the table above, a weight of two was used, but if, for example, a lot of people are elderly or disabled, or if the walking environment is very bad, people might pay more to avoid walking.

A reasonable average stopping distance is around 450 meters for low-capacity stations and 600 meters for larger, high-capacity stations. This spacing is the best way to minimize walking distances, while keeping vehicle speeds at a reasonable level. BRT stations are typically located near major destinations such as commercial centers, large office or residential buildings, educational institutions, major junctions, or any concentration of trip origins and destinations. Usually this siting is done based on intuitive local knowledge and space availability. The station area will typically consume more right-of-way than other parts of the BRT infrastructure. As such, station location may look for places where the right-of-way can be most easily widened; mid-block rather than at intersections where road space is at a premium; locations where small parcels of public land, variances in the road right-of-way, or the presence of low-cost land such as surface parking lots adjacent to the corridor.

Reducing the number of stations does not reduce variable dwell time, as in most cases the vast majority of boarding and alighting delay will just redistribute to other stations if a station is eliminated.

6.7.2 Implementing Limited-Stop Services

As discussed in the previous subsection, every station adds delay to customers on board, a BRT vehicle usually needs from 12 to 30 seconds of dead time per station, and an average can be readily calculated for a specific corridor by observation. The idea of introducing limited and express services into a BRT system is to reduce this fixed dwell time.

The introduction of a new, limited-stop service usually implies reducing frequencies on the local service. While the new limited-stop service will travel at a higher speed, the demand on the corridor is now divided between the local route or routes and the new limited route. The frequency of the original route therefore goes down, and the drop in frequency introduces some additional delay to local route customers making trips not served by the express route, as they have to wait longer for their vehicle to arrive.

Generally, routes should have a frequency of at least 10 vehicles per hour. If adding a limited route drops the frequency of the local service below 10 vehicles per hour, the chances are that the longer waiting time faced by the customers who cannot take the limited as an alternative will outweigh the time savings for those who can take the limited. There are, of course, exceptions.

This reduced frequency may also have an extra benefit in some cases because too high service frequencies commonly lead to service irregularity. Consider, for example, a vehicle that is a minute behind schedule in a service with 5-minute headways (12 vehicles per hour) service: when it arrives at the station the number of customers waiting to board is 20 percent larger than expected by the schedule, so it will need a bit more time for boarding and will be a bit more delayed. The next vehicle arriving at the same station (also on the schedule) will have 20 percent fewer boarding customers and will leave a bit sooner. The vehicle in front will increase the number of alighting customers per station as well. As the two vehicles continue down the route, the vehicle in front will fall farther and farther behind until the two vehicles are running together. If frequency is higher than 30 vehicles an hour (2-minute headway), the chances that one vehicle will arrive at its destination crowded and late, and the vehicle directly behind it will arrive nearly empty rises sharply. This irregularity leads to vehicle queue delays at stations (see Eq. 6.22).

Therefore, if there are more than 30 vehicles an hour, there will be time savings from splitting the demand into more than one service, a local and a limited-stop service, just as a way of reducing the station queueing delay associated with this irregularity. Empirical evidence indicates that 22 vehicles an hour is optimal from the perspective of improving service regularity.

As a baseline, then, routes with frequencies of 20 or more per hour are candidates for the introduction of limited-stop services. If it is assumed that a standard 12-meter vehicle is at a reasonable design capacity at 60 customers per vehicle, 20 vehicles per hour translates roughly into a maximum load of 1,200 customers per hour. Limited-stop services can therefore be considered for services that have maximum load above 1,200 customers per hour, as follows:

1. *At loads of 1,200–1,800:* It may make sense to introduce a service that only stops at the more popular stops when most boarding and alighting demand is concentrated at only a few stops along the corridor, but where the simple elimination of the stop is difficult for political reasons.
2. *At loads greater than 1,800*: If demand is relatively evenly distributed along a corridor, it is desirable to split this demand up into more specialized services, as it will not add much waiting time (due to high frequencies related to the demand), and will increase speed for many customers, while also improving comfort and regularity of service.
3. If trip lengths are long, or the renovation rate is low, these may indicate the need for limited-stop or express services.

Beyond these basic principles, more detailed analysis should be done to determine whether limited-stop services are needed and where they should stop. To make a more detailed determination, something needs to be known of the trip origins and destinations of the customers using each bus route. Normally this is done by gathering enough information to put a corridor-specific OD matrix into a simulation model, and then running alternative scenarios to see how they perform. The following sections provide some basic guidance as to the sorts of local and limited-stop service patterns that one might test and why. Once he demand patterns of the alternaive services are output from the model, the following provides some tools to make a determination on the best pattern using cost-benefit analysis.

6.7.2.1 The Costs of Implementing Limited-Stop Services

The primary downside of implementing a limited-stop service is that it divides the ridership between the two services, cutting the frequency of the original local service, and hence increasing waiting times for the local service. Therefore, in order to determine whether it makes sense to add a limited-stop service, one must begin by calculating the total cost associated with waiting for a bus on a local route, as this will be the main cost of adding a limited route. In the sections that follow, the benefits will be calculated.

The cost of implementing an express route results in:

Eq. 6.50

$$\text{ExpressCost} = \text{WaitCost}_{\text{express}} + \text{WaitCost}_{\text{local}} - \text{WaitCost}_{\text{original service}}$$

Where:

- ExpressCost: Additional cost of waiting during the peak hour with express service implementation;
- $\text{WaitCost}_{\text{original service}}$:Total waiting cost of the original service;
- $\text{WaitCost}_{\text{express}}$: Total waiting cost of the included express service;
- $\text{WaitCost}_{\text{local}}$: Total waiting cost of the new local service.

The cost of waiting for a route (original, new express, or new local) service (WaitCostrouteexpress) is calculated using the previously explained formula from Section 6.4.3 Equation 6.12:

$$\text{WaitCost}_{\text{route}} = \text{Ren}_{\text{route}} * \text{Cost}_{\text{wait}} * 0.5 * (1 + Irr_{\text{route}}) * \text{LoadFactor} * \text{VSize}$$

Where:

- WaitCostRoute: Total waiting time cost generated to the route users (in $);
- $\text{Ren}_{\text{route}}$: Renovation factor of the route;
- Costwait: Average user waiting cost ($/time);
- Irrroute: Irregularity index of the route; measure of the variance between the actual headways and the scheduled headways (usually near 0.3, see Section 6.3.9);
- V_{Size}: Vehicle capacity;
- LoadFactor: Design load factor (usually 0.85).

Note that frequency itself does not factor into this equation as the cost of waiting does not change based on how long customers must wait. The more demand, the greater number of people waiting, but the higher the frequency, the shorter wait per person; as a result, the total cost of the wait is the same either way. For low demand, each person faces a longer wait but the wait affects fewer people, so in the end, total demand is not related to total waiting cost.

If a BRT service is unlikely to have a functional operational control system, or if a regular bus service cannot easily be measured, it is often sufficient to simply use a standard operational irregularity index, which is usually around 0.3 based on empirical observation, or:

$$\text{WaitCost}_{\text{route}} = \text{Ren}_{\text{route}} * \text{Cost}_{\text{wait}} * 0.5 * (1 + 0.3) * \text{LoadFactor} * \text{VSize}$$

However, the level of irregularity usually varies with the frequency, and that will have a significant impact on irregularity. In order to evaluate irregularity varying with frequency (Freqroute), the formula needs to be modified to the following:

Eq. 6.51

$$\text{WaitCost}_{\text{route}} = \text{Ren}_{\text{route}} * \text{Cost}_{\text{wait}} * 0.5 * (1 + (\frac{\text{Freq}_{\text{route}}}{\text{Freq}_{\text{optimum}}})^2) * \text{LoadFactor} * \text{VSize}$$

Where:

- WaitCostRoute: Total waiting time cost generated to the route users (in $);
- $\text{Ren}_{\text{route}}$: Renovation factor of the route;
- Costwait: Average user waiting cost ($/time);
- Irrroute: Irregularity index of the route; measure of the variance between the actual headways and the scheduled headways (usually near 0.3, see Section 6.3.9);
- Freq_{route}: Frequency of the route (vehicles/time)
- V_{Size}: Vehicle capacity;
- LoadFactor: Design load factor (usually 0.85);

- $\text{Freq}_{optimum}$: Optimum frequency to avoid irregularity of boarding and alighting;
  Therefore, the formula can simply be rewritten as:

$$\text{WaitCost}_{\text{route}} = \text{Ren}_{\text{route}} * \text{Cost}_{\text{wait}} * 0.5 * (1 + (\frac{\text{Freq}_{\text{route}}}{22})^2) * \text{LoadFactor} * \text{VSize}$$

For example, if a route is split in two, one local and the other limited, and if half of the original frequency is assigned to each new route, the results for each route become:

$\text{WaitCost}_{\text{express}} = \text{WaitCost}_{\text{local}} = Re_{\text{original service}} * \text{Cost}_{\text{wait}} * 0.5 * (1 + (\frac{\text{Freq}_{\text{original service}}}{22})^2) * \text{LoadFactor} * \text{VSize}$

If we call $K = Ren_{\text{original service}} * \text{Cost}_{\text{wait}} * 0.5 * \text{LoadFactor} * \text{VSize}$, Eq. 6.42 can be rewritten as:

$$\text{ExpressCost} = \text{WaitCost}_{\text{express}} + \text{WaitCost}_{\text{local}} - \text{WaitCost}_{\text{originalservice}}$$

$$\text{ExpressCost} = 2 * \text{WaitCost}_{\text{local}} - \text{WaitCost}_{\text{originalservice}}$$

$$\text{ExpressCost} = 2 * K * (1 + (\frac{0.5 * \text{Freq}_{\text{original service}}}{22})^2) - K * (1 + (\frac{0.5 * \text{Freq}_{\text{original service}}}{22})^2)$$

$$\text{ExpressCost} = K * (2 + 2 * (\frac{0.5 * \text{Freq}_{\text{original service}}}{22})^2 - 1 - (\frac{\text{Freq}_{\text{original service}}}{22})^2)$$

$$\text{ExpressCost} = K * (1 + 2 * 0.25 * (\frac{\text{Freq}_{\text{original service}}}{22})^2 - (\frac{\text{Freq}_{\text{original service}}}{22})^2)$$

$$\text{ExpressCost} = K * (1 + 0.5 * (\frac{\text{Freq}_{\text{original service}}}{22})^2 - (\frac{\text{Freq}_{\text{original service}}}{22})^2)$$

$$\text{ExpressCost} = K * (1 - 0.5 * (\frac{\text{Freq}_{\text{original service}}}{22})^2)^2)$$

The express cost multiplier $(1 - 0.5 * (\frac{\text{Freq}_{\text{original service}}}{22})^2)^2)$ is shown on the graph in Figure 6.60 as is K shown in function of $\frac{\text{Freq}_{\text{original service}}}{22}$ $(22 = \text{Freq}_{\text{optimum}})$:

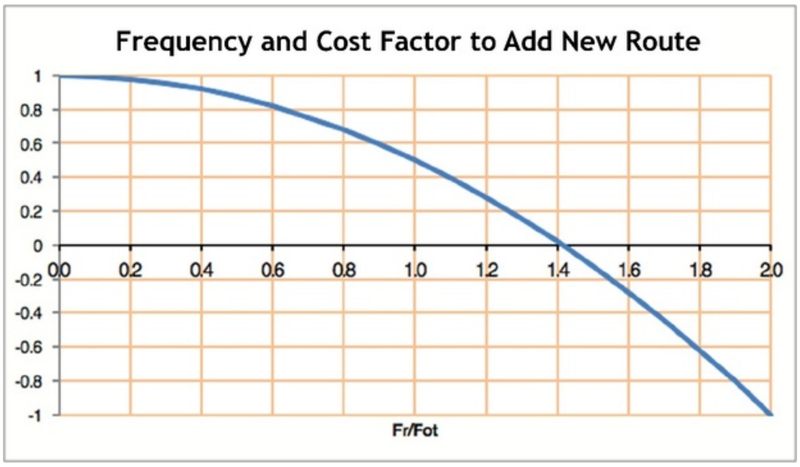

Figure 6.60. The cost factor of splitting a route into a local route and a new limited-stop route when the relation of frequency to optimal frequency ($\frac{Fr}{Fot}$) is considered: When the frequency rises above 31 ($\frac{31}{22=1.4}$) the benefit from reduced service irregularity is greater than the time lost waiting for a lower frequency service. *Arthur Szász.*

In the graph on Figure 6.60, the "1" on the x axis represents 22 buses per hour ($\frac{22}{22}$). The 1.4 represents roughly 31 buses per hour ($\frac{31}{22=1.4}$). At greater than 31 buses per hour, the additional waiting caused by the reduced frequency from the splitting of the original route for the creation of a new express service is outweighed by the benefit of reducing the irregularity in bus arrivals to the point where CostWait always becomes a negative cost, or in other words, a benefit. Therefore, if a BRT route has more than thirty-one vehicles an hour, it generally makes sense to split it into a new limited-stop service just to reduce irregularity, even if boarding and alighting volumes are nearly uniform between stops.

If multiple (n) routes are created, then the total wait cost for each new route needs to be calculated:

Eq. 6.52

$$\text{ExpressCost} = \text{WaitCost}_{\text{express(1)}} + \ldots + \text{WaitCost}_{\text{express(n)}} + \text{WaitCost}_{\text{local}} - \text{WaitCost}_{\text{original service}}$$

Where:

ExpressCost: Additional cost of implementing limited-stop services;

$WaitCost_{\text{express(1)}}$: Total waiting cost of the first added express service;

$WaitCost_{\text{express(n)}}$: Total waiting cost of n-th additional added express service;

$WaitCost_{\text{local}}$: Total waiting cost of adding one local service;

$WaitCost_{\text{original service}}$: Total waiting cost of the original service.

6.7.2.2 Benefits of Implementing Limited-Stop Services

The main advantage of removing stations from a given service is that these vehicles will travel faster. For the most part, the total ridership on the route will simply be divided between the original service and the new limited-stop service, so there will be no significant impact on overall boarding (Tb) and alighting (Ta) time.

Hence, the benefit is a function of the reduction of fixed dwell time (T_0) for each station removed.

The value of this benefit comes from two things:

- *A* The reduction in the travel time for all the customers that are using the limited-stop route ($\text{Load}_{\text{limited-stop at k}}$) on each link where a station k is skipped. This should be multiplied by the value of customers' time (C_{travel}), which is usually treated as half their cost of waiting, or $C_{\text{travel}} = Cw/2$. In the above examples, a constant value of waiting of US$12 per hour has been used so that in the examples in this section a constant value of travel time will be $6 per hour. It is usually set at one-third of the average wage.
- *B* The reduction in the travel time for the BRT vehicles, which would need less time to deliver the same service. The value of the operational cost reduction per bus resulting from the faster bus speeds is equal to the bus operational cost per hour (Cost_{bus}) multiplied by the number of buses that benefit from the stop reduction ($F_{\text{limited-stop-at-k}}$).

So the benefit of creating a limited-stop service is expressed as follows:

Eq. 6.53

$ExpressBenefit = T_0 * \sum_{k=\text{k=skipped station}} \text{Load}_{\text{limited-stop-at-k}} * \text{Cost}_{\text{travel}} + \text{Freq}_{\text{limited-stop-at-k}} * \text{Cost}_{\text{bus}}$ Where:

- ExpressBenefit: Benefit of implementing limited-stop services;
- T_0: Fixed dwell time (or "dead time");
- $\text{Load}_{\text{limited stop at k}}$: Passenger load that uses the new limited-stop route on each link where a station k is skipped;
- $\text{Cost}_{\text{travel}}$: Passenger value of time when travelling;
- $\text{Freq}_{\text{limited-stop-at-k}}$: Number of buses that benefit from the removal of station, k;
- Cost_{bus}: Bus operational cost per hour (see Section 6.3.12).

An express route should be created when there is a net benefit, or when $\text{Benefit}_{\text{express}}$ is greater than the total waiting cost of adding that route, as calculated in the previous subsection item.

Eq. 6.54

$$\text{ExpressBenefit} > \text{ExpressCost}$$

Where:

- ExpressBenefit : Benefit of implementing limited-stop services;
- ExpressCost : Total waiting cost of adding route.

For more complex scenarios, the total benefits of each route added need to be weighed against the total costs of each route added.

6.7.2.3 Examples of Typical Service Patterns

In the examples that follow, the standard data set in Table 6.31 will not vary by scenario. This data can easily be collected for a planned BRT corridor.

It is assumed that it has already been decided that the optimum number of BRT stations is twenty-five, based on the formula provided in Section 6.7.1, showing an optimal distance between stations. We also assume that the vehicle design capacity has already been decided as a 150-passenger (i.e., VSize * LoadFactor) articulated bus due to the high demand. Then, based on the BRT design and vehicle type, each station is assumed to have a fixed dwell time of thirty seconds, based on data collected from bus operators. The operational cost of this vehicle is US$105 per hour (this is the total bus operating costs needed for the calculation, rather than just the fixed costs). Based on the prevailing wage rate and willingness-to-pay studies, the cost of travel time is US$6 per hour, and waiting is US$12 per hour.

Table 6.31. Data Set for Examples of Limited-Stop Services Inclusion

Description	Variable	Value	Unit
Number of stations	Nstations	25	stations
Renovation rate	Ren	1.461	–
Optimal frequency	Freqoptimum	22	BRT-vehicles/hour
BRT vehicle design capacity	Vsize * LoadFactor	150	pax
Fixed dwell time	T 0	30	seconds
BRT vehicle operational cost	Costbus	105	US$/hour
Customer travel cost	Costtravel	6	US$/hour
Customer wait cost	Costwait	12	US$/hour

6.7.3 Limited-Stop Services When Demand Is Uniform

Some BRT services have fairly uniform demand, with customers getting on and off a route in more or less even numbers consistently throughout the corridor. Limited-stop services are the least likely to be attractive in the context of homogenous demand, but they are still sometimes attractive, particularly if there is a lot of irregularity resulting from high frequencies. In many instances, limited-stop services are attractive only during peak periods.

When demand is uniform, certain patterns of limited-stop service prove to be mathematically optimal—namely those that skip a cluster of stations.

In this example, it is assumed that there is a one-way local bus route, and demand is shaped in a perfect curve throughout the route, as per Table 6.32. In other words, it is assumed that each of the twenty-five station stops is a trip origin (O) and a trip destination (D) in a local origin-destination matrix, and that fifty-eight customers are travelling between each zone.

In a real-world situation, this data should have already been collected and put into a spreadsheet. Most demand modeling software can estimate the OD matrix from boarding and alighting counts, but it is better to have real station-to-station OD data.

Table 6.32. Uniform Origin-Destination (OD) Matrix Example

Zone/Stop	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Boardings
1	0	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	1392
2		0	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	1334
3			0	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	1276
4				0	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	1218
5					0	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	1160
6						0	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	1102
7							0	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	1044
8								0	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	986
9									0	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	928
10										0	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	870
11											0	58	58	58	58	58	58	58	58	58	58	58	58	58	58	812
12												0	58	58	58	58	58	58	58	58	58	58	58	58	58	754
13													0	58	58	58	58	58	58	58	58	58	58	58	58	696
14														0	58	58	58	58	58	58	58	58	58	58	58	638
15															0	58	58	58	58	58	58	58	58	58	58	580
16																0	58	58	58	58	58	58	58	58	58	522
17																	0	58	58	58	58	58	58	58	58	464
18																		0	58	58	58	58	58	58	58	406
19																			0	58	58	58	58	58	58	348
20																				0	58	58	58	58	58	290
21																				0	0	58	58	58	58	232
22																						0	58	58	58	174
23																							0	58	58	116
24																								0	58	58
25																									0	0
Alightings	0	58	116	174	232	290	348	406	464	522	580	638	696	754	812	870	928	986	1044	1102	1160	1218	1276	1334	1392	

The OD matrix of Table 6.32 would result in the boarding and alighting per station and loads after leaving the station as shown on Table 6.33 and Figure 6.61 where the dots near the x axis show the number of customers boarding (blue) and alighting (red) at each station; the green line indicates the load at each station.

Note that other OD patterns could yield the boarding and alighting results observed in the table, and a different OD matrix will require another optimal service pattern; that is why it is best to have the real OD matrix for the whole operating time or day.

The maximum hourly load on the critical link is 9,048 (MaxLoad). It occurs between the twelfth and thirteenth stations. As the design bus capacity (VSize * LoadFactor) is 150, the frequency (F) should be set at around 61 per hour, or

$$F = \frac{9048}{150} = 61.32$$

The determination to be made is whether there would be benefits in splitting this demand into a limited-stop service and a local service, and if so, which stations should be skipped by the limited-stop service. There are multiple service patterns that might be tested, but certain standard approaches tend to optimize results. In the case of homogenous demand, a limited-stop service that bypasses the middle stations in the corridor, where the relation of loads to boarding and alighting are higher, proves mathematically to always be superior to other stopping patterns such as skipping stations or clusters of stations at the beginning, middle, and end of a route. As such, no other alternatives are tested under homogenous demand.

When demand is relatively uniform in a manner similar to this example, it often makes sense to have a limited service run local at the beginning and at the end of its route, and run express in the middle of the route. Figure 6.62 demonstrates this by dividing the route into three zones—A, B, and C. In this case, the limited skips all seven stations in the middle Zone B (stations ten to seventeen).

For a limited service to yield benefits, a sufficient number of customers need to gain enough time from the removal of stations to make up for the loss of frequency that results from splitting the route. To make it worthwhile for customers, the service needs to pass at least a cluster of stations where the total fixed dwell time saved is greater than the new waiting time imposed by the loss of frequency.

From looking at the curve, it may appear that the limited-stop service bypasses the majority of the demand, but keep in mind that the curve says that the majority of the demand is actually *on the bus* in the middle of the corridor and that boardings and alightings combined are uniform throughout.

Based on the proposed split of the service in two:

Table 6.33. Boarding, Alighting, and Loads per Station

Bus Stop	Boarding	Alighting	Load
0			0
1	1392	0	1392
2	1334	58	2668
3	1276	116	3828
4	1218	174	4872
5	1160	232	5800
6	1102	290	6612
7	1044	348	7308
8	986	406	7888
9	928	464	8352
10	870	522	8700
11	812	580	8932
12	754	638	9048
13	696	696	9048
14	638	754	8932
15	580	812	8700
16	522	870	8352
17	464	928	7888
18	406	986	7308
19	348	1044	6612
20	290	1102	5800
21	232	1160	4872
22	174	1218	3828
23	116	1276	2668
24	58	1334	1392
25	0	1392	0
Total/MAX	17400	17400	9048

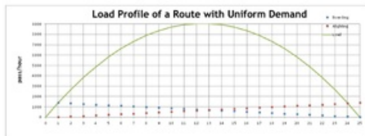

Figure 6.61. Demand profile on a route where a uniform number of customers (fifty-eight) are travelling between each possible stop. Blue dots represent the number of boardings at each stop, red dots represent the alightings at each stop, and the green line represents the number of customers on board buses between each stop during the peak hour. *Pedro Szász.*

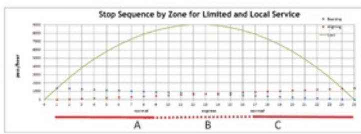

Figure 6.62. Stop sequence for an express service with uniform demand profile (fifty-eight customers between each stop) where both the local and the express stop at all Zone "A" stations and Zone "C" stations but where the express does not stop in Zone "B" stations. Image *Pedro Szász.*

- Customers travelling between points within Zone A or between points within Zone C will be indifferent to the two services, and will just take whichever vehicle comes first; there is no cost and no benefit derived from the creation of the new service for those customers;
- Customers travelling between Zone A and Zone B, or between Zone B and Zone C will have to take the local bus, and they will perceive time losses due to the lower frequency on the local service;
- While customers travelling between Zone A and Zone C could take either service, all would take the limited-stop service because, in this example, the time saved from skipping the intermediate stops is greater than the time lost due to waiting for another vehicle. Those who cannot figure out how to read the service maps or confused tourists might be exceptions.

Those taking the limited-stop service gain significant time savings through by-passing stops in Section B from their route.

In Table 6.34, the areas highlighted in yellow are trips within Zone A and within Zone C that will be split evenly between the local and express service. The area in pink will be served entirely by the local service, and the area in blue will be served entirely by the express service.

Table 6.34. Demand Division by Zone

Zone	A	B	C
A	SHARED	LOCAL	LIMITED
B		LOCAL	LOCAL
C			SHARED

Table 6.35. Origin Destination Matrix for Uniform Demand on a Bus Route

Origin Destionation Matrix for Uniform Demand on a Bus Route

Zone/Stop		Zone A									Zone B							Zone C									
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Boardings
Zone A	1	0	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	1392
	2		0	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	1334
	3			0	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	1276
	4				0	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	1218
	5					0	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	1160
	6						0	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	1102
	7							0	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	1044
	8								0	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	986
	9									0	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	928
Zone B	10										0	58	58	58	58	58	58	58	58	58	58	58	58	58	58	58	870
	11											0	58	58	58	58	58	58	58	58	58	58	58	58	58	58	812
	12												0	58	58	58	58	58	58	58	58	58	58	58	58	58	754
	13													0	58	58	58	58	58	58	58	58	58	58	58	58	696
	14														0	58	58	58	58	58	58	58	58	58	58	58	638
	15															0	58	58	58	58	58	58	58	58	58	58	580
	16																0	58	58	58	58	58	58	58	58	58	522
Zone C	17																	0	58	58	58	58	58	58	58	58	464
	18																		0	58	58	58	58	58	58	58	406
	19																			0	58	58	58	58	58	58	348
	20																				0	58	58	58	58	58	290
	21																				0	0	58	58	58	58	232
	22																						0	58	58	58	174
	23																							0	58	58	116
	24																								0	58	58
	25																									0	0
Alightings		0	58	116	174	232	290	348	406	464	522	580	638	696	754	812	870	928	986	1044	1102	1160	1218	1276	1334	1392	

Given the demand profile presented here, the load for each service would divide as shown in Figure 6.63.

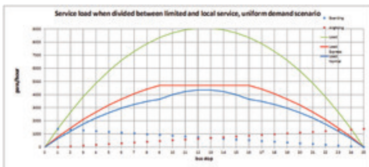

Figure 6.63. Service Load divided between the local and the limited service in a uniform demand example scenario. Image *Pedro Szász.*

If this division of the demand is assigned on a station-by-station basis to each service, the boarding and alighting numbers for the limited route are given in Table 6.35. The difference between the boarding and alighting numbers on the limited-stop service and on the original route would be the boarding and alighting remaining on the local service (not shown).

Table 6.36. Example Division of Customers between Limited-Stop and Local Services

Division of Passengers Between Limited and Local

	Original Service			Local	Limited Service		
Bus Stop	Boarding	Alighting	Load	Load Local	Load Limited	Boarding Limited	Alighting Limited
0			0	0	0		
1	1392	0	1392	638	754	754	0
2	1334	58	2668	1218	1450	725	29
3	1276	116	3828	1740	2088	696	58
4	1218	174	4872	2204	2668	667	87
5	1160	232	5800	2610	3190	638	116
6	1102	290	6612	2958	3654	609	145
7	1044	348	7308	3248	4060	580	174
8	986	406	7888	3480	4408	551	203
9	928	464	8352	3654	4698	522	232
10	870	522	8700	4002	4698	0	0
11	812	580	8932	4234	4698	0	0
12	754	638	9048	4350	4698	0	0
13	696	696	9048	4350	4698	0	0
14	638	754	8932	4234	4698	0	0
15	580	812	8700	4002	4698	0	0
16	522	870	8352	3654	4698	0	0
17	464	928	7888	3480	4408	232	522
18	406	986	7308	3248	4060	203	551
19	348	1044	6612	2958	3654	174	580
20	290	1102	5800	2610	3190	145	609
21	232	1160	4872	2204	2668	116	638
22	174	1218	3828	1740	2088	87	667
23	116	1276	2668	1218	1450	58	696
24	58	1334	1392	638	754	29	725
25	0	1392	0	0	0	0	754

In this case, the benefit is quite simple to estimate, by formula (Equation 6.53):

$$ExpressBenefit = T_0 * \sum_{k=\text{skiped station}} \text{Load}_{\text{limited-stop-at-k}} * \text{Cost}_{\text{travel}} + \text{Freq}_{\text{limited-stop-at-k}} * \text{Cost}_{\text{bus}}$$

Sum for all stations “k” where the limited does not stop.

The $\text{Load}_{\text{limited stop at k}}$ is the number of customers on board the express bus that are passing any station “k” that is jumped by the limited-stop service. In this example, all trips from Zone A to Zone C, which is the area shaded in blue on Table 6.35, or demand from stations (one to nine) to stations (seventeen to twenty-five):

$$\sum_{k=\text{skipped station}} \text{Load}_{\text{limited-stop-at-k}} = 9 * 9 * 58 = 4698\text{pass/h}$$

This is because there are nine by nine zones where there are only express customers and each interzonal demand is 58, so 4,698 customers.

The frequency of the limited and the local route will vary depending on the demand the limited route captures. In this case,

$$F_{\text{express}} = \frac{4698}{150} = 31.32\text{bus/hour}$$
$$F_{\text{local}} = \frac{4350}{150} = 28.68\text{bus/hour}$$

Therefore

$$ExpressBenefit = 30/3600 * 7 * (4698 * 6 + 31.32 * 105) = 1826\text{US\$/hour}$$

Where $30/3600 * 7 = 30$ seconds of fixed dwell time per stop removed/3600 seconds in an hour times 7 stops removed; 4,698 is the number of customers; 6 is their value of an hour; 31.32 is the frequency; and 105 is the operating cost per bus per hour.

Recalling that the cost of adding the limited-stop service will be as follows (Equation 6.52):

$$\text{ExpressCost} = \text{WaitCost}_{\text{express(1)}} + \ldots + \text{WaitCost}_{\text{express(n)}} + \text{WaitCost}_{\text{local}} - \text{WaitCost}_{\text{original service}}$$

And that (Equation 6.51):

$$\text{WaitCost}_{\text{route}} = \text{Ren}_{\text{route}} * \text{Cost}_{\text{wait}} * 0.5 * (1 + (\frac{\text{Freq}_{\text{route}}}{\text{Freq}_{\text{optimum}}})^2) * \text{LoadFactor} * \text{VSize}$$

Given the data set for all examples:

- $\text{LoadFactor} * \text{VSize} = 150$
- $\text{Ren} = 1.46$
- $\text{Cost}_{\text{wait}} = 12$
- $\text{Freq}_{\text{originalservice}} = 60$
- $\text{Freq}_{\text{local}} = 28.68$
- $\text{Freq}_{\text{express}} = 31.32$

$$\text{WaitCost}_{\text{original service}} = 0.5 * 1.461 * 150 * 12 * (1 + (0.5 * 60/22)^2 = 3760$$

$$\text{WaitCost}_{\text{local}} = 0.5 * 1.461 * 150 * 12 * 1 + (0.5 * 31.32/22)^2 = 1874$$

$$\text{WaitCost}_{\text{express}} = 0.5 * 1.461 * 150 * 12 * 1 + (0.5 * 31.32/22)^2 = 1981$$

$$\text{ExpressCost} = 1981 + 1874 - 3760 = 95\text{US\$/hour}$$

So, in this case, $\text{ExpressBenefit} = 1826\text{US\$/hour}$ and $C_{w\text{total}} = 95\text{US\$/hour}$. In this case, the waiting cost associated with adding another service is very low, because the original service was so frequent that there was a lot of needless waiting due to the irregularity of service, and much of this delay is mitigated by the reduction in frequencies. (Note that the effect of irregularity reduction is a bit exaggerated here, as the portion of users that can take both services will contribute to irregularity of both services in Zones A and C as if it was only one service with a frequency of sixty BRT vehicles per hour.)

Therefore, as $\text{ExpressBenefit} > \text{ExpressCost}$ it can be said that adding a limited-stop service is a very good idea in this case.

The optimal number of stations to be skipped on the proposed express service is the next determination to make. A rough calculation can be used as a basic guide.

In short, the service should make sure that the time saved by the people able to skip stations is greater than the additional time added by the loss of frequency for the people that have to remain on the local service. For example, cutting the frequency from sixty to thirty-one buses per hour implies only an additional minute of waiting. While the average wait is half a minute, one minute is used because the actual average wait time is multiplied by two to factor in people's perception of the wait time. Thus, the reduction in frequency adds about 1.3 minutes in new delay to customers, if a standard irregularity of 0.3 is used.

With a fixed dwell time at the station stops at thirty seconds, at least three or four stations need to be removed to attract any customers, and probably more. If too many stations are taken away, there will not be enough customers on the new limited to justify a high-frequency limited service, so the range of stations to be removed shall be limited as well.

The following method provides a way of testing whether more or fewer stations should be removed. In essence, the same process run for the specific scenario (seven stations removed) needs to be tested for all other reasonable alternatives.

Table 6.37. Total Benefits with Varying Numbers of Stops Removed from the Example

Limited Route Demand Distribution								Benefits			
Bus stop use pattern			passenger demand division				frequency of limited	benefits for limited service			Total Benefit
limited and local stops	local stops only	Limited and local stops	limited	shared	local	total	bus/h	time savings per bus	passenger hours of benefit	bus hours saved	US$/h
11	3	11	7018	6380	4002	17400	46.79	1.500	175.45	1.170	1176
10	5	10	5800	5220	6380	17400	38.7	2.5	242	1.61	1619
9	7	9	4698	4176	8526	17400	31.3	3.5	274	1.83	1836
8	9	8	3712	3248	10440	17400	24.7	4.5	278	1.86	1865
7	11	7	2842	2436	12122	17400	18.9	5.5	261	1.74	1745
6	13	6	2088	1740	13572	17400	13.9	6.5	226	1.51	1516
5	15	5	1450	1160	14790	17400	9.7	7.5	181	1.21	1214
4	17	4	928	696	15776	17400	6.2	8.5	131	0.88	881
3	19	3	522	348	16530	17400	3.5	9.5	83	0.55	554
2	21	2	232	116	17052	17400	1.5	10.5	41	0.27	272
1	23	1	58	0	17342	17400	0.4	11.5	11	0.07	74

In Table 6.37, the first three columns represent the stopping pattern of various alternative limited services (divided into Segments A, B, and C). The first row represents a scenario where the first eleven stations are both local and limited, the next three stations are local only, and the last eleven stations are both local and limited. The second row represents a scenario in which the first ten stations are shared, then the express service skips five stations, then the last ten stations are again shared, and so on.

The second set of columns (four columns) shows the division of customers between the limited only, the local only, and the customers shared by the two services based on the previously stated assumptions. It is broken out in this way because only the riders interested in taking the express service (going from Zone A to Zone C) enjoy benefits from the removal of stations. The remainder of the limited bus customers (those who take the express and use it as a local within Zone A and Zone C) do not benefit from the removal of stations.

In the third row of the table the initial example is tested. An express service is implemented with seven stops skipped and there are 4,698 customers who benefit from the removal of stations, or those customers moving between Zone A and Zone C.

In addition to showing the required frequency for the limited-stop service, the table also includes calculations of time savings per bus, which is equal to the number of stations skipped by the limited service in Zone B, multiplied by thirty seconds of fixed dwell time saved per station. So for the first row, Zone B stations are equal to three in scenario I, so 1.5 minutes are saved per bus; if five stations are removed, 2.5 minutes are saved per bus, and so forth.

The next column shows the number of customer hours of benefit from the express service. It multiplies the number of express customers that bypass the seven stations (total load of customers passing stations in Zone B) by the savings per bus.

The next column shows the benefits in terms of bus travel time, so it multiplies the frequency of the limited-stop service (46.8 for the first row) by the time savings per bus (1.5 minutes for the first row), then divides the total by 60 to give an hour figure (yields 1.17 hours of bus operating time saved in the scenario of the first row).

Finally, times saved for customers and vehicles are respectively multiplied by the value of time (in the first row: customers' 175.45 hours saved multiplied by US$6/hour results in US$1,053 and operating cost per bus of US$105/hour times saved 1.17 hours save results in US$123, so the total benefit of the express service [for 3 stops removed] is US$1,176).

These benefits then need to be compared to the net cost of replacing the original service with two new services, one local and one express, as is shown on Table 6.38. These net costs can be deducted from the benefit to indicate total net benefits (last column).

Table 6.38. Benefits Net of Costs for Varying Numbers of Eliminated Stops

Stops			Benefits	Costs				
Bus stop use pattern			Total Benefit	Cost of Original	Cost of limited	Cost of local	Net cost of limited	maximum benefit
Segment A: Limited and local stops	Segment B: Local stops only	Segment C: Limited and local stops	US$/h	US$/h	US$/hr	US$/hr	US$/hr	US$/hr
11	3	11	1176	3760	2802	1433	475	700
10	5	10	1619	3760	2330	1624	194	1425
9	7	9	1836	3760	1981	1874	95	1741
8	9	8	1865	3760	1731	2159	130	1735
7	11	7	1745	3760	1559	2460	258	1487
6	13	6	1516	3760	1447	2757	444	1072
5	15	5	1214	3760	1378	3036	654	560
4	17	4	881	3760	1341	3282	863	18
3	19	3	554	3760	1323	3485	1048	-494
2	21	2	272	3760	1317	3636	1192	-920
1	23	1	74	3760	1315	3729	1284	-1209

These net benefits are then calculated for all situations proposed, following the method of the original scenario used in this example. The result turns out to favor the initially tested situation: skipping seven stations. The net benefit of skipping seven stations—US$1,741—exceeds the net benefit of every other scenario.

The following table shows the degree of sensitivity of the total benefit to total demand. In Table 6.39, the same attributes are assigned, except the demand is cut by 40 percent across the board. In that situation, instead of the frequency dropping from 60 to 30, with a considerable improvement of irregularity (with 22 being optimal) it drops from 30 to 15 and the irregularity benefit is smaller. Once the time penalty for adding the service is relatively greater and the number of beneficiaries of the new limited service is relatively lower, skipping nine stations becomes slightly more beneficial than skipping seven stations. Hence, in uniform demand, the benefits of the limited service are highly sensitive to demand levels.

Table 6.39. Net Benefits of Costs with Varying Numbers of Eliminated Stops under Lower Demand Scenario

Stops			Benefits	Costs				
Bus stop use pattern			Total Benefit	Cost of Original	Cost of limited	Cost of local	Net cost of limited	maximum benefit
Segment A: Limited and local stops	Segment B: Local stops only	Segment C: Limited and local stops	US$/h	US$/h	US$/hr	US$/hr	US$/hr	US$/hr
11	3	11	1176	3760	2802	1433	475	700
10	5	10	1619	3760	2330	1624	194	1425
9	7	9	1836	3760	1981	1874	95	1741
8	9	8	1865	3760	1731	2159	130	1735
7	11	7	1745	3760	1559	2460	258	1487
6	13	6	1516	3760	1447	2757	444	1072
5	15	5	1214	3760	1378	3036	654	560
4	17	4	881	3760	1341	3282	863	18
3	19	3	554	3760	1323	3485	1048	-494
2	21	2	272	3760	1317	3636	1192	-920
1	23	1	74	3760	1315	3729	1284	-1209

6.7.3.1 Demand Patterns Typical of Trunk-and-Feeder Systems

In some systems, such as a trunk-and-feeder system, it is likely that demand will be concentrated at the beginning and/or end of the BRT trunk corridor—for instance, at the transfer station on one end and the downtown on the other. Demand will tend to concentrate in this way because the feeder routes on one end would tend to discharge large numbers of customers at the transfer terminal, and there would be a similar concentration of boardings and alightings at the central business district (CBD).

In this example, a total of 17,276 boardings and alightings are assumed, the same number as in the uniform demand example, but in this case, 50 percent of them occur at the first and last stations (25 percent at each) instead of only 8.3 percent.

The boarding and alighting and OD matrix of the corridor, if all other stations have uniform demand, would look like Table 6.40 and, if only one service operated with this OD pattern, the load would look like the load diagram in Figure 6.64.

Table 6.40. Origin Destination Matrix for Demand Concentrated at Terminals

Origin Destination Matrix for Demand Concentrated at Terminals																										
Zone/Stop	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Boardings
1	0	188	188	188	188	188	188	188	188	188	188	188	188	188	188	188	188	188	188	188	188	188	188	188	4327	8651
2		0	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	188	562
3			0	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	188	545
4				0	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	188	528
5					0	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	188	511
6						0	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	188	494
7							0	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	188	477
8								0	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	188	460
9									0	17	17	17	17	17	17	17	17	17	17	17	17	17	17	17	188	443
10										0	17	17	17	17	17	17	17	17	17	17	17	17	17	17	188	426
11											0	17	17	17	17	17	17	17	17	17	17	17	17	17	188	409
12												0	17	17	17	17	17	17	17	17	17	17	17	17	188	392
13													0	17	17	17	17	17	17	17	17	17	17	17	188	375
14														0	17	17	17	17	17	17	17	17	17	17	188	358
15															0	17	17	17	17	17	17	17	17	17	188	341
16																0	17	17	17	17	17	17	17	17	188	324
17																	0	17	17	17	17	17	17	17	188	307
18																		0	17	17	17	17	17	17	188	290
19																			0	17	17	17	17	17	188	273
20																				0	17	17	17	17	188	256
21																					0	17	17	17	188	239
22																						0	17	17	188	222
23																							0	17	188	205
24																								0	188	188
25																									0	0
Alightings	0	188	205	222	239	256	273	290	307	324	341	358	375	392	409	426	443	460	477	494	511	528	545	562	8651	17276

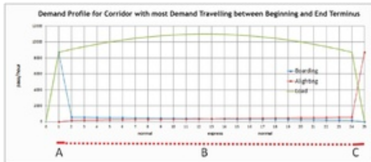

Figure 6.64. Demand profile for a corridor where most demand is travelling between the two end terminals. *Pedro Szász.*

In this case, it is worth considering adding a service that runs directly between the first station (the transfer terminal) and the last terminal (downtown). If such a service were added, the ridership would split between the limited and local service as per Table 6.41.

Table 6.41. Loads on the Local and Limited

Loads on the Local and Limited					
Stop	Boardings	Alightings	Load	Load Local	Load Limited
1	8651	0	8651	4324	4327
2	562	188	9025	4698	4327
3	545	205	9365	5038	4327
4	528	222	9671	5344	4327
5	511	239	9943	5616	4327
6	494	256	10181	5854	4327
7	477	273	10385	6058	4327
8	460	290	10555	6228	4327
9	443	307	10691	6364	4327
10	426	324	10793	6466	4327
11	409	341	10861	6534	4327
12	392	358	10895	6568	4327
13	375	375	10895	6568	4327
14	358	392	10861	6534	4327
15	341	409	10793	6466	4327
16	324	426	10691	6364	4327
17	307	443	10555	6228	4327
18	290	460	10385	6058	4327
19	273	477	10181	5854	4327
20	256	494	9943	5616	4327
21	239	511	9671	5344	4327
22	222	528	9365	5038	4327
23	205	545	9025	4698	4327
24	188	562	8651	4324	4327
25	0	8651	0	0	0
	17276	17276	10895	6568	4327

On Table 6.42, the same stopping pattern is tested for their ridership and comparative costs and benefits, but in each one, an additional station is removed at the beginning and ending of the limited-stop service; the formulas and method from the previous example are used to calculate the net benefit.

Table 6.42. Costs and Benefits of Varying Stopping Patterns

Stop pattern								time savings				Costs				Net Benefit
Bus stop use pattern			passenger division				F limited	limited			savings	cost of original service	cost of express	cost of local	net cost of express	net benefit
limited and local	local only	limited and local	limited	shared	local	total	bus/h	min per bus	passenger time saved	fleet	US$/h	US$/h	US$/hr	US$/hr	US$/hr	US$/hr
11	3	11	9852	5330	2218	17400	65.7	1.5	246	1.64	1650	3780	4245	1337	1822	-171
10	5	10	9147	4642	3611	17400	61.0	2.5	381	2.54	2554	3780	3841	1316	1396	1157
9	7	9	8476	3989	4935	17400	56.5	3.5	494	3.30	3313	3780	3484	1323	1047	2266
8	9	8	7840	3370	6190	17400	52.3	4.5	588	3.92	3940	3780	3170	1355	766	3174
7	11	7	7239	2785	7376	17400	48.3	5.5	664	4.42	4446	3780	2897	1409	545	3901
6	13	6	6671	2235	8494	17400	44.5	6.5	723	4.82	4842	3780	2658	1479	377	4465
5	15	5	6138	1719	9542	17400	40.9	7.5	767	5.12	5141	3780	2452	1562	254	4886
4	17	4	5640	1238	10523	17400	37.6	8.5	799	5.33	5353	3780	2275	1656	171	5182
3	19	3	5175	791	11434	17400	34.5	9.5	819	5.46	5490	3780	2123	1756	120	5370
2	21	2	4745	378	12276	17400	31.6	10.5	830	5.54	5564	3780	1995	1861	96	5468
1	23	1	4350	0	13050	17400	29.0	11.5	834	5.56	5586	3780	1886	1968	94	5492

In this case, a limited-stop service that stops only at the first and last stations brings more benefits to customers. These benefits significantly outweigh the costs. With a maximum load on the critical link of the limited route at 4,327, and a related frequency of 29 trips per hour (4,327/150), the maximum load remaining on the local service of 6,568 passengers per hour yields a frequency of 44. This is still high enough to cause an elevated level of irregularity in the boarding and alighting process, so another express route might be added. Based on the previous example, this new service would skip the middle stations.

6.7.4 Demand Concentrated at a Few Stops

It is also common for demand to be concentrated at a few stops along a corridor because there are some large trip generators or attractors in those locations, like hospitals, schools, high-density housing developments, or shopping malls. Such a corridor might result in a boarding and alighting pattern like Figure 6.65.

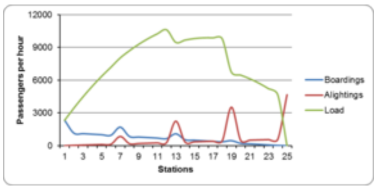

Figure 6.65. Demand profile for a corridor with demand heavily concentrated between a few important stops. *Pedro Szász.*

The trip origin and destination matrix would look something like that shown in Table 6.43, where the total number of trips is similar to the previous examples.

Table 6.43. Origin Destination Matrix Example for Clustered Demand on a Corridor

Origin Destination Matrix for Clustered Demand on a Bus Route																										
Zone/Stop	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	Boardings
1	0	35	45	55	65	75	223	75	75	75	75	75	223	75	75	75	75	75	223	75	75	75	75	75	223	2292
2		0	15	15	15	15	190	15	15	15	15	15	223	15	15	15	15	15	223	15	15	15	15	15	223	1144
3			0	15	15	15	157	15	15	15	15	15	223	15	15	15	15	15	223	15	15	15	15	15	223	1096
4				0	15	15	124	15	15	15	15	15	223	15	15	15	15	15	223	15	15	15	15	15	223	1048
5					0	15	91	15	15	15	15	15	223	15	15	15	15	15	223	15	15	15	15	15	223	1000
6						0	58	15	15	15	15	15	223	15	15	15	15	15	223	15	15	15	15	15	223	962
7							0	35	45	55	65	75	223	75	75	75	75	75	223	75	75	75	75	75	223	1694
8								0	15	15	15	15	190	15	15	15	15	15	223	15	15	15	15	15	223	846
9									0	15	15	15	157	15	15	15	15	15	223	15	15	15	15	15	223	798
10										0	15	15	124	15	15	15	15	15	223	15	15	15	15	15	223	750
11											0	15	91	15	15	15	15	15	223	15	15	15	15	15	223	702
12												0	58	15	15	15	15	15	223	15	15	15	15	15	223	654
13													0	35	45	55	65	75	223	75	75	75	75	75	223	1096
14														0	15	15	15	15	190	15	15	15	15	15	223	548
15															0	15	15	15	157	15	15	15	15	15	223	500
16																0	15	15	124	15	15	15	15	15	223	452
17																	0	15	91	15	15	15	15	15	223	404
18																		0	58	15	15	15	15	15	223	366
19																			0	35	45	55	65	75	190	465
20																				0	15	15	15	15	157	217
21																					0	15	15	15	124	169
22																						0	15	15	91	121
23																							0	15	58	73
24																								0	25	25
25																									0	0
Alightings	0	35	60	85	110	135	843	185	210	235	260	285	2181	335	360	385	410	435	3519	485	510	535	560	585	4669	17402

Two options are tested to illustrate some general principles, correspondent boarding, alighting, and loads are shown in Table 6.44 where the stations highlighted in red would be both limited and local stops, while the stations in gray would be served only by the local service.

- One limited-stop service that stops only at the high volume stations, #1, #7, #13, #19, and #25.
- One limited-stop service that stops at #1–7, then #13, then #19–25.

Table 6.44. Boardings, Alightings, and Load Comparison between Varying Service Patterns for Clustered Demand Example

Original Service				Alternative I					Alternative II				
Bus Stop	Boardings	Alightings	Load	Bus Stop	Load Limited	Load Local	Board Limited	Alight Limited	Bus Stop	Load Express	Load Local	Board Limited	Alight Limited
1	2292	0	2292	1	892	1400	892	0	1	1293	999	1293	0
2	1144	35	3401	2	892	2509	0	0	2	2144.5	1256.5	869	17.5
3	1096	60	4437	3	892	3545	0	0	3	2959.5	1477.5	845	30
4	1048	85	5400	4	892	4508	0	0	4	3738	1662	821	42.5
5	1000	110	6290	5	892	5398	0	0	5	4480	1810	797	55
6	952	136	7107	6	892	6215	0	0	6	5185.5	1921.5	773	67.5
7	1694	843	7958	7	1338	6620	669	223	7	5808	2150	1044	421.5
8	846	185	8619	8	1338	7281	0	0	8	5808	2811	0	0
9	798	210	9207	9	1338	7869	0	0	9	5808	3399	0	0
10	750	236	9722	10	1338	8384	0	0	10	5808	3914	0	0
11	702	260	10164	11	1338	8826	0	0	11	5808	4356	0	0
12	654	285	10533	12	1338	9195	0	0	12	5808	4725	0	0
13	1096	2181	9448	13	1338	8110	446	446	13	5068	4380	821	1561
14	548	335	9661	14	1338	8323	0	0	14	5068	4593	0	0
15	500	360	9801	15	1338	8463	0	0	15	5068	4733	0	0
16	452	385	9868	16	1338	8530	0	0	16	5068	4800	0	0
17	404	410	9862	17	1338	8524	0	0	17	5068	4794	0	0
18	356	435	9783	18	1338	8445	0	0	18	5068	4715	0	0
19	465	3519	6729	19	859	5870	190	669	19	3516.5	3212.5	232.5	1784
20	217	485	6461	20	859	5602	0	0	20	3307.5	3153.5	108.5	317.5
21	169	510	6120	21	859	5261	0	0	21	3062	3058	84.5	330
22	121	535	5706	22	859	4847	0	0	22	2780	2926	60.5	342.5
23	73	560	5219	23	859	4360	0	0	23	2461.5	2757.5	36.5	355
24	25	585	4659	24	859	3800	0	0	24	2106.5	2552.5	12.5	367.5
25	0	4659	0	25	0	0	0	859	25	0		0	2106.5
Max/Total	17402	17402	10533	Max/Tota	1338	9195	2197	2197	Max/Total	5808	4725	7798	7798
F (Lm/150)			70.22		8.92	61.3				38.72	31.5		

The loads assumes that the time savings from the number of stations skipped is greater than the loss of time waiting for the next express bus for all possible express bus trips, so customers between the stations served by the express service (red cells) use that service.

Table 6.45. Loads Passing Stations and Benefits for Two Alternative Express Services under Clustered Demand Example

Option I					Option II				
Stations Passed	Load (k)	Time Saved	Time Value	Total	Stations Passed	Load (k)	Time Saved	Time Value	Total
stations	passengers	min/ station	$/hr	$/hr	Stations	Passengers	min/station	$/hr	$/hr
5	892	0.5	$6	223.00	5	5808	0.5	$6	1452
5	1338	0.5	$6	334.50	5	5068	0.5	$6	1267
5	1338	0.5	$6	334.50					
5	859	0.5	$6	214.75					
20				1,106.75	10				2719

The loads aboard an express service passing the stations skipped for each alternative are listed under the column "Load (k)" in Table 6.45, and the value of the time savings associated with this benefit are calculated in the "Total" column.

In Table 6.46, the required frequency for the new express route is calculated from the maximum load on the express route divided by 150, the designed bus capacity. This is multiplied by the number of stations removed in each scenario and by the operational cost savings per hour to yield the total bus cost savings for each alternative.

Table 6.47 shows the (waiting) costs associated with the lower frequency to be subtracted from the benefits.

In the second option of express service, the new express service captures a lot more demand, bringing the frequency of both the express and the local service into a more optimal range, significantly reducing the irregularity of service. The benefit from reduced irregularity is greater than the cost in waiting caused by the reduction in frequency, so in this case the "cost" is negative, or a "benefit."

As a result, the net benefit of the alternative with express service attending a cluster of stations at the beginning and ending of the route, rather than only stopping at the high-demand stations, performs much better, as shown in Table 6.48.

Table 6.46. Frequency and Operational Vehicle Benefits for Two Alternative Express Services under Clustered Demand Example

	Frequency Buses/Hr	Op Cost $/hr	Stations Removed	Time/ Station	Total Savings
Option I	8.92	105	20	0.5	$156.10
Option II	38.72	105	10	0.5	$338.80

Table 6.47. Costs of the Two Alternative Express Services under Clustered Demand Example

	Option I	Option II
Original Cost	4,663.85	4,663.85
Express Cost	1,368.94	2,333.16
Local Cost	3,867.06	1,988.82
Cost of Express	572.15	(341.87)

Table 6.48. Net Benefits of the Two Alternative Express Services under Clustered Demand Example

	Option I	Option II
Cost	572.15	-341.87
Operational Benefit	156.10	338.80
Time Savings Benefit	1,106.75	2,719.00
Net Benefit	$690.70	$3,399.67

At these high levels of demand, additional express routes can be tried following similarly clustered patterns focusing on higher demand clusters of stations, and their relative costs and benefits tested.

Several clusters of stopping stations should be tested, adding more types of services until the frequency of each route is near the optimal range of twenty-two. The diagram in Figure 6.66 is the original service concept that was developed for TransMilenio in Bogotá loosely based on these principles.

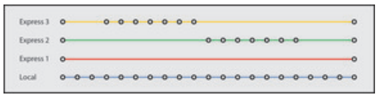

Figure 6.66. Diagram of original service concept for TransMilenio, based on the concept of clustering stations served by express services (each dot is a served station). It included three express services in order to place each service frequency in the range of optimal frequencies. Diagram *ITDP.*

6.7.5 Demand Concentrated at One End of a Corridor

There are occasions when there is a very high demand at the beginning of a route and this demand gradually diminishes throughout the route. This situation normally results in the afternoon peak, when there is a monocentric CBD, or when there is a large transfer terminal.

The demand in this case is always decreasing as in Figure 6.67, and the internal O/D matrix with total similar to the previous examples is shown in Table 6.48.

Table 6.49. Origin Destination Matrix Example for Declining Demand on a Bus Corridor

Origin Destination Matrix for Declining Demand on a Bus Corridor																																			
Zone/Stop	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	Boarding
1	0	455	455	455	455	455	455	455	455	455	455	455	455	455	455	455	455	455	455	455	455	455	455	455	455	455	455	455	455	455	455	455	455	455	15000
2		0	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	100
3			0	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	200
4				0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	50
5					0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	30
6						0	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	100
7							0	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	80
8								0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	50
9									0	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	200
10										0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	50
11											0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	30
12												0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	25
13													0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	40
14														0	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	180
15															0	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	200
16																0	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	60
17																	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	20
18																		0	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	100
19																			0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	20
20																				0	4	4	4	4	4	4	4	4	4	4	4	4	4	4	50
21																					0	10	10	10	10	10	10	10	10	10	10	10	10	10	135
22																						0	6	6	6	6	6	6	6	6	6	6	6	6	75
23																							0	4	4	4	4	4	4	4	4	4	4	4	45
24																								0	9	9	9	9	9	9	9	9	9	9	90
25																									0	0	0	0	0	0	0	0	0	0	0
26																										0	13	13	13	13	13	13	13	13	105
27																											0	9	9	9	9	9	9	9	60
28																												0	8	8	8	8	8	8	45
29																													0	6	6	6	6	6	30
30																														0	0	0	0	0	0
31																															0	5	5	5	15
32																																0	45	45	90
33																																	0	120	120
34																																		0	0
Alightings	0	455	458	464	466	467	470	473	475	483	485	487	488	490	499	509	513	514	520	521.3	525	535	542	545.6	555	555	568	578	584	590	590	595	640	780	17395

This yields the following boarding, alighting, and load pattern on the original service. This example is taken from the real case of the Santo Amaro—Nove de Julho corridor, project implemented in 1986 in São Paulo.

In this example there are 15,000 customers boarding at the first station, a transfer terminal, and just 2,395 customers boarding at the remaining 33 stations. In this situation, a service plan similar to the one shown in Figure 6.68 turns out to be optimal.

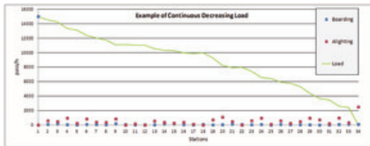

Figure 6.67. Demand profile for a corridor with all trips boarding at a single terminal but alighting in even numbers at station stops along the corridor. *Pedro Szász.*

Each route serves a specific stretch of the corridor. The route goes express from the terminal (or CBD) to the beginning of the stretch it services, then it makes all the stops in its service area, and then returns (usually express) to the terminal. The return is express, because the demand in the opposite direction is generally much lower.

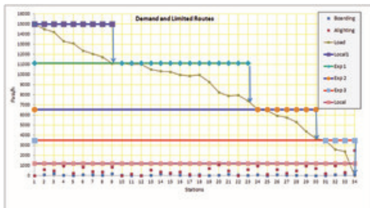

Figure 6.68. Optimal service pattern for a corridor with most demand boarding at a single terminal but alighting in even numbers at station stops along the corridor. Image *Arthur Szász.*

The big difference between this scenario and earlier scenarios is that, as the express routes do not reach the end of the corridor, there is a significant reduction in total cycle time (TC) and consequently a sizable fleet reduction. Each express service is designed to meet the direct demand from the terminal (or CBD) to a specific service zone.

Table 6.50. Boarding, Alighting, and Load per Designed Service on Declining Demand Example Corridor

Original Service			Local I			Express I			Express II			Express III			Local II		
Boarding	Alighting	Load	Boarding	Alighting	Load	Boarding	Alighting	Load	Boarding	Alighting	Load	Boarding	Alighting	Load	Boarding	Alighting	Load
15000	0	15000	3636	0	3636	6364	0	6364	3182	0	3182	1818	0	1818	0	0	0
100	455	14645	0	455	3182	0	0	6364	0	0	3182	0	0	1818	100	3	97
200	458	14388	0	455	2727	0	0	6364	0	0	3182	0	0	1818	200	10	287
50	464	13974	0	455	2273	0	0	6364	0	0	3182	0	0	1818	50	11	326
30	466	13538	0	455	1818	0	0	6364	0	0	3182	0	0	1818	30	12	344
100	467	13171	0	455	1364	0	0	6364	0	0	3182	0	0	1818	100	16	428
80	470	12781	0	455	909	0	0	6364	0	0	3182	0	0	1818	80	19	489
50	473	12357	0	455	455	0	0	6364	0	0	3182	0	0	1818	50	21	518
200	475	12082	0	455	0	0	0	6364	0	0	3182	0	0	1818	200	29	690
50	483	11649				0	455	5909	0	0	3182	0	0	1818	50	31	709
30	485	11193				0	455	5455	0	0	3182	0	0	1818	30	32	707
25	487	10732				0	455	5000	0	0	3182	0	0	1818	25	33	696
40	488	10284				0	455	4545	0	0	3182	0	0	1818	40	35	703
180	490	9974				0	455	4091	0	0	3182	0	0	1818	180	44	839
200	499	9675				0	455	3636	0	0	3182	0	0	1818	200	55	984
60	509	9226				0	455	3182	0	0	3182	0	0	1818	60	58	986
20	513	8734				0	455	2727	0	0	3182	0	0	1818	20	59	947
100	514	8320				0	455	2273	0	0	3182	0	0	1818	100	65	982
20	520	7820				0	455	1818	0	0	3182	0	0	1818	20	67	935
50	521	7349				0	455	1364	0	0	3182	0	0	1818	50	70	915
135	525	6959				0	455	909	0	0	3182	0	0	1818	135	81	989
75	536	6498				0	455	455	0	0	3182	0	0	1818	75	87	957
45	542	6002				0	455	0	0	0	3182	0	0	1818	45	91	911
90	546	5546							0	455	2727	0	0	1818	90	100	901
0	555	4992							0	455	2273	0	0	1818	0	100	801
105	555	4542							0	455	1818	0	0	1818	105	113	792
60	568	4034							0	455	1364	0	0	1818	60	122	731
45	575	3503							0	455	909	0	0	1818	45	129	646
30	584	2949							0	455	455	0	0	1818	30	135	541
0	590	2359							0	455	0	0	0	1818	0	135	406
15	590	1784										0	455	1364	15	140	281
90	595	1280										0	455	909	90	185	185
120	640	780										0	455	455	120	305	0
0	780	0										0	455	0	0		0
17395	17395	15000	3636	3636	3636	6364	6364	6364	3182	3182	3182	1818	1818	1818	2395	2395	986
Fleet		100			24.2			42.4			21.2			12			7

One local service can attend to all the trips not destined for the terminal (2,395 passengers per hour that board and alight along the corridor). This service has a maximum load of around 986 passengers per hour.

In this case, the benefits to passengers of the new services are as shown in Table 6.51 and the benefits to operations of the new services are as shown in Table 6.52.

Table 6.51. Benefits of New Services to Passengers

Service	Stations Passed	Load (k)	Time Saved	Time Value	Total
	stations	passengers	min/station	$/hr	$/hr
Express I	9	6364	0.5	$6	477.30
Express II	22	3182	0.5	$6	583.37
Express III	29	1818	0.5	$6	439.35
Total					1,500.02

Table 6.52. Benefits of New Services to Operations

Service	Stations Skipped	Frequency	Time saved stations	Total Time Saved stations	Time Saved free running	Segments eliminated	Free Running time saved	Total time saved	Operating Cost	Total
	stations	Buses/hr	min/station	Hours	min between station	links between stops	hours	hours	$/hr	$/hr
Express I	19	42.4	0.5	6.71	0.75	11	5.8	12.5	105	1317.05
Express II	26	21.2	0.5	4.59	0.75	4	1.1	5.7	105	593.60
Express III	29	12	0.5	2.90	0.75	0	0.0	2.9	105	304.50
Local I	25	24.2	0.5	5.04	0.75	25	7.6	12.6	105	1323.44
Local II	0	7	0.5	0.00	0.75	0	0.0	0.0	105	0.00
										3538.59

In this case, because of the early return of some of the vehicles, there are savings in running time for vehicles, not only from the removal of stations. To include this benefit, the operational time savings for not running till the end of the corridor are also calculated.

Benefits add operational savings (US$3,538) and passenger savings (US$1,500) to the total of US$5,038.

Following the formula for calculating the costs of implementing the new express routes (the net balance of wait cost per route), the additional cost is US$524, as summarized in Table 6.53. Resulting in a net benefit of (US$5,038–US$524) US$4,515. In this example, the fact that many services allowed early return led to a dramatic reduction in operating costs, as buses were able to reduce their cycle times.

Table 6.53. Costs

Costs	
Service	Costs
Original	8106.74
Express I	2537.31
Express II	1620.50
Express III	1414.69
Local I	1714.05
Local II	1344.27
Total	524.08

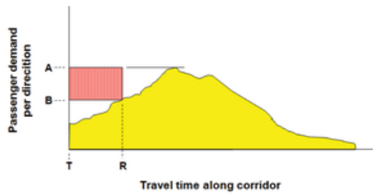

Figure 6.69. Adding a second local service that covers only the highest demand segment of a corridor can reduce operating costs while limiting additional delay for customers. Image *Pedro Szász.*

6.7.6 Shortened Routes

Even within simple BRT systems that only allow for local stations, it is possible to adjust the service to better meet the demand by having some bus routes turn around before reaching the terminal. The same corridor can host several routes of varying lengths. A single corridor may be split into two or more routes covering a different portion of the corridor.

In Figure 6.69, a diagram shows the loads along an existing bus corridor. If the demand on a given part of the corridor is high, a second service can be added that operates only on that part of the route. All customers travelling between any OD pair on the shorter service will be indifferent to the two bus routes, so there is no lost travel time for any customer. There are, however, significant operational cost savings, as in the previous example, and the BRT vehicles operating on the shortened service avoid a large number of stations.

Shortened routes focusing on higher-demand central areas will contribute to high operating efficiencies. These efficiency gains will help reduce the number of vehicles required to serve the corridor.

Looking at Figure 6.69, where most of the corridor's demand occurs in the central area, if there is only one service operating the entire length of the corridor, all vehicles would depart from point T and operate with low load factors at the beginning and the end of the corridor. However, if vehicles were to operate a shortened route beginning from point R, then the number of vehicles required to serve the corridor will be reduced and the load factor per bus will increase. This fleet reduction is calculated as:

Eq. 6.55

$$\text{Fleet reduction} = \frac{\frac{2*|R-T|}{V_{\text{corridor}}} * A - B)}{\text{VSize} * \text{LoadFactor}}$$

Where:

- T: Terminal position;
- R: Early return position;
- V_{corridor}: Corridor commercial speed;
- $|R - T|$: Distance between early return position and terminal;
- $|R - T|/V_{\text{corridor}}$: Travel time between early return position and terminal;
- A: Maximum Demand on the Critical Link (MaxLoad);
- B: Load on point $.

Example:

$A = 15,000$passengers/hour;

$B = 10,000$passengers/hour;

$V = 25$km/hour;

$T = 0$;

$R = 5$km;

$(R - T)/V = 12$minutes(uni-directional time) $= (5/25)$hours;

VSize $*$ LoadFactor $= 150 pax/bus(vehiclecapacity)$.

$$\text{Fleet reduction} = \frac{2 * |5 - 0|/over25 * 15,000–10,000}{150} = 6\text{vehicles}$$

In this case, as might be typical of a downtown, most of the demand may be headed downtown from two different directions. For instance, in Yichang, China, along the new BRT corridor, bus routes previously operated all the way through the CBD from north to south and south to north.

In this situation, the vehicles frequently run with low occupancy on either end. Severing one long route in the middle of the city center would force a transfer on a large number of customers with destinations on the far side of the city center. However, having each route pass through to the far edge of the CBD, overlapping through the highest demand section of the city, avoids the transfer and also allows for a higher frequency of service for all customers operating in the zone where the routes from both sides overlap.

The specific costs and benefits of these general approaches should be tested with the actual OD matrix for each corridor.

These early turn-around services can significantly improve the system's financial performance, but they must be linked with clear customer information about which vehicle is approaching the station and its destination. Otherwise, customers can become confused and frustrated.

In general, the shortened routes are not terminated at the station with the highest boarding and alighting volumes in the system. These stations are already stressed by the quantity of customers and the intensity of customer movements. Further, since these stations tend to be located in the densest portion of the urban area, there are fewer opportunities to efficiently turn the vehicles around. Normally these shortened services terminate just beyond such high-volume stations.

This type of service programming will typically reduce overall operational costs by as much as 10 percent. In order to accommodate a shortened route option, the planning process should provide sufficient flexibility with regard to:

- Providing places where vehicles can make U-turns within the BRT system;
- Designing the station areas with sufficient extra capacity to allow for service adjustments.

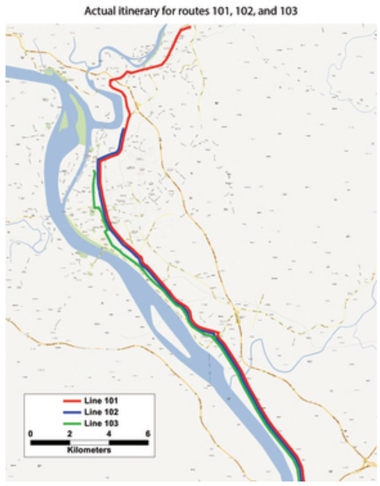

Figure 6.70. Yichang overlapping services can be maintained only in the CBD doubling frequency in the high demand part of the corridor, while limiting total route length to minimize irregularity. *ITDP.*

Figure 6.71. The need for transfers is also reduced when local routes are overlapping in the CBD, zoom of proposed design in Yichang CBD. *ITDP.*

6.8 Creating New Routes and Combining Old Routes

"The path is the goal."

— Mahatma Gandhi, political and spiritual leader, 1847–1948

There are two fairly typical problems of existing public transport routing that emerge for historical reasons. One problem is that a traditional public transport market may have routes that run along a major road and then terminate at a terminal in the middle of the city, where at some time in the past, a terminal was built, or a minibus taxi rank was created. Often, however, there are many customers who are not going anywhere near the downtown terminal, but to some point beyond it. As such, these traditional routes may force a majority of customers to have to transfer and leave a lot of buses needlessly idling downtown. In such conditions, routes that continue through the CBD for some distance should be considered. In other words, this is the opposite problem of the one addressed in subsection *Shortened Routes* of Section 6.7.2 above where a route needlessly continued too far, and an early return would have been more efficient. In this case, the route was artificially severed midway for historical reasons. In both cases, the approach to a solution should be similar.

Another typical situation that emerges is that bus routes in cities are organized along a fixed grid pattern. These service patterns also emerged historically for ease of customer network legibility. These grid network patterns also have the advantage of allowing for a lot of directional flexibility with only one transfer. This sort of service plan is common in cities in the United States, where for decades each bus service will tend to ply up and down one specific street in a grid. This is a reasonable service pattern if little else is known about the pattern of trip origins and destinations, or if trip patterns are randomly distributed across the grid. In most cases, where there is a grid, many people are transferring at least once and possibly twice to reach their destination. As there is delay involved in the transfer, if a majority of people are all headed in a single direction that requires a transfer (say, toward downtown), it may make more sense to offer a service that turns the corner rather than just running straight up and down a single arterial and forcing a majority of customers to transfer.

When a BRT corridor is introduced into a grid, one service on a particular street is suddenly much faster than services on alternative streets. If the speed improvement is significant, it may well pull a lot of demand off of bus services on parallel streets, particularly for longer distance trips, capturing demand that otherwise would have been distributed to several stops. In this case, offering some services between popular trip origins and destinations that turn onto the BRT corridor and off the BRT corridor could prove to be advantageous by avoiding the transfer penalty on as many customers as possible.

An example of this can be seen from the BRT service planning for Ashland Avenue in Chicago. The bus routes in Chicago mainly run north and south up the major arterials, or east and west on crosstown streets. The city plans to build Gold or Silver-standard BRT infrastructure through both the Central Loop downtown (Washington and Madison Streets) and along Ashland Avenue. One existing non-BRT bus route (#20) runs east-west connecting Ashland and points west to the Central Loop. Another bus route (#9) runs north-south on Ashland Avenue. The demand on Ashland from Route #9 alone came nowhere near to saturating the planned BRT corridor, so tests were run to see if there would be any benefit in pulling additional demand onto Ashland.

In this case, the service planning team had boarding and alighting data on all the relevant bus routes that interacted with the two corridors, and transfer survey data from all the relevant transfer points. The team mapped the transfer volumes to give a first indication of where customers might be transferring, and did further transfer surveys in those locations. Using simple probability to predict how many customers are likely to transfer from one bus route to the next, the team constructed a corridor-specific origin destination (OD) matrix to test the likely demand and time savings of a few alternative additional services.

They ended up testing the demand levels, and costs and benefits of several alternative routes:

In addition to recommending a BRT service to replace Route #9 up and down Ashland, a southern "L" shaped route was recommended connecting to the Central Loop BRT link, a northern "L" shaped route connecting to the Central Loop BRT, and two "S" shaped routes, coming from the west, turning onto Ashland for a stretch, and then turning again into the Central Loop, as shown above.

Figure 6.72. For the Ashland and Central Loop BRT projects in Chicago, original typical grid-pattern bus services will not optimally serve the demand when converted to BRT. Image *Pedro Szász.*

Figure 6.73. For the Ashland and Central Loop BRT projects in Chicago, BRT service planning revealed that two L-shaped (top) and two S-shaped services (bottom) providing direct connections between Ashland and the Central Loop could provide the optimal service improvement. Image *Pedro Szász.*

Table 6.54. Recommended Frequency per Route

Scenario	Baseline	Standard BRT Route	L Shaped Routes	L and S Shaped Routes
Local Route	6.5	2	1	1
BRT 1	0	10	4	4
LN	0	0	6	5
NS	0	0	5	4
SN	0	0	0	4
SS	0	0	0	4
SE	0	0	0	0

In this case, with the construction of the BRT corridor, the introduction of L- and S- shaped routes that better corresponded to the travel patterns of most people would bring significant user benefits. Total travel time would be reduced for some customers because of increased speeds along the BRT corridor. Some customers would benefit because they would avoid the time previously consumed by transferring either to a bus or a rail line. While the frequency per route drops, because most customers can choose either the direct route or the L-shaped route, the customers who benefit from the inclusion of the new routes outweigh the additional waiting times for a few customers.

These benefits are significantly greater in high-demand scenarios, where reducing the frequency per route is generally beneficial, and they are marginal in lower demand scenarios. Another service-planning problem that has emerged in some of the larger BRT networks is the lack of inter-corridor routes. This problem tends to manifest itself most acutely in trunk-only or trunk-and-feeder systems. Mexico City, Teheran, and Jakarta all initially developed trunk-only services. These systems all had BRT corridors with very simple services that operated only one local service up and down each BRT trunk corridor. This resulted in crush transfer loads at critical transit points in the BRT network. The worst example of this, which persists, is the overcrowding at the Harmony station in Jakarta. Similar crush loads are observed at the key transfer points in Teheran. Much of this overcrowding has already been mitigated in Mexico City and Jakarta by simply adding a route that travels between one corridor and the next, avoiding the need for a substantial portion of the customers to transfer.

If the original BRT system was developed with "direct" BRT services with a reasonably optimal service plan, this problem would be unlikely.

If the corridor selection process outlined in Chapter 5: Corridor and Network Development is followed, the first BRT corridor is the corridor with the highest vehicle demand and the slowest speeds. If this corridor is given services that operate on and off the BRT trunk corridor, then chances are that the second corridor will simply be an infrastructure upgrade along one or more of these services that already use the first BRT corridor. Even if the original BRT system is a trunk-and-feeder system, it is usually no problem to introduce inter-corridor routes within the trunk system.

Bogotá's TransMilenio system, despite being a trunk-and-feeder system, has an extensive variety of inter-corridor routes. Customers at a single station may have as many as ten different routes from which to choose, including local and limited-stop services.

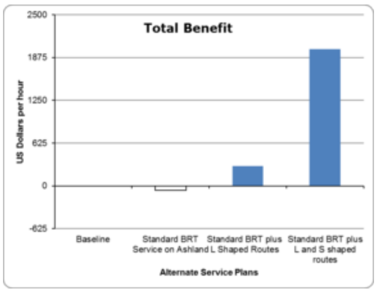

Figure 6.74. Total estimated benefits for four alternative service plans based on modeled results on Chicago's Ashland corridor: Existing services (baseline), the initial proposal for eliminated stops along Ashland, a service scenario where two additional routes with direct services to the CBD have been added, and a final service scenario where "S" shaped routes have been added. Image *Pedro Szász.*

Figure 6.75. Jakarta's BRT Harmoni (a central transfer) station during the peak hour. Image *Karl Fjellstrom, Far East BRT.*

Figure 6.76. BRT and the synergies of route permutations. Image *ITDP.*

6.9 Pulling Services onto a BRT Trunk Corridor from a Parallel Corridor

"Eventually, all things merge into one, and a river runs through it."

— Norman Maclean, author, 1902–1990

If the BRT trunk corridor is not saturated after adding all the existing routes onto the corridor by the BRT service plan, it may be advantageous to take a bus route that currently does not use the BRT corridor, and pull it onto the BRT corridor. The result will likely be a travel time savings for some customers, as their trip will be sped up on the BRT portion of the route. However, it could also mean a travel time loss for other customers, if the rerouting results in a longer trip for them or longer walks. These costs and benefits need to be weighed in order to make the decision.

Above are three simplified scenarios that show the basic options for handling an existing route that travels *near* the BRT corridor.

- Option I represents the way bus routes are currently configured—the green line is the BRT corridor with a BRT route on top of it, and the blue line is an existing bus route that travels near the BRT corridor and ends in the same place;
- Option II represents a decision to "route on" the blue service to use the BRT infrastructure, but retain it as a "direct service";
- Option III represents a route that has been "routed on" to a BRT corridor, but split into a trunk feeder service.

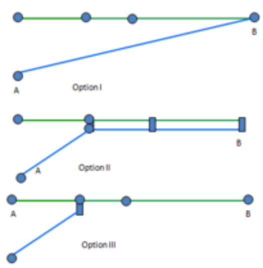

Figure 6.77. Three options for planning routes near a BRT corridor. Image *ITDP.*

If there is sufficient demand to justify it, a fourth option would be to retain the current route and add a new route that uses the BRT trunk corridor for part of the route. Option I is preferable when pulling a bus service onto a new, faster BRT corridor introduces more delay due to the indirectness of the route than it saves due to the superior BRT infrastructure. Option II is preferred when the travel-time savings of pulling the route onto the BRT corridor for part of its journey saves more time and serves as many customers as the current route operating in mixed traffic conditions. Option II introduces some indirectness of route but avoids any transfer penalty. Option III would be preferred mainly when there are significant time savings benefits to rerouting onto the BRT trunk corridor, yet the addition of a fully direct service in the optimal vehicle size for that service would saturate the BRT corridor, slowing down the speeds for the busway. The indirectness of route and transfer penalty would need to be compensated by both the higher speeds of using the BRT trunk corridor and the higher frequencies in the new feeder route.

In some cases, it is best to create a hybrid of Options I and II, where the blue route is routed onto the BRT corridor, while the original blue route service is retained. Frequency would need to be split between the two, and this would allow customers who benefit more from one or the other scenario to have the option of which route to take. Many of the issues described in the limited-services section apply here since you are again splitting frequencies. However, this might also be a more politically feasible solution—even when there are greater benefits to routing a service onto the BRT corridor—because it can often be politically challenging to eliminate a route altogether.

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7. System Speed and Capacity

Designing a BRT system to comfortably handle high customer demand in a rapid manner is paramount to delivering a car-competitive service. The cities of Bogotá, Colombia; Rio de Janeiro, Brazil; Belo Horizonte, Brazil; Istanbul, Turkey; Guangzhou, China; and Brisbane, Australia, have firmly demonstrated that high-speed and high-capacity operations can be achieved with BRT at a considerably lower cost than rail options, while providing shorter distances and shorter access times to destinations than rail options.

Although accessibility, comfort, communication, cost, capacity, speed, and frequency are all noticeable features of successful BRT systems, speed sets BRT apart from conventional bus systems. Once detailed service planning is in place, infrastructure and technology specifications must be made in order to guarantee that the system can perform as required to deliver sufficient speeds.

This chapter explains how the basic features of the BRT system and the details of the station's specifications affect the capacity of the system, and how to make the right decisions to guarantee that the system will maintain high speeds for any given demand forecast. The chapter explores the reasoning behind the procedures used in Chapter 6: Service Planning to show that the planning process is simple; difficulty arises only when there are too many variables. If data is properly organized, the optimum results are achievable.

The first section revisits the goals of the design; the second section outlines the process of evaluating corridor capacity and speed; the third section focuses on how increasing capacity affects speed through the concept of station saturation; and the fourth section provides the equation for calculating speeds and capacity for a proposed solution. The last two sections consider the effects of basic features on system capacity and speed.

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7.1 Design Objectives

> *"An optimist will tell you the glass is half-full; the pessimist, half-empty; and the engineer will tell you the glass is twice the size it needs to be."*
>
> — Anonymous

BRT projects seek to optimize one basic parameter: minimizing door-to-door travel time. Thus, to achieve that goal, BRT must be designed and planned—including corridor selection, routes and service plan, and alternatives—to ensure that:

- Capacity is sufficient to handle expected customer demand;
- Waiting and transfer times are reduced by providing frequent service;
- Speeds are high, because of reduced delay at stations; ideally, average speeds should be above 20 kph in areas with frequent intersections, 25 kph where there is little mixed traffic interference, and above 40 kph for limited-stop services.

The reduction of waiting/transfer times should have been addressed with service planning. The focus of this chapter is how to achieve sufficient capacity and high speeds. As the number of vehicles and customers increases, the opportunity for bottlenecks and operational problems multiplies. Busway systems can be designed to operate at high capacities, but in some cases, high-demand designs have also produced relatively slow commercial speeds. For example, prior to the Bogotá TransMilenio system, the busway on the Avenida Caracas corridor was able to move more than 30,000 passengers per hour per direction (pphpd); this is less than the current BRT system in the same corridor, but it still exhibits a very high demand. However, due to significant congestion, the vehicles only averaged 10 kph. By comparison, the TransMilenio BRT system operates at an average commercial speed of approximately 27 kph.

Assuming that congestion in mixed traffic is ruled out with the creation of a busway, two obvious candidates can cause delay in the BRT system: intersections and stations. Unless there is conflict between station and intersection design, one should assume that, at intersections, buses would experience a delay similar to cars. One can expect that the delay experienced by the BRT at intersections is similar to cars in off-peak hours and that BRT will perform better than cars at rush hour. Chapter 24: Intersections and Traffic Signals addresses station location in relation to intersection design, reviews station delays associated with intersections, and suggests how to improve BRT and car travel times at intersections. *If stations are properly designed, they are far more likely to increase BRT speeds.* If not properly designed, however, stations may contribute to decreased speeds, as well as decreased capacity in relation to a conventional system.

The demand analysis process and demand forecast modelling can help quantify existing public transport demand, as well as provide projections of expected demand and growth. A system's infrastructure should be designed for capacities projected at least one decade into the future. The size of the growth cushion will depend on how fast a city's population and mobility needs are increasing. For example, in some rapidly urbanizing Chinese cities, growth rates of up to 25 percent are being realized in fewer than five years. In such instances, a growth cushion of 50 percent or higher may be appropriate for sizing the system's capacity. In other regions that are already highly urbanized, such as Latin America, growth rates are much lower. In Latin American cities, a growth cushion of 25 percent has been used.

Figure 7.1. Designing a system along corridors with demands exceeding 30,000 passengers per hour per direction, like the one in Bogotá is quite different from designing systems with less than 3,000 pphpd, like the one shown in figure 7.2 *Carlos F. Pardo.*

Figure 7.2. System to serve less than 3,000 pphd in Orlando (Florida, USA), is quite different from system to serve 30.000 ppphpd as the shown in figure 7.1 *Lloyd Wright.*

Designing a high-capacity and high-speed BRT system does not guarantee that door-to-door travel times will be minimized. High-capacity and high-speed services can be achieved simply by eliminating all the stops along a BRT corridor, and having service run only between the two terminals. Metro systems are often designed with very long distances between station stops in order to increase average speeds and capacity. However, this has an adverse impact on door-to-door travel times, as customers will have much farther to walk to reach the nearest public transport station. The system's design therefore must be optimized so as to minimize door-to-door travel times for the majority of customers—not just in terms of speed and capacity.

The specific design solutions to achieve high capacity vary widely for different levels of demand. For example, a BRT system that only needs to handle a demand of 5,000 passengers per hour per direction (pphpd) will be significantly different from a system requiring over 30,000 pphpd (Figures 7.1 and 7.2).

7.2 The Process of Designing High-Capacity and High-Speed BRT Corridors

"Design is the conscious effort to impose a meaningful order."

— Victor Papanek, designer and educator, 1927–1998

To clearly understand the following three sections, the reader must be familiar with the definitions outlined in the "Basic Concepts" section of Chapter 6: Service Planning.

7.2.1 Concepts Review

One can reasonably expect that capacities are independent of demand — that once the specifications of design and operation are given, the capacity could be calculated regardless of the demand. This is true for each feature of BRT, but there are so many possible limitations to these features that a global analysis without restricting them to the intended use has no practical purpose. Consider the analogy of a truck's capacity (or a glass mug's, as in Figure 7.3): maximum volume, maximum weight, and maximum dimensions are clearly defined, but discussing capacity without knowing what will be transported — cotton, steel, or windmill blades—leaves too many possibilities open. Similarly, given an elevator design — load, speed, door opening times, and protocol to answer calls — one can simulate the wait and travel times for a given demand pattern, but to evaluate all of them would be impractical. It is much easier to evaluate the capacity for a given use.

For this edition, we changed the approach for calculating operational capacity of a corridor: *the capacity of the corridor is the capacity of its bottleneck* One must evaluate the capacity of each station and traffic lights under predicted conditions to check the corridor capacity.

In order to compare situations for design, *capacity* is defined as the number of customers that *can* pass through a given cross section during a time interval. For practical purposes, we will examine that cross section for one-way traffic only and use one hour as a reference measure for the interval.

The *capacity of a segment* (or link) should be given by the lower capacity of a section within it (lower capacity section along the segment). Unlike intersections, where the stop line can be readily identified as the bottleneck of the approaching segment, BRT stations with multiple sub-stops are harder to model as single session; they are easier seen as segments which will have still many potential sections to evaluate for discovering the lower-capacity section. Anyway, the capacity is the maximum possible load across the station.

Figure 7.3. Analyzing capacity without use assumptions leaves too many possibilities open. *Arthur Szász.*

Further confusion could arise by considering the station as a segment, because the load entering the station is not the load leaving the station, unlike a traditional demand segment or link in modelling that is between stations. But that is not a problem for calculating capacity because we are considering the maximum possible load. When dealing with demand load, every demand load in the system would still be taken into account because the load that leaves one station arrives at the next. For the purposes of calculating capacity here, the demand load of a station is the demand load that arrives at it.

As mentioned before and as will be highlighted many times in the following discussions and examples, high capacity is achievable at the cost of speed. Therefore, in agreement with our design objectives, we define the **operational capacity** as **the capacity that does not cause bus queues at the stations**.

What constitutes a queue is still a bit subjective and will be discussed when queue formation is evaluated. One should notice that having no queue does not necessarily imply reduced time at the station. For example, one station in a well-designed system could have a boarding and alighting process taking one minute regularly every five minutes (20 customers boarding through a stepped door), and that would be a fine operation with low operational capacity, which will also be shown later in the chapter.

This definition of capacity is not the capacity of the station itself, but the capacity of the corridor segment where the station is. The station itself has other capacities that need to be specified (or calculated for a given design), including:

- Number of waiting customers, which varies based on comfort parameters;
- Number of boardings per hour and number of alightings per hour, which may be given by a curve when one is dependent of the other (i.e., they use the same door).

More information on station design can be found in Chapter 25: Stations.

The renovation rate is an important concept for understanding that the total number of customers transported by a route may be higher than the capacity of the route as usually defined (it can be lower, too, but that is not difficult to understand). The same concept is needed to evaluate the BRT corridor: the number of customers using the system may be higher than its capacity.

Another observation must be made regarding the renovation rate: when operators and business analysts mention it, they normally refer to transported customers (in a trip, route, or corridor) over the effective supply (the capacity of the vehicles providing the service—trip-places), ignoring both the load factor required for appropriate planning and the fact that in the first years of operation the supply is often lower than capacity, because corridors need to be designed for higher capacity than existing demand, and thus, supply.

One must keep in mind that transport systems' speeds, waiting times, supplied trip-places, demand, and maximum loads will change throughout the day, throughout the seasons, and throughout the years. By monitoring operational data of a built system, one can certainly tell the lower bounds of its capacity (capacity will certainly be greater or equal to the maximum load observed), but even so, the operational capacity would be subject to debate.

7.2.2 Simulating Solutions

Regardless of the debate about operational capacities of transport systems, it is very simple to evaluate the capacity and speed of a proposed design solution under any condition and compare it with other solutions and conditions, including using a car. Besides understanding how to compute dwell time and queuing time in stations, which will be discussed in this chapter, and at traffic lights, which will be discussed in Chapter 24: Intersections and Traffic Signals, the basic requirement is manipulation of the cinematic concept of speed.

Speed is useful to bringing users travelling different distances to a common location, but for evaluation of the system, only the use of speed for evaluation is necessary because people, including planners in and stakeholders of the project, are familiar with speeds, knowing the sensation of movement associated with the readings in a speedometer of a car. A planner compares alternatives of the same implementation and operational cost by comparing the sum of travel times for all people in the city (both those using and not using the system) with the implementation of each alternative.

That said, the equations needed to simulate and compare speeds are:

$$\text{average speed} = \frac{\text{travel distance}}{\text{travel time}} \leftrightarrow \text{travel time} = \frac{\text{travel distance}}{\text{average speed}}$$

$$\text{travel time}_{A-Z} = \text{travel time}_{A-M} + \text{wait time}_{M} + \text{travel time}_{M-Z}$$

The last equation assumes point M is part of travelling itinerary between points A and Z. It can be further divided, assuming that point B is between points A and M.

$$\text{travel time}_{A-M} = \text{travel time}_{A-B} + \text{wait time}_{B} + \text{travel time}_{B-M}$$

This implies the obvious understanding that the travel time along a corridor is the sum of travel time in every segment (or link) with the wait time at every stopping point.

A simple table like Table 7.1 can be constructed to compare travel time and speed for different alternatives and conditions.

Table 7.1. Example of Travel Time Simulation under Different Conditions

		PEAK HOURS										OFF-PEAK HOURS							
		ALTERNATIVE A conventional bus, inside fare collection, median busway, with overtaking at stations				ALTERNATIVE B platform-station, external fare collection median busway with overtaking at stations						ALTERNATIVE A conventional bus, inside fare collection, median busway, with overtaking at stations				ALTERNATIVE B platform-station, external fare collection median busway with overtaking at stations (no limited express service off-peak)			
		ONLY LOCAL SERVICE		CAR		LOCAL SERVICE		LIMITED STOP SERVICE		CAR		ONLY LOCAL SERVICE		CAR		LOCAL SERVICE		CAR	
local	distance (km)	travel time or wait time (seconds)	speed (km/hour)	travel time or wait time (seconds)	speed (km/hour)	travel time or wait time (seconds)	speed (km/hour)	travel time or wait time (seconds)	speed (km/hour)	travel time or wait time (seconds)	speed (km/hour)	travel time or wait time (seconds)	speed (km/hour)	travel time or wait time (seconds)	speed (km/hour)	travel time or wait time (seconds)	speed (km/hour)	travel time or wait time (seconds)	speed (km/hour)
at Terminal A		155		0		28		28		0		105		0		23		0	
Terminal A to Intersection 1	1.2	86	50	123	35	86	50	86	50	108	40	86	50	108	40	86	50	86	50
at Intersection 1		30		30		30		30		30		30		30		30		30	
Intersection 1 to Intersection 2	0.3	22	50	31	35	22	50	22	50	27	40	22	50	27	40	22	50	22	50
at Intersection 2		30		30		30		30		30		30		30		30		30	
Intersection 2 to Station B	0.3	22	50	31	35	22	50	22	50	27	40	22	50	27	40	22	50	22	50
at Station B		55		0		18		0		0		45		0		17		0	
Station B to Intersection 3	0.3	22	50	31	35	22	50	22	50	27	40	22	50	27	40	22	50	22	50
at Intersection 3		30		30		30		30		30		30		30		30		30	
Intersection 3 to Station C	0.2	14	50	21	35	14	50	14	50	18	40	14	50	18	40	14	50	14	50
at Station C		155		0		28		0		0		105		0		23		0	
from station C to Station D	0.5	36	50	51	35	36	50	36	50	45	40	36	50	45	40	36	50	36	50
at station D		80		0		20		20		0		60		0		18		0	
...																			
at station Y		55		0		18		0		0		45		0		17		0	
from station Y to intersection 20	0.1	7	50	10	35	7	50	7	50	9	40	7	50	9	40	7	50	7	50
at intersection 20		30		30		30		30		30		30		30		30		30	
from intersection 20 to Terminal Z	0.6	43	50	62	35	43	50	43	50	54	40	43	50	54	40	43	50	43	50
at Terminal Z		105		0		23		23		0		75		0		20		0	
From Terminal A to Terminal Z	**17.5**	**4885**	**13**	**2400**	**26**	**2523**	**25**	**2210**	**29**	**2175**	**29**	**4035**	**16**	**2175**	**29**	**2438**	**26**	**1860**	**34**

This table can be placed in a different order, joining the unshaded rows (segment times), green shaded rows (intersection times), the gray shaded rows (station times) and programmed to calculate each value based on the characteristics of the proposed design and operation based on the following formulas of this chapter for stations, the formulas given in Chapter 24: Intersections and Signal Control, and in the basic speed formula given for segments. In the initial planning phases, assumptions for intersections plus segments based on observed travel times are good enough for a practical evaluation of alternatives.

A similar table (as shown in Table 7.1) can be made for the capacity of each section, once formulas for capacity are given for stations in the remainder of the chapter, and formulas for capacity of segments, and intersections are given in Chapter 24, based on the proposed design characteristics.

So, with the forecast demand and the design, one can tell if the required performance, initially taken as an assumption, is reached. If not, modifications need to be proposed for the infrastructure (or technology) where failure was observed in relation to expected results. In the unlikely case that an excessive performance is seen, adjustments could also be proposed for a more adequate system. For both cases, the last two sections of this chapter (7.5 and 7.6) will discuss how station, vehicle, and operation features affect speed and capacity.

The next section (7.3) explains how the station design associated with the service plan affects system speed and the following (Section 7.4) discusses how the design of the station for a given boarding and alighting demand affects system capacity.

7.3 Understanding Station Saturation

> *"How did it get so late so soon? It's night before it's afternoon. December is here before it's June. My goodness how the time has flewn. How did it get so late so soon?"*
>
> — Theodor Seuss Geisel (aka "Dr. Seuss"), writer and cartoonist, 1904–1991

If the highest frequency at a BRT corridor bottleneck is one bus per minute, the rest of the corridor will have at most a one bus per minute frequency. Identifying this weak link in the system is the foundation for improving capacity and avoiding congestion, which in turn improves travel times. In general, the critical factor on a public transport system is *vehicle congestion at the station*.

The fact that BRT systems are now able to reach speeds and capacities comparable to all but the highest capacity metro systems is due to dramatic improvements in vehicle capacity at stations. Other factors are also important to reaching these speed and capacity goals, but none are as important as preventing docking bay congestion. Many existing BRT systems are burdened with slow operating speeds due to incorrect demand projections at particular stations. Poorly designed stations can lead to peak-hour vehicle queues that stretch for several hundred meters.

The proper design of a station to prevent congestion is directly related to the concept of *saturation level*, usually referred to simply as *saturation*.

The *saturation level* of a docking bay refers to the proportion of time that a vehicle docking bay is occupied. A docking bay is the designated area in a BRT station where a vehicle will stop and align itself to the boarding platform.

A docking bay might be considered occupied at any given moment, if a bus that wants to position itself at that docking bay cannot proceed with the proper maneuver. Therefore, a vehicle is "using" the docking bay from the moment its approach will prevent other vehicles from doing the same thing until the moment it leaves the area so that another vehicle can approach. The amount of time that any given vehicle occupies a docking bay is called dwell time (T_d).

Box 7.1. Sub-Stops and Docking Bays

A schematic view of a station, from *The BRT Standard*, shows the components of a station including the sub-stops and the docking bays, defined as follows:

- *Sub-stop*: a station subdivision or "module" that includes docking bays and customer circulation and waiting areas. One station can have multiple sub-stops that are physically connected. In order for multiple sub-stops to function, they typically need overtaking lanes or a functional equivalent such as in the "directional" BRT stations used in Lanzhou and Yichang.
- *Docking bay*: the platform-vehicle interface; this is where the bus pulls up in order to let customers on and off.

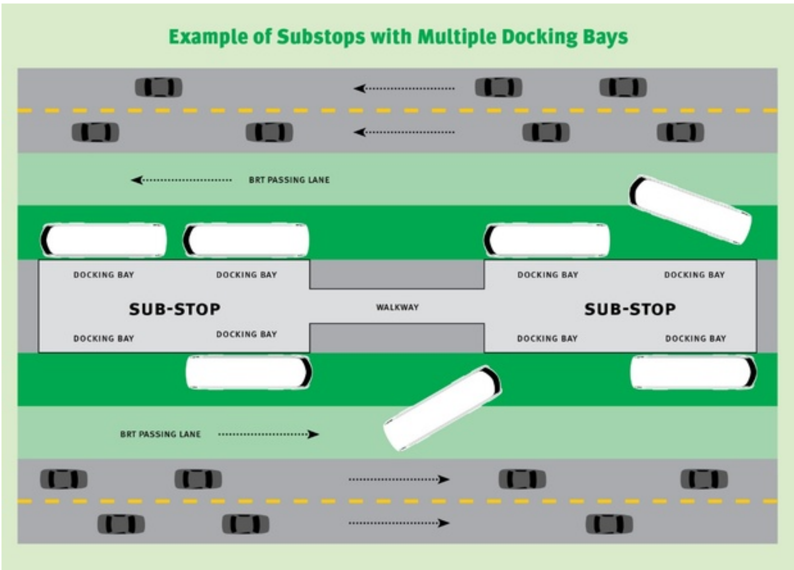

Figure 7.4. Scheme of station with two substops *ITDP*

Therefore, the saturation of a docking bay (x_dock) measured for a certain time interval (Δt) would be given by the sum of dwell times of each bus docking ($Tidi$)

during that interval, divided by the duration of the interval, as expressed by Equation 7.1.

Eq. 7.1 Saturation of a docking bay concept:

$$x_{\text{dock}} = \frac{\sum_{\text{docking bus}i \in \Delta t} T_{id}}{\Delta t}$$

Where:

- x_{dock}: Saturation of a docking bay;
- $\sum_{\text{docking bus}i \in \Delta t} T_{id}$: Sum of docking times of buses;
- Δt: Time interval.

Calling T_d the average dwell time (which is equivalent to assuming that all buses will have the same dwell time T_d), saturation would be:

$$x_{\text{dock}} = \frac{N_{\text{buses}\in \Delta t} * T_{id}}{\Delta t}$$

And calculating the saturation for one hour would result in the following equation:

Eq. 7.2 Saturation of a docking bay for one hour:

$$x_{\text{dock}} = \frac{Freq_{\text{dock}} * T_d}{3600\text{sec}}$$

Where:

- x_{dock}: Saturation of a docking bay;
- $\text{Freq}_{\text{dock}}$: Frequency of buses docking;
- T_d: Dwell time.

The dwell time consists of three separate categories: boarding time, alighting time, and dead time. Boarding and alighting times can partially happen simultaneously, depending on the system protocol for boarding and alighting. Dead time is the time consumed by a vehicle slowing down when approaching a station, opening its doors (and after a variable dwell time for boarding and alighting), closing its doors, and then regaining free flow speed. It is also called *fixed dwell time* because it is the part of dwell time that does not vary with the number of customers boarding and alighting at each stop, and it usually does not vary between stops in a system.

Two elements of the BRT vehicle affect dead time: the rate of vehicle deceleration when approaching a stopping bay and the rate of acceleration when departing from a docking bay. Besides the vehicle capabilities (power-to-weight and gear relations), the deceleration and acceleration rates often involve a trade-off between speed and customer comfort, as well as the ability to properly align the vehicle to the stopping-bay interface.

Vehicle size also affects the dead time. In non-congested situations, vehicles typically require ten to sixteen seconds to open and close their doors and pull in and out of a station and, when in a queue, up to twenty seconds. However, larger vehicles require more time, and additional time between 0.17 to 0.25 seconds per meter of vehicle is generally required for pulling in and out of the station. For a more detailed model, these values need to be calibrated to produce the amount of dead time, but as a conservative approach Equation 7.3 can be used.

Eq. 7.3 Impact of vehicle length on dwell time without queue

$$T_0 = 13 + L_{\text{vehicle}} * 0.25$$

Where:

- T_0: Dead time in seconds;
- L_{vehicle}: Length of the vehicle in meters.

As for the variable part of dwell time (boarding and alighting time), the main factors affecting it include:

- Customer-flow volumes;
- Number of vehicle doorways;

- Width of vehicle doorways;
- Entry characteristics, e.g., stepped or at-level entry, using all doors or having specific doors to board and alight;
- Open space near doorways (on both vehicle and station sides);
- Fare collection position, e.g., at the station entrance, at the bus entrance, in the middle of the bus;
- Doorway control system.

BRT systems are able to operate metro-like service in large part due to the ability to reduce total stop time to twenty seconds or less. A conventional bus service often requires more than sixty seconds for stop time, though the specific time will be a function of the number of customers and other factors. In general, dwell times may be somewhat higher during peak periods than nonpeak periods. The increase during peak periods is due to the additional time needed to board and alight the higher customer volumes.

In a system where both boarding and alighting happens through all doors, dwell time is given by Equation 7.4:

Eq. 7.4 Dwell time for one bus with an external fare collection and all-door boarding: $T_d = T_0 + p_b * t_b + p_a * t_a$

Where:

- T_d: Dwell time for a given bus;
- T_0: Dead time for the given bus;
- t_b: Average boarding time per customer;
- t_a: Average alighting time per customer;
- p_b: Number of boarding customers at the given bus;
- p_a: Number of alighting customers at the given bus.

If boarding is made exclusively through different doors than alighting, then the dwell time for a bus is given by Equation 7.5:

Eq. 7.5 Dwell time for one bus with specific doors for boarding or alighting:

$$T_d = T_0 + Max(p_b * t_b, p_a * t_a)$$

Where:

- T_d: Dwell time for a given bus;
- T_0: Dead time for the given bus;
- t_b: Average boarding time per customer;
- t_a: Average alighting time per customer;
- p_b: Number of boarding customers at the given bus;
- p_a: Number of alighting customers at the given bus.

Equation 7.6 shows the saturation calculation for the situation where both boarding and alighting occur through the same doors.

Eq. 7.6 Calculating the saturation level of a docking bay for a given time interval, under external fare collection and all door boarding:

$$x_{\text{dock}} = \frac{T_0 * N_{\text{bus}} + [(P_b * t_b) + (P_a * t_a)]}{\Delta t}$$

Where:

- x_{dock}: Saturation level of a docking bay for a given time interval;
- N_{bus}: Number of vehicles that use the docking bay during the interval (if the time interval is an hour it is the usual frequency of services referenced in vehicles per hour);
- T_0: Average dead time per bus;
- t_b: Average boarding time per customer;
- t_a: Average alighting time per customer;
- P_b: Number of boarding customers at docking bay during interval;
- P_a: Number of alighting customers at docking bay during interval;

- Δt: Time interval duration (this is usually seen as 3,600 since one hour calculation is normally done and other times are given in seconds).

The equation shows that for a given demand (number of customers) using a docking bay to board and alight, the way to reduce saturation is by minimizing the time needed to board or alight or by reducing the number of buses, given that the dead time cannot be significantly reduced. The remaining alternative is to split the demand in more docking bays.

To illustrate the saturation calculation, we take the example of a TransMilenio's, Modulo A2 of Alcalá Station (March 8, 2007, data) where between 7:00 a.m. and 8:00 a.m. there were 62 vehicles stopping, 975 boarding customers, and 23 alighting customers. The dead time is 15 seconds, boarding time per customer is 0.3 seconds, and alighting time per customer is 0.2 seconds. This way, the saturation level between 7:00 a.m. and 8:00 a.m. can be estimated as:

$$x = \frac{15\frac{\text{sec}}{\text{vehicle}} * 62\text{vehicles} + [(975\text{pax} * 0.3\frac{\text{sec}}{\text{pax}}) + (23\text{pax} * 0.2\frac{\text{sec}}{\text{pax}})]}{3,600\text{sec}}$$

$$x = \frac{930\text{sec} + [(292.5\text{sec}) + (4.6\text{sec})]}{3,600\text{sec}} = \frac{409\text{sec}}{3,600sec} = 0.11$$

Understanding saturation is important because queue formation is a function of it.

According to the theory of queues, the expected queue a vehicle faces when approaching a station would be given by Equation 7.7

Eq. 7.7 Queue size:

$$\text{QueueSize}_{\text{dock}} = \frac{0.5 * (Irr_{\text{arrival}} + Irr_{\text{departure}}) * x_{\text{dock}}^2}{(1 - x_{\text{dock}})}$$

Where:

- $\text{QueueSize}_{\text{dock}}$: Average or expected queueing size at docking bay;
- x_{dock}: Saturation level of a docking bay for a given time interval; xdock = Saturation of a docking bay;
- Irr_{arrival}: Irregularity of arrivals ($= \frac{\text{Variance}_{\text{arrivals' intervals}}}{\text{Mean}^2_{\text{arrivals' intervals}}}$);
- $Irr_{\text{departure}}$: Irregularity of departures ($= \frac{\text{Variance}_{\text{departures' intervals}}}{\text{Mean}^2_{\text{departures' intervals}}}$).

The mean of the intervals for arrivals and departures is the headway, and the variance would be similar to the variance for boardings and alightings if there were no traffic lights and starting schedules were exactly followed. If a service was totally regular, no queues would be expected. The particular case when irregularities for arrival and departure are random ($Irr_{\text{arrivals}} = Irr_{\text{departures}} = 1$) would result in the queue given by Equation 7.8.

Eq. 7.8 Queue size for random arrivals and random boarding-alighting times (the mean can be known):

$$\text{QueueSize}_{\text{dock}} = \frac{x_{\text{dock}}^2}{(1 - x_{\text{dock}})}$$

Where:

- $\text{QueueSize}_{\text{dock}}$: Average or expected queueing size at docking bay;
- x_{dock}: Saturation level of a docking bay for a given time interval.

For the common irregularities observed in urban busways with high volumes (headways below one minute), Equation 7.9, derived from observation, can be used:

Eq. 7.9 Queue size for busways in typical urban conditions:

$$\text{QueueSize}_{\text{dock}} = \frac{0.7 * x_{\text{dock}}^2}{(1 - x_{\text{dock}})}$$

Where:

- $\text{QueueSize}_{\text{dock}}$: Average or expected queueing size at docking bay;
- x_{dock}: Saturation level of a docking bay for a given time interval.

The expected (average) waiting time in queue (T_{queue}) is given by the queue size multiplied by the average headway, as expressed in Equation 7.10:

Eq. 7.10 Time waiting in queue:

$$T_{\text{queue}} = \text{QueueSize} * \text{Hdwy}$$

Where:

- T_{queue}: Time waiting in queue;
- $QueueSize$: Average or expected queueing size;
- Hdwy : Average headway.

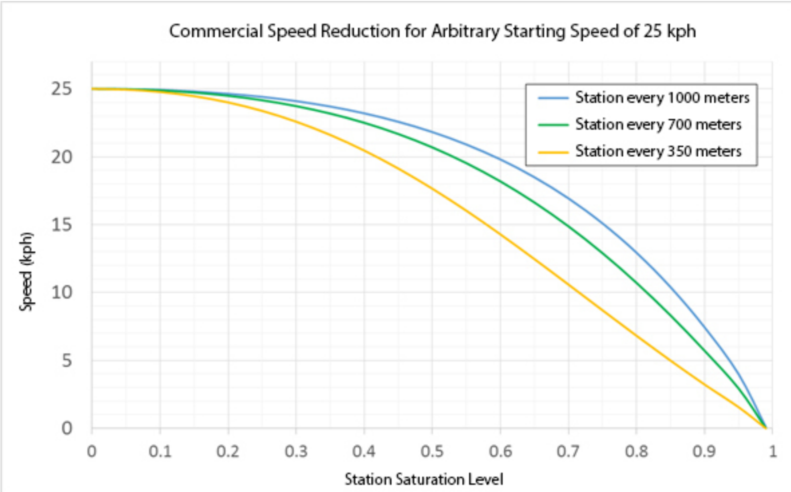

Figure 7.5. The Impact of saturation on vehicle velocity is bigger the closer the stations are to each other as each station implies more queueing delay. *Elebeta.*

A low saturation level or a high level of service means that there are no vehicles queuing at a docking bay. A high saturation level means that there will be long queues at docking bays. Therefore, increasing station saturation tends to lead to a gradual deterioration of service quality. For saturation levels over one ($x > 1$), the system is unstable with queues increasing until the demand is reduced after the peak period.

For the previous example, the module of Alcalá station has a low saturation rate (0.11). At this level, one should not expect to have congestion problems at the station, as the expected queue size and time would be irrelevant:

$$\text{QueueSize}_{\text{dock}} = \frac{0.7 * x_{\text{dock}}^2}{(1 - x_{\text{dock}})} = \frac{0.7 * 0.11^2}{(1 - 0.11)} = 0.0095$$

$$T_{\text{queue}} = \text{QueueSize} * \text{Hdwy} = 0.0095\text{vehicles} * \frac{1}{62\,\frac{\text{vehicles}}{\text{hour}}} = 0.00153\text{hour} = 0.55\text{sec}$$

The decision about which saturation levels can be tolerated in specific locations should be considered within the overall design context. However, one must keep in mind that for saturation levels above 0.60 (or 60 percent), the risk of severe congestion and system breakdown is considerable. For BRT stations, 40 percent is the maximum accepted for planning purposes, allowing a reasonable safety margin for uncertainties in the planning process. That is, the cumulative time that a vehicle is stopped at a station should not exceed 40 percent of the total time available in an hour.

Expected station saturation effects on commercial speeds are shown in Figure 7.5. Bogotá's TransMilenio strives to keep the saturation value in the range of 0.35 to 0.45. The Calle 76 station of the TransMilenio system illustrates the importance of accurately projecting customer movements and station saturation levels. Originally, this critical station was planned for a saturation level of 0.40, but during actual operation the saturation reached 0.65 due to an unexpectedly high number of transfers. Similar levels of saturation were experienced at Heroes Station (which has subsequently been expanded), where saturation was much higher than the 0.40 level anticipated. This experience shows the importance of being somewhat conservative by planning for 40 percent station saturation.

When boarding is made through different doors, one could expect saturation to be calculated as given by Equation 7.11.

Eq. 7.11 Simplified saturation level of a docking bay where boarding is through specific doors:

$$x_{\text{dock}} = \frac{T_0 * N_{\text{bus}} + Max(p_b * t_b, p_a * t_a)}{\Delta t}$$

Equation 7.11 works when one of the movements between boarding and alighting is clearly longer or if customers arrive at stations in a completely regular fashion between the bus passages (the longer the headway the more regular this number is). But if the times for boarding and alighting are similar, then there will be a certain number of times when boarding will end first and a certain number of times when alighting will end first. If the expected times for each operation were equal, then each operation would be expected to end first half of the time.

For a random distribution of boarding and alighting times (where the average times are known), the number of occasions that the one operation will be longer than the other is given by Equation 7.12.

Eq. 7.12 Expected occurrence of the shortest time overcoming the longer:

$$rf1 = \frac{\overline{t1}}{\overline{t1} + \overline{t2}}$$

Where:

- $rf1$: Relative frequency where event 1 is longer than event 2;
- $\overline{t1}$: Average length of distribution of events 1;
- $\overline{t2}$: Average length of distribution of events 2;

Using the Poisson distribution, a discrete probability distribution, for events 1 and 2, where the standard deviation is equal to the mean, is assumed.

If we call the mean boarding time per bus of T_b, with $T_b = t_b * P_b$, and mean alighting time per bus of Ta, with $T_a = t_a * p_a$, the average dwell time would be given by Equation 7.13.

Eq. 7.13 Saturation level of a docking bay where boarding is through specific doors:

$$T_d = T_0 + T_a + (\frac{T_b}{T_a + T_b}) * T_b = T_0 + T_b + (\frac{T_a}{T_a + T_b}) * T_a$$

Where:

- T_d: Average dwell time for all buses on a docking bay;
- T_o: Average dead time for all buses on a docking bay;
- T_a: Average alighting time for all buses on a docking bay;
- Tb: Average boarding time for all buses on a docking bay;
- $\frac{T_b}{T_a+T_b}$: Relative frequency that boarding will be longer than alighting;
- $\frac{T_a}{T_a+T_b}$: Relative number of times that alighting will be longer than boarding.

Therefore the saturation for a docking bay where boarding is made through specific doors is given by Equation 7.14.

Eq. 7.14 Saturation calculation when boarding is through a specific door:

$$x_{\text{dock}} = \frac{T_0 * N_{\text{bus}} + P_b * t_b + (\frac{P_a * t_a}{P_a * t_a + P_b * t_b}) * P_a * t_a}{\Delta t}$$

Where:

- x_{dock}: Saturation level of a docking bay for a given time interval;

- N_{bus} :: Number of vehicles that use the docking bay during the interval (if the time interval is an hour it is the usual frequency of services referenced in vehicles per hour);
- T_0: Average dead time per bus;
- t_b: Average boarding time per customer;
- t_a: Average alighting time per customer;
- P_b: Number of boarding customers at docking bay during interval (average boarding time per bus is given by $T_b = t_b * P_b$);
- P_a: Number of alighting customers at docking bay during interval(average alighting time per bus is given by $T_a = t_a * P_a$;
- Δt: Time interval duration (this is usually seen as 3,600 since one hour calculation is normally done and other times are given in seconds).

For example, a regular bus stop in front of a children's hospital in São Paulo, using data from between 6:00 a.m. and 7:00 a.m. on February 2, 2007, is served by two routes with a frequency of four trips per hour each. The average number of boardings per vehicle is 4.1, for a total of 33, and the average number of alightings per vehicle is 10, for a total of 80. People carrying babies count as one. The average time per person for boarding is five seconds, and for alighting it is three seconds, with one wheelchair alighting taking around forty-five seconds. The saturation of this stop would be calculated as:

$$x_{\text{dock}} = \frac{T_0 * N_{\text{bus}} + P_b * t_b + (\frac{P_a * t_a}{P_a * t_a + P_b * t_b}) * P_a * t_a}{\Delta t}$$

$$x = \frac{16\frac{\text{sec}}{\text{vehicle}} * 8\text{vehicles} + (33\text{pax} * 5\frac{\text{sec}}{\text{pax}}) + (\frac{80*3.0}{80*3.0+33*5}) * 80\text{pax} * 3.0\frac{\text{sec}}{\text{pax}}}{3,600\text{sec}}$$

$$x = \frac{128\text{sec} + (165\text{sec}) + (\frac{240}{240+165}) * 240\text{sec}}{3,600\text{sec}}$$

$$x = \frac{128\text{sec} + (165\text{sec}) + (\frac{240}{405}) * 240\text{sec}}{3,600\text{sec}}$$

$$x = \frac{128\text{sec} + (165\text{sec}) + 0.59 * 240\text{sec}}{3,600\text{sec}} = 0.12$$

With the stop being occupied only 12 percent of the time, the average expected queue is 0.012 (each hundred arrivals the stop will be used by another bus), and the average queue delay is 5 seconds, as calculated below:

$$\text{QueueSize} = \frac{0.7 * x_{\text{dock}}^2}{(1 - x_{\text{dock}})} = \frac{0.7 * 0.12^2}{(1 - 0.12)} = 0.0116$$

$$T_{\text{queue}} = \text{QueueSize} * \text{Hdwy} = 0.0116\text{vehicles} * \frac{1}{8\frac{\text{vehicles}}{\text{hour}}} = 0.001455\text{hour} = 5.23\text{sec}$$

7.3.1 Saturation on a Sub-Stop with Many Docking Bays

The defining characteristic of a sub-stop with two or more docking bays is that a vehicle can leave the sub-stop only if the vehicle in front of it has already left. We can assume that if this design is under consideration, the saturation for only one docking bay is relatively high, so we may ignore the situations where frequency is low and dwell times are short. We are facing something between two extreme situations:

- Low frequencies with many customers boarding and alighting in a terminal-like situation;
- High frequencies with short dwell time.

Of course, another situation could be when there is a high boarding-alighting demand with high service frequencies without the use of overtaking lanes.

Same service at all docks

If the vehicles that dwell at the sub-stop with N docking bays were all serving the same route and the vehicles were riding in a platoon (of N vehicles), this would be equivalent to having a longer vehicle (like a train): the number of doors would be multiplied by N, both the boarding time and the frequency of this longer vehicle would be the original frequency divided by N too, which in this case, saturation would be divided by N.

That is ignoring that the dead time for the "train" would be slightly longer than that of one vehicle alone; this difference would not be meaningful considering the lack of precision in the previously proposed Equation 7.3 when there is no queue.

But when the bay is congested (i.e., is a queue moving), which is the likely situation when multiple docking bays are under consideration, the dead time for the whole convoy would be given by Equation 7.15.

Eq. 7.15 Dead time for convoy:

$$T_{0\text{convoy}} = 13 + 0.25 * L_{\text{vehicle}} * 0.25 + (2 + 0.17 * L_{\text{vehicle}}) * (N - 1)$$

Where:

- $T_{0convoy}$: Dead time in seconds for the whole convoy;
- N: Number of vehicles in the convoy;
- L_{Vehicle}: Length of each convoy vehicle in meters (average vehicle length when vehicles are different).

Ordered platoon (routes attributed to docks)

If the routes stopping at the sub-stop are different, but platoons are organized when entering the busway (Figure 7.6) always in an order that customers can be positioned on the platform in front of the right docking bay, the whole "train" would leave the station once boarding and alighting in the most heavily demanded "car" was completed.

If the number of arrivals of customers at the station was regular and equally distributed at all routes, the saturation for the sub-stop would be equal to the saturation of the most congested docking bay, when an average queue size is N times bigger.

But if the number of customers that arrive at a station to board each route is variable, then an additional dwell time must be added to calculate the saturation of the most congested docking bay. To do this, within that variability, there is an expected regularity, with the known mean and equal standard deviation value of the worst case. This is a situation similar to boarding and alighting through different doors, as at certain times the boarding-alighting times of each platform may overcome the others.

Assuming $T_{ib/a}$ is the average boarding and alighting time calculated for the ith docking bay, if there were two docking bays, the average dwell time for the convoy would be given by Equation 7.16.

Eq. 7.16 Average dwell time for two docking bays in a sub-stop:

$$T_{\text{d 2 bays}} = T_0 + T_1 + T_2 - \frac{1}{\frac{1}{T_1} + \frac{1}{T2}} = T_0 + T_1 + \frac{T_2}{T1 + T2} * T2$$

If there are three platforms, the equation (shown in 7.17) gets a bit longer.

Eq. 7.17 Average dwell time for three docking bays in a sub-stop:

$$T_{\text{d 3 bays}} = T_0 + T_1 + T_2 + T_3$$
$$- \frac{1}{\frac{1}{T_1} + \frac{1}{T2}} - \frac{1}{\frac{1}{T_1} + \frac{1}{T3}} - \frac{1}{\frac{1}{T_2} + \frac{1}{T3}}$$

$$+\frac{1}{\frac{1}{T_1}+\frac{1}{T_2}+\frac{1}{T3}}$$

For four platforms it gets even longer and becomes too impractical and difficult to apply.

Eq. 7.18 Average dwell time for four docking bays in a sub-stop:

$$T_{\text{d 4 bays}} = T_0 + T_1 + T_2 + T_3 + T_4$$
$$-\frac{1}{\frac{1}{T_1}+\frac{1}{T2}}-\frac{1}{\frac{1}{T_1}+\frac{1}{T3}}-\frac{1}{\frac{1}{T_1}+\frac{1}{T4}}-\frac{1}{\frac{1}{T_2}+\frac{1}{T3}}-\frac{1}{\frac{1}{T_2}+\frac{1}{T4}}-\frac{1}{\frac{1}{T_3}+\frac{1}{T4}}$$
$$+\frac{1}{\frac{1}{T_1}+\frac{1}{T_2}+\frac{1}{T3}}+\frac{1}{\frac{1}{T_1}+\frac{1}{T_3}+\frac{1}{T4}}+\frac{1}{\frac{1}{T_2}+\frac{1}{T_3}+\frac{1}{T4}}$$
$$-\frac{1}{\frac{1}{T_1}+\frac{1}{T_2}+\frac{1}{T_3}+\frac{1}{T4}}$$

Where:

- $T_{\text{d N bays}}$: Average dwell time for a sub-stop with N docking bays (equation will have 2^N terms);
- T_0: Dead time (given by Equation 7.15);
- T_i: Variable dwell time for ith docking bay calculated in isolation (given by Equation 7.4 or 7.13 minus T_0).

This equation can be extended to any number of platforms and can be relatively easily implemented by an algorithm, but an alternative formula (Equation 7.19) that underestimates saturation by 2 percent for each additional docking bay above two can be used for practical purposes.

Eq. 7.19: Practical approximation for average dwell time for N docking bays in a sub-stop:

$$T_{\text{d N bays}} : T_0 + \frac{3}{N+2} * \sum_{i=1}^{N} T_i$$

Where:

- $T_{\text{d N bays}}$: Average dwell time for a sub-stop with N bays (equation will have 2N terms);
- N: Number of vehicles in the convoy;
- T_0: Dead time (given by Equation 7.15);
- T_i: Variable dwell time for ith docking bay calculated in isolation (given by Equation 7.4 or 7.13 without considering T_0 there).

Figure 7.6. Convoying systems order vehicles when entering the corridor, so they ride as "train" and the docking position for every route at the station is fixed, preventing users from running up and down the platform. *Pedro Szász.*

Unordered vehicles

If the routes stopping at the sub-stops are different and may arrive in any order, the approximation for saturation is the same, but what is observed in reality is that for sub-stops with three or more docking bays, a certain quantity of vehicles stops twice to pick up customers that miss the vehicle dwelling at the first time. Unless there is operational enforcement for preventing this second stop, this can be seen as enforcing bad service.

In a design situation, more than three docking bays without organized convoys should not be proposed. If dealing with an existing situation, the safest thing to do is to measure the existing saturation.

7.4 Calculating Corridor Capacity

> *"If I have the belief that I can do it, I shall surely acquire the capacity to do it even if I may not have it at the beginning."*
> — Mahatma Gandhi, political and spiritual leader, 1847–1948

7.4.1 Corridor Capacity at Station Calculation

The provision of high capacities without creating undue saturation is a principal design consideration of most BRT systems. Once the bottleneck of the system is the station, the capacity of a BRT corridor is given by the capacity of its busiest station section, which is basically dependent on the vehicle size, load factor, and sum of service frequencies dwelling at each sub-stop with those who "jump" the station (direct services). Equation 7.20 below shows this.

Eq. 7.20 Corridor capacity at the station:

$$\text{CorridorCapacity}_{\text{at station}} = \text{VSize} * \text{LoadFactor} * (\text{Freq}_{\text{direct}} + \sum_{i=1}^{N_{\text{sub-stops}}} \text{Freq}_i)$$

Where:

- $\text{Corridor Capacity}_{\text{at station}}$: Number of people the corridor can transport through a given station section, in passengers per hour per direction (pphpd);
- VSize: Maximum vehicle capacity;
- LoadFactor: Average occupancy of the vehicles at the station, expressed as a proportion of the maximum vehicle capacity;
- $\text{Freq}_{\text{direct}}$: Frequency of limited-stop services that skip the station under analysis;
- Freq_i Vehicle frequency at sub-stop i is the number of vehicles that dwells at all docking bays of sub-stop i during the evaluated interval (usually an hour);
- $N_{\text{sub-stops}}$: Number of independent sub-stops in each station.

For a more generic evaluation, assuming the frequency in each sub-stop is the same, the corridor capacity at the station is:

Eq. 7.21 Basic formula for corridor capacity at station

$$\text{CorridorCapacity}_{\text{at station}} = \text{VSize} * \text{LoadFactor} * (\text{Freq}_{\text{direct}} + \text{NSubstops} * \text{Freq}_{\text{sub-stop}})$$

Table 7.2 shows sample corridor capacities for a range of common scenarios without limited-stop services. By varying only the vehicle capacity and the number of sub-stops per station, it shows just how powerful these two factors are in determining system capacity. It must be noted that the actual potential capacities for a given city will not be influenced by other system characteristics. But it should also be noticed that the table and the equation do not reveal anything about system speed.

Table 7.2. BRT Corridor Capacity at Station Scenarios

Vehicle capacity (passengers)	Load factor	Vehicle frequency per hour per sub-stop	Number of sub-stops per station	Capacity flow (passengers per hour per direction)
70	0.85	60	1	3,570
160	0.85	60	1	8,160
270	0.85	60	1	13,770

70	0.85	60	2	7,140
160	0.85	60	2	16,320
270	0.85	60	2	27,540
70	0.85	60	4	14,280
160	0.85	60	4	32,640
270	0.85	60	4	55,080
160	0.85	60	5	40,800
270	0.85	60	5	68,850

Source: Institute of Transportation Studies, University of California, Berkeley

The value of sixty vehicles per hour at a sub-stop with one docking bay is a common and relatively easy way to achieve value—that is, one vehicle per minute. A regular bus stop (let us say a curbside stop in a congested mixed traffic environment) with space for two 12-meter vehicles loading simultaneously would handle 60 vehicles per hour, while the average number of boardings per bus is not bigger than 30 customers (which is one-third of such bus maximum capacity); we assume 20 seconds of dead time (dead time is shorter under congested conditions) and 3 seconds per boarding customer (which is achievable with one step boarding at one door as long as fare collection is in the middle the bus).

The tricky part of the design is achieving that frequency without forming queues at the station. For the example of the last paragraph, at a one docking bay capacity, one should expect a queue of 12 vehicles after one hour of operation, 24 vehicles after two hours of operation, and so on. If instead of an average of 30 customers boarding per bus, the average would be 20 customers boarding per bus, a saturation level of 75 percent, after one hour of operation the expected queue would be of 2.5 buses and of similar size after that. This still would mean an extra delay of two minutes for all customers inside the bus at this bus stop. The total time at the station would be three minutes instead of two. That is quite a lot if compared with TransMilenio (see the example illustrating Equation 7.1) where the time at a station for twenty customers to board would be twenty-one seconds.

The number of docking bays can also create serious problems, unless operating in a controlled convoy, a station split in two curbside stops as in the previous example (operating at a 75 percent saturation level) would have to be apart from each other by 100 meters to create queueing places for the buses (even the average queue is of 2 to 3 vehicles, it will likely reach 7 vehicles queueing behind the 2 already loading in the course of an hour of operation), otherwise the vehicles forming the queue for boarding at the front pole will block the exit of buses loading at the back pole, creating more queues, resulting in congestion.

7.4.2 Detailed Capacity Calculation

While Chapter 6: Service Planning provided guidance on how to select routes to include on the corridor (Section 6.5.3) and to skip stations (Section 6.6.4) so that operational capacity was not surpassed, the following sections of this chapter (Sections 7.5 and 7.6) evaluate how system characteristics will affect operational capacity, so proper features can be selected to reach the required operational capacity.

The capacity calculation for a station given earlier (Equation 7.20), applied to the segment with the higher number of services, would give the system capacity.

If a design is proposed where saturations are above 40 percent, it can be considered above operational capacity and adjustments have to be made. As an example, let us consider a corridor where the demand study indicated that the boarding and alighting requirements per station in one direction at the morning peak hour are as given in Table 7.3, for the first and tenth years of operation.

Table 7.3. Corridor Demand Example

	MORNING PEAK HOUR - YEAR 0		MORNING PEAK HOUR - YEAR 10	
station	Boarding passengers (pax/hour)	Alighting passengers (pax/hour)	Boarding passengers (pax/hour)	Alighting passengers (pax/hour)
A	824	0	1030	0
B	734	8	918	10
C	646	15	808	19
D	554	43	693	54
E	768	82	960	102
F	364	176	455	220
G	272	235	340	294
H	180	424	225	530
I	161	358	201	448
J	144	330	180	413
K	130	298	162	372
L	118	260	147	325
M	94	544	117	680
N	70	568	87	710
O	64	533	80	666
P	48	499	60	624
Q	43	199	54	249
R	34	214	42	267
S	19	230	24	288
T	0	250	0	312

The load of all segments is already defined, as the load of the preceding segment plus boarding of preceding station minus alighting at the preceding station.

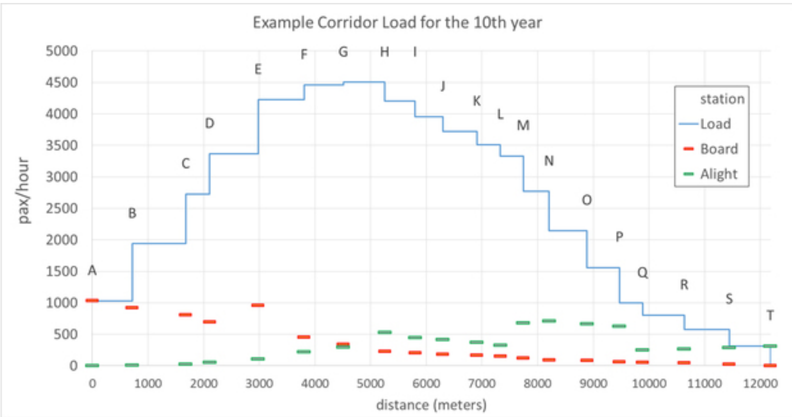

Figure 7.7. Example corridor morning peak loads for the tenth year, boarding and alighting per station. *Elebeta.*

For the beginning year of operations (year 0), an initial service plan proposed a closed trunk corridor with twenty stations, with one service stopping at all stations. The service will be operated using a seventy-passenger vehicle with a headway of one minute.

The proposed standard station will have an elevated platform with external fare collection, resulting in boarding or alighting times of one second per customer (for either of the two vehicle doors).

The supply is defined as 4,200 pphpd (60 vehicles per hour multiplied by 70 passengers per vehicle) for the entire corridor. The system capacity, by using a design load factor of 0.85 in order to avoid overcrowding due to irregularity, is 3,570 pphpd.

Table 7.4, which can be reproduced with the formulas discussed in the previous sections of this chapter, shows that the proposed solution leads to a load factor of 0.86 at the critical link, as well as saturation levels above the accepted limit.

Table 7.4. Station Saturation at Example Corridor for First Year Initial Proposal

station	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	TOTAL
Boarding passengers (pax/hour)	824	734	646	554	768	364	272	180	161	144	130	118	94	70	64	48	43	34	19	0	**5266**
Alighting passengers (pax/hour)	0	8	15	43	82	176	235	424	358	330	298	260	544	568	533	499	199	214	230	250	**5266**
Load (pax/hour)	824	1550	2182	2693	3379	3567	3604	3360	3162	2976	2808	2666	2215	1717	1248	797	641	461	250	0	**3604**
Frequency (veh/hour)	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	60	**60**
Vehicle Capacity (pax/veh)	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	**70**
dead time (sec)	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	
boarding time per passenger (sec)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	
alighting time per passenger (sec)	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	
average dwell time (sec)	29	27	26	25	29	24	23	25	24	23	22	21	26	26	25	24	19	19	19	19	
Saturation	0.48	0.46	0.43	0.42	0.49	0.40	0.39	0.42	0.39	0.38	0.37	0.35	0.43	0.43	0.42	0.40	0.32	0.32	0.32	0.32	
Queue Size (veh)	0.31	0.27	0.23	0.21	0.32	0.19	0.18	0.21	0.18	0.17	0.15	0.14	0.22	0.22	0.21	0.19	0.10	0.10	0.10	0.10	
Queue Time (sec)	18.48	16.08	13.96	12.45	19.30	11.20	10.54	12.59	10.78	9.90	9.04	8.20	13.37	13.37	12.43	11.35	6.20	6.26	6.29	6.29	
Load Factor	0.20	0.37	0.52	0.64	0.80	0.85	0.86	0.80	0.75	0.71	0.67	0.63	0.53	0.41	0.30	0.19	0.15	0.11	0.06	0.00	
Pax in queue (pax*hour)	4.23	6.92	8.46	9.31	18.12	11.10	10.55	11.75	9.47	8.19	7.05	6.07	8.23	6.38	4.31	2.51	1.10	0.80	0.44	0.00	**135**
distance from previous station (km)	0	0.72	0.96	0.43	0.87	0.83	0.71	0.74	0.55	0.5	0.61	0.42	0.41	0.47	0.68	0.58	0.41	0.75	0.81	0.74	**12**
free flow travel speed (if there is direct service, km/hour)		32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	**32**
time at station (sec)		43	40	37	48	35	34	38	34	33	31	29	39	39	37	35	25	25	25	25	**656**
BRT speed (km/hour)		**20.8**	**23.3**	**18.1**	**21.4**	**23.2**	**22.4**	**22.1**	**20.5**	**20.2**	**22.0**	**19.7**	**17.4**	**18.3**	**21.5**	**20.8**	**20.8**	**24.6**	**25.0**	**24.5**	**21.6**

To reduce the load factor to the proposed value of 0.85, it is enough to raise service frequency to 61 vehicles per hour. While only one more bus per hour, this is nearly a 2 percent capacity increase.

If instead of using a 2-door vehicle, a 3-door vehicle is proposed, with a reduction of boarding or alighting time from 1.0 second per customer to 0.7 seconds per customer, then saturation gets closer to an acceptable level, as shown in Table 7.5.

Table 7.5. Station Saturation at Example Corridor for First Year Second Proposal

station	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	TOTAL
Boarding passengers (pax/hour)	824	734	646	554	768	364	272	180	161	144	130	118	94	70	64	48	43	34	19	0	**5266**
Alighting passengers (pax/hour)	0	8	15	43	82	176	235	424	358	330	298	260	544	568	533	499	199	214	230	250	**5266**
Load (pax/hour)	824	1550	2182	2693	3379	3567	3604	3360	3162	2976	2808	2666	2215	1717	1248	797	641	461	250	0	**3604**
Frequency (veh/hour)	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	61	**61**
Vehicle Capacity (pax/veh)	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	**70**
dead time (sec)	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	
boarding time per passenger (sec)	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	
alighting time per passenger (sec)	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	
average dwell time (sec)	24	24	23	22	25	21	21	22	21	20	20	19	22	22	22	21	18	18	18	18	
Saturation	0.41	0.40	0.38	0.37	0.42	0.36	0.35	0.37	0.36	0.35	0.34	0.33	0.38	0.38	0.37	0.36	0.30	0.30	0.30	0.30	
Queue Size (veh)	0.21	0.18	0.17	0.15	0.21	0.14	0.13	0.15	0.14	0.13	0.12	0.11	0.16	0.16	0.15	0.14	0.09	0.09	0.09	0.09	
Queue Time (sec)	12.11	10.91	9.81	9.00	12.51	8.32	7.94	9.08	8.08	7.58	7.09	6.59	9.50	9.50	8.99	8.40	5.37	5.41	5.43	5.43	
Load Factor	**0.19**	**0.36**	**0.51**	**0.63**	**0.79**	**0.84**	**0.84**	**0.79**	**0.74**	**0.70**	**0.66**	**0.62**	**0.52**	**0.40**	**0.29**	**0.19**	**0.15**	**0.11**	**0.06**	**0.00**	
Pax in queue (pax*hour)	2.77	4.70	5.94	6.73	11.75	8.24	7.95	8.47	7.10	6.27	5.53	4.88	5.85	4.53	3.12	1.86	0.96	0.69	0.38	0.00	**98**
distance from previous station (km)	0	0.72	0.96	0.43	0.87	0.83	0.71	0.74	0.55	0.5	0.61	0.42	0.41	0.47	0.68	0.58	0.41	0.75	0.81	0.74	**12**
free flow travel speed (if there is direct service, km/hour)		32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	**32**
time at station (sec)		34	32	31	37	30	29	31	29	28	27	26	32	32	31	30	23	23	23	23	**551**
BRT speed (km/hour)		**22.4**	**24.6**	**19.6**	**23.2**	**24.3**	**23.5**	**23.3**	**21.7**	**21.4**	**23.0**	**20.7**	**19.0**	**19.9**	**22.8**	**22.0**	**21.4**	**25.1**	**25.5**	**25.0**	**22.8**

If such levels were found at the tenth year of operation, one could tolerate this proposal, but as the demand will grow, this saturation is clearly not acceptable.

Indeed, looking at the MaxLoad for the tenth year of operation, 4,505 passengers per hour, after station G (shown in Table 7.6), one can tell that 76 vehicles per hour will be required (capacity equal to 4,522 pphpd), and with such frequencies, all stations will be at risk of experiencing severe congestion. The resulting times and speeds in Table 7.6 seem acceptable, but due to planning uncertainties, saturations above the 0.4 limit expose the system to breakdown.

Table 7.6. Station Saturation at Example Corridor for Tenth Year First Proposal

station	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	TOTAL
Boarding passengers (pax/hour)	1030	918	808	693	960	455	340	225	201	180	162	147	117	87	80	60	54	42	24	0	**6583**
Alighting passengers (pax/hour)	0	10	19	54	102	220	294	530	448	413	372	325	680	710	666	624	249	267	288	312	**6583**
Load (pax/hour)	1030	1938	2727	3366	4224	4459	4505	4200	3953	3720	3510	3332	2769	2146	1560	996	801	576	312	0	**4505**
Frequency (veh/hour)	76	76	76	76	76	76	76	76	76	76	76	76	76	76	76	76	76	76	76	76	**76**
Vehicle Capacity (pax/veh)	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	**70**
dead time (sec)	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	
boarding time per passenger (sec)	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	
alighting time per passenger (sec)	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	
average dwell time (sec)	24	24	23	22	25	21	21	22	21	20	20	19	22	22	22	21	18	18	18	18	
Saturation	0.52	0.50	0.48	0.46	0.52	0.45	0.44	0.46	0.44	0.43	0.42	0.41	0.47	0.47	0.46	0.45	0.38	0.38	0.38	0.38	
Queue Size (veh)	0.39	0.34	0.31	0.28	0.40	0.25	0.24	0.28	0.25	0.23	0.21	0.20	0.29	0.29	0.28	0.26	0.16	0.16	0.16	0.16	
Queue Time (sec)	18.34	16.29	14.47	13.15	19.03	12.05	11.46	13.28	11.67	10.89	10.12	9.35	13.96	13.96	13.13	12.18	7.49	7.55	7.58	7.58	
Load Factor	**0.19**	**0.36**	**0.51**	**0.63**	**0.79**	**0.84**	**0.85**	**0.79**	**0.74**	**0.70**	**0.66**	**0.63**	**0.52**	**0.40**	**0.29**	**0.19**	**0.15**	**0.11**	**0.06**	**0.00**	
Pax in queue (pax*hour)	5.25	8.77	10.96	12.29	22.33	14.92	14.34	15.49	12.82	11.26	9.86	8.65	10.74	8.32	5.69	3.37	1.67	1.21	0.66	0.00	**179**
distance from previous station (km)	0	0.72	0.96	0.43	0.87	0.83	0.71	0.74	0.55	0.5	0.61	0.42	0.41	0.47	0.68	0.58	0.41	0.75	0.81	0.74	**12**
free flow travel speed (if there is direct service, km/hour)		32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	**32**
time at station (sec)		40	37	35	44	33	32	35	33	31	30	29	36	36	35	33	25	25	25	25	**622**
BRT speed (km/hour)		**21.4**	**23.8**	**18.6**	**22.1**	**23.6**	**22.7**	**22.5**	**20.9**	**20.5**	**22.3**	**19.9**	**17.9**	**18.9**	**22.0**	**21.2**	**20.7**	**24.6**	**25.0**	**24.5**	**22.0**

Vehicle sizes were determined for minimizing the sum of waiting and operating costs. By increasing vehicle size to increase operational capacity, waiting times would also increase, especially in the first years of operation. One of the objectives of the system is to reduce travel times door-to-door, so this has to be weighed in that light. Increasing the vehicle size to a 15-meter vehicle for 100 passengers, however, would allow some stations in the example to perform above operational capacity (4,505 passengers per hour with 53 vehicles per hour) in the tenth year of operation, as shown in Table 7.7, with a more acceptable saturation level.

Table 7.7. Station Saturation at Example Corridor for Tenth Year Increasing Vehicle Size to 100 Passengers

station	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	TOTAL
Boarding passengers (pax/hour)	1030	918	808	693	960	455	340	225	201	180	162	147	117	87	80	60	54	42	24	0	**6583**
Alighting passengers (pax/hour)	0	10	19	54	102	220	294	530	448	413	372	325	680	710	666	624	249	267	288	312	**6583**
Load (pax/hour)	1030	1938	2727	3366	4224	4459	4505	4200	3953	3720	3510	3332	2769	2146	1560	996	801	576	312	0	**4505**
Frequency (veh/hour)	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	53	**capacity:**
Vehicle Capacity (pax/veh)	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	**4505**
dead time (sec)	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	
boarding time per passenger (sec)	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	
alighting time per passenger (sec)	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	
average dwell time (sec)	29	27	26	25	29	24	23	25	24	23	22	21	26	26	25	24	19	19	19	19	
Saturation	0.42	0.40	0.38	0.37	0.43	0.35	0.34	0.37	0.35	0.34	0.32	0.31	0.38	0.38	0.37	0.35	0.28	0.28	0.28	0.28	
Queue Size (veh)	0.21	0.19	0.16	0.15	0.22	0.13	0.13	0.15	0.13	0.12	0.11	0.10	0.16	0.16	0.15	0.14	0.08	0.08	0.08	0.08	
Queue Time (sec)	14.57	12.79	11.20	10.05	15.16	9.10	8.58	10.16	8.77	8.09	7.42	6.76	10.76	10.76	10.04	9.21	5.17	5.22	5.24	5.24	**184**
Load Factor	**0.19**	**0.37**	**0.51**	**0.64**	**0.80**	**0.84**	**0.85**	**0.79**	**0.75**	**0.70**	**0.66**	**0.63**	**0.52**	**0.40**	**0.29**	**0.19**	**0.15**	**0.11**	**0.06**	**0.00**	
Pax in queue (pax*hour)	4.17	6.88	8.48	9.40	17.79	11.27	10.74	11.86	9.63	8.36	7.24	6.26	8.27	6.41	4.35	2.55	1.15	0.83	0.45	0.00	**136**
distance from previous station (km)	0	0.72	0.96	0.43	0.87	0.83	0.71	0.74	0.55	0.5	0.61	0.42	0.41	0.47	0.68	0.58	0.41	0.75	0.81	0.74	**12**
free flow travel speed (if there is direct service, km/hour)		32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	**32**
time at station (sec)		40	37	35	44	33	32	35	32	31	29	28	36	36	35	33	24	24	24	24	**615**
BRT speed (km/hour)		**21.4**	**23.8**	**18.6**	**22.1**	**23.6**	**22.8**	**22.5**	**20.9**	**20.6**	**22.4**	**20.1**	**17.9**	**18.9**	**22.0**	**21.2**	**21.1**	**24.8**	**25.2**	**24.7**	**22.1**

Using an articulated 160-passenger vehicle would bring saturation at the critical station to a comfortable saturation level of 0.34. If the design included a fourth door, reducing boarding time to 0.5 seconds per customer, than saturation at the critical station would be 0.29. But in the first year, frequency would be twenty-six vehicles per hour (over a two-minute headway) and average wait time would be over one minute in the peak, and during the off-peak time this value would likely double or triple.

Without having to add overtaking lanes at the stations (although overtaking lanes may be feasible without affecting mixed traffic capacity if stations are properly located; see Chapter 24: Intersections and Signal Control), the only solution left keeping those vehicle sizes would be to use two docking bays per station, as shown in Table 7.8. As this is not a congested situation, dead times will not be heavily affected. What is expected is that a certain number of times (proportional to the queue size of Table 7.6), boarding will occur through the second platform of the station. Total passenger queueing time is significantly reduced from 136 hours to 83.

Table 7.8. Station Saturation at Example Corridor for Tenth Year with Two Docking Bays per Station

station	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	TOTAL
Boarding passengers (pax/hour)	1030	918	808	693	960	455	340	225	201	180	162	147	117	87	80	60	54	42	24	0	**6583**
Alighting passengers (pax/hour)	0	10	19	54	102	220	294	530	448	413	372	325	680	710	666	624	249	267	288	312	**6583**
Load (pax/hour)	1030	1938	2727	3366	4224	4459	4505	4200	3953	3720	3510	3332	2769	2146	1560	996	801	576	312	0	**4505**
Frequency (veh/hour)	76	76	76	76	76	76	76	76	76	76	76	76	76	76	76	76	76	76	76	76	**capacity:**
Vehicle Capacity (pax/veh)	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	**4522**
dead time (sec)	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	
boarding time per passenger (sec)	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	
alighting time per passenger (sec)	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	
number of dockin bays	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
average dwell time per vehicle (sec)	24	24	23	22	25	21	21	22	21	20	20	19	22	22	22	21	18	18	18	18	
Station Saturation (0.75 of dock)	0.39	0.37	0.36	0.35	0.39	0.34	0.33	0.35	0.33	0.32	0.32	0.31	0.35	0.35	0.35	0.34	0.28	0.28	0.28	0.28	
Queue Size (veh)	0.34	0.31	0.28	0.26	0.35	0.24	0.23	0.26	0.23	0.22	0.20	0.19	0.27	0.27	0.26	0.24	0.15	0.16	0.16	0.16	
Queue Time (sec)	8.14	7.35	6.62	6.09	8.40	5.64	5.39	6.14	5.48	5.15	4.82	4.49	6.42	6.42	6.08	5.69	3.66	3.69	3.70	3.70	113
Load Factor	**0.19**	**0.36**	**0.51**	**0.63**	**0.79**	**0.84**	**0.85**	**0.79**	**0.74**	**0.70**	**0.66**	**0.63**	**0.52**	**0.40**	**0.29**	**0.19**	**0.15**	**0.11**	**0.06**	**0.00**	
Pax in queue (pax*hour)	2.33	3.96	5.02	5.69	9.86	6.98	6.74	7.16	6.01	5.32	4.70	4.15	4.94	3.83	2.64	1.57	0.81	0.59	0.32	0.00	83
distance from previous station (km)	0	0.72	0.96	0.43	0.87	0.83	0.71	0.74	0.55	0.5	0.61	0.42	0.41	0.47	0.68	0.58	0.41	0.75	0.81	0.74	12
free flow travel speed (if there is direct service, km/hour)		32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32
time at station (sec)		31	29	28	33	27	26	28	26	26	25	24	29	29	28	27	21	22	22	22	502
BRT speed (km/hour)		**23.2**	**25.2**	**20.3**	**23.9**	**24.8**	**24.0**	**23.9**	**22.4**	**22.0**	**23.5**	**21.3**	**19.7**	**20.6**	**23.4**	**22.7**	**21.9**	**25.5**	**25.9**	**25.4**	**23.4**

To consider the provision of overtaking lanes, one must look at the internal origin-destination matrix of the BRT system (in Table 7.9) to identify potential route splits to create limited services. Ideally, these limited routes should have a headway between 2.5 to 3 minutes in order to reduce the effects of irregularity on each route. But in our example, we are initially creating only one limited route that jumps from station E to station L. These stations were selected to avoid 45 seconds of queueing for a large volume of passengers per hour (1,666). The results were quite similar if the limited route jumped stations F to M. The resulting saturation is shown in Table 7.10 assuming that all passengers highlighted in yellow in the matrix will use the limited service, passengers highlighted in pink will be shared by two services proportionally to the frequency, and the remaining passengers (in orange) will use the local service.

Table 7.9. Example Corridor Internal O/D Matrix for the Tenth Year

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
A	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C	10	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
D	20	18	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E	30	27	24	21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
F	50	45	40	35	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
G	60	54	48	42	60	30	0	0	0	0	0	0	0	0	0	0	0	0	0	0
H	100	90	80	70	100	50	40	0	0	0	0	0	0	0	0	0	0	0	0	0
I	80	72	64	56	80	40	32	24	0	0	0	0	0	0	0	0	0	0	0	0
J	70	63	56	49	70	35	28	21	21	0	0	0	0	0	0	0	0	0	0	0
K	60	54	48	42	60	30	24	18	18	18	0	0	0	0	0	0	0	0	0	0
L	50	45	40	35	50	25	20	15	15	15	15	0	0	0	0	0	0	0	0	0
M	100	90	80	70	100	50	40	30	30	30	30	30	0	0	0	0	0	0	0	0
N	100	90	80	70	100	50	40	30	30	30	30	30	30	0	0	0	0	0	0	0
O	90	81	72	63	90	45	36	27	27	27	27	27	27	27	0	0	0	0	0	0
P	80	72	64	56	80	40	32	24	24	24	24	24	24	24	32	0	0	0	0	0
Q	30	27	24	21	30	15	12	9	9	9	9	9	9	9	12	15	0	0	0	0
R	30	27	24	21	30	15	12	9	9	9	9	9	9	9	12	15	18	0	0	0
S	30	27	24	21	30	15	12	9	9	9	9	9	9	9	12	15	18	21	0	0
T	30	27	24	21	30	15	12	9	9	9	9	9	9	9	12	15	18	21	24	0

Table 7.10. Station Saturation at Example Corridor for Tenth Year with One Limited-Stop Service

station	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	TOTAL
Boarding passengers (pax/hour)	1030	918	808	693	960	455	340	225	201	180	162	147	117	87	80	60	54	42	24	0	**6583**
Alighting passengers (pax/hour)	0	10	19	54	102	220	294	530	448	413	372	325	680	710	666	624	249	267	288	312	**6583**
Load (pax/hour)	1030	1938	2727	3366	4224	4459	4505	4200	3953	3720	3510	3332	2769	2146	1560	996	801	576	312	0	**4505**
Vehicle Capacity (pax/veh)	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	**capacity:**
Local service frequency (veh/hour)	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	48	**2856**
Limited-stop service frequency (veh/h	28	28	28	28									28	28	28	28	28	28	28	28	**1666**
Load Local	526	986	1385	1700	2558	2793	2839	2534	2287	2054	1844	1666	1401	1097	808	523	427	312	171	0	**2839**
Load Limited-stop service	504	952	1342	1666	1666	1666	1666	1666	1666	1666	1666	1666	1368	1049	752	473	374	264	141	-0	**1666**
dead time (sec)	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	
boarding time per passenger (sec)	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	
alighting time per passenger (sec)	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	
overtaking lane					x	x	x	x	x	x	x	x									
number of dockin bays	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
average dwell time per vehicle (sec)	24	24	23	22	30	25	24	26	24	24	23	22	22	22	22	21	18	18	18	18	
Station Saturation (0.75 of dock)	0.39	0.37	0.36	0.35	0.30	0.25	0.24	0.26	0.24	0.24	0.23	0.22	0.35	0.35	0.35	0.34	0.28	0.28	0.28	0.28	
Queue Size (veh)	0.34	0.31	0.28	0.26	0.19	0.11	0.11	0.13	0.11	0.10	0.09	0.09	0.27	0.27	0.26	0.24	0.15	0.16	0.16	0.16	
Queue Time (sec)	8.14	7.35	6.62	6.09	7.02	4.31	4.07	4.80	4.16	3.85	3.53	3.22	6.42	6.42	6.08	5.69	3.66	3.69	3.70	3.70	103
Load Factor Local service	**0.16**	**0.29**	**0.41**	**0.51**	**0.76**	**0.83**	**0.84**	**0.75**	**0.68**	**0.61**	**0.55**	**0.50**	**0.42**	**0.33**	**0.24**	**0.16**	**0.13**	**0.09**	**0.05**	**0.00**	
Load Factor Limited-stop service	**0.26**	**0.49**	**0.68**	**0.85**	**0.85**	**0.85**	**0.85**	**0.85**	**0.85**	**0.85**	**0.85**	**0.85**	**0.70**	**0.54**	**0.38**	**0.24**	**0.19**	**0.13**	**0.07**	**0.00**	
Pax in queue Local service (pax*hour)	1.19	2.01	2.55	2.88	4.99	3.35	3.21	3.38	2.64	2.19	1.81	1.49	2.50	1.96	1.37	0.83	0.43	0.32	0.18	0.00	39
Pax in queue Direct service (pax*hour)	1.14	1.94	2.47	2.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.44	1.87	1.27	0.75	0.38	0.27	0.14	0.00	15

The additional queue waiting time in relation to the previous alternative is forty seconds, but after the addition of the limited service, the travel time difference between local and limited stop is only twenty-six seconds, which would end up making no difference for users who can take the limited service to use that route. If customers could be forced to behave the way we assumed, the total queueing time would be further reduced from eighty-three to fifty-five. To force this behavior, one can propose, in addition to the limited service, to split the local service into two early return services: the first (Local 1) would attend from station A to station L, and the second (Local 2) from station E to station T.

Passengers shown in the OD matrix would have the options below:

- Light pink: Local 1 or Limited-stop
- Light orange: Local 1
- Yellow: Limited-stop
- Brownish orange: Local 1 or Local 2
- Medium orange: Local 2
- Darker pink: Limited-stop or Local 2

When splitting the original local in two, splitting the original frequency (48 vehicles per hour) is not enough to serve the loads between stations D and E and stations L and M, so the sum of frequencies of this new service (28.5 and 23.1) ends up being higher than the original alternative. Total travel time before the split was 25.6 vehicle-hours (during the peak hour), and after it became 19.2 vehicle-hours, indicating a potential fleet reduction. If a reversion time of five minutes on each side is considered, a symmetrical return and a constant demand (PHtoCC = 0), instead of needing sixty vehicles, only forty-eight are needed to run the local service.

Besides that, as shown in Table 7.11, there is some meaningful reduction in saturation for stations from A to D and M to T while the stations E to L face a small increase. Passenger time in queue is further reduced to fifty hours, against eighty-three without overtaking lanes and direct service. Figure 7.8 shows the resulting loads in each service.

Table 7.11. Station Saturation at Example Corridor for Tenth Year with Limited and Early Return Local Services

station	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	TOTAL
Boarding passengers (pax/hour)	1030	918	808	693	960	455	340	225	201	180	162	147	117	87	80	60	54	42	24	0	**6583**
Alighting passengers (pax/hour)	0	10	19	54	102	220	294	530	448	413	372	325	680	710	666	624	249	267	288	312	**6583**
Load (pax/hour)	1030	1938	2727	3366	4224	4459	4505	4200	3953	3720	3510	3332	2769	2146	1560	996	801	576	312	0	**4505**
Vehicle Capacity (pax/veh)	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	**capacity:**
Local service 1 frequency (veh/hour)	28.5	29	29	29	29	29	29	29	29	29	29	29									**0**
Local service 2 frequency (veh/hour)					23.1	23	23	23	23	23	23	23	23	23	23	23	23	23	23	23	**1374**
Limited-stop service frequency (veh/h	28	28	28	28									28	28	28	28	28	28	28	28	**1666**
Load Local 1	518	976	1375	1700	1413	1543	1568	1400	1263	1134	1018	920									**1700**
Load Local 2					1145	1250	1271	1134	1024	920	826	746	1380	1066	772	491	393	282	152	0	
Load Limited-stop service	512	962	1352	1666	1666	1666	1666	1666	1666	1666	1666	1666	1389	1080	788	505	408	294	160	0	**1666**
dead time (sec)	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	
boarding time per passenger (sec)	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	
alighting time per passenger (sec)	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	
overtaking lane					x	x	x	x	x	x	x	x									
number of dockin bays	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	
average dwell time per vehicle (sec)	28	26	25	24	29	24	24	25	24	23	22	21	26	26	25	24	19	19	19	19	
Station Saturation	0.33	0.31	0.30	0.29	0.32	0.26	0.25	0.27	0.26	0.25	0.24	0.23	0.28	0.28	0.27	0.26	0.20	0.20	0.21	0.21	
Queue Size (veh)	0.22	0.20	0.18	0.16	0.20	0.13	0.12	0.14	0.12	0.11	0.11	0.10	0.15	0.15	0.14	0.13	0.07	0.07	0.07	0.07	
Queue Time (sec)	7.07	6.31	5.60	5.09	7.14	4.45	4.21	4.94	4.30	3.98	3.67	3.36	5.18	5.18	4.86	4.48	2.57	2.60	2.61	2.61	**90**
Load Factor Local service 1	**0.26**	**0.49**	**0.69**	**0.85**	**0.71**	**0.77**	**0.79**	**0.70**	**0.63**	**0.57**	**0.51**	**0.46**									
Load Factor Local service 2					**0.71**	**0.77**	**0.79**	**0.70**	**0.63**	**0.57**	**0.51**	**0.46**	**0.85**	**0.66**	**0.48**	**0.30**	**0.24**	**0.17**	**0.09**	**0.00**	
Load Factor Limited-stop service	**0.26**	**0.49**	**0.69**	**0.85**	**0.85**	**0.85**	**0.85**	**0.85**	**0.85**	**0.85**	**0.85**	**0.85**	**0.71**	**0.55**	**0.40**	**0.26**	**0.21**	**0.15**	**0.08**	**0.00**	
Pax in queue Local service 1 (pax*hour)	1.02	1.71	2.14	2.40	2.80	1.91	1.83	1.92	1.51	1.26	1.04	0.86									**20**
Pax in queue Local service 2 (pax*hour)					2.27	1.55	1.49	1.56	1.22	1.02	0.84	0.70	1.99	1.54	1.04	0.61	0.28	0.20	0.11	0.00	**16**
Pax in queue Direct service (pax*hour)	1.01	1.68	2.10	2.35									2.00	1.56	1.06	0.63	0.29	0.21	0.12	0.00	**13**
distance from previous station (km)	0	0.72	0.96	0.43	0.87	0.83	0.71	0.74	0.55	0.5	0.61	0.42	0.41	0.47	0.68	0.58	0.41	0.75	0.81	0.74	**12**
free flow travel speed (if there is direct service, km/hour)		32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	32	**32**
travel time from previous station (sec)		81	108	48	98	93	79	83	61	56	69	47	46	52	77	66	47	84	91	83	**1370**
time at station (sec)	35	33	31	29	37	29	28	30	28	27	26	25	31	31	30	29	22	22	22	22	**565**
BRT Limited-stop service speed (km/hour)		**22.8**	**24.9**	**19.9**	**32.0**	**32.0**	**32.0**	**32.0**	**32.0**	**32.0**	**32.0**	**32.0**	**19.1**	**20.1**	**23.0**	**22.2**	**21.8**	**25.4**	**25.8**	**25.3**	**26.2**
BRT Local service speed (km/hour)		**22.8**	**24.9**	**19.9**	**23.3**	**24.5**	**23.7**	**23.5**	**21.9**	**21.6**	**23.2**	**21.0**	**19.1**	**20.1**	**23.0**	**22.2**	**21.8**	**25.4**	**25.8**	**25.3**	**22.7**

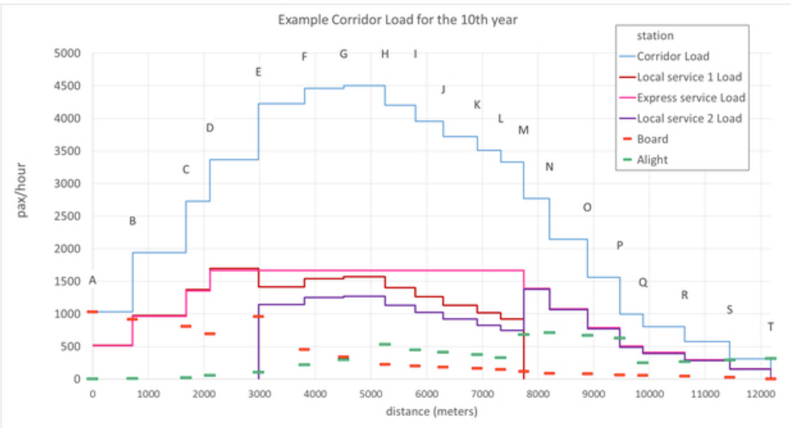

Figure 7.8. Example corridor morning peak loads for the tenth year, boarding and alighting per station. Image *Ele-beta.*

7.5 Expanding Corridor Capacity

> *"Good design begins with honesty, asks tough questions, comes from collaboration and from trusting your intuition."*
>
> — Freeman Thomas, designer, 1957–

Various design modifications in BRT services and infrastructure expand the capacity of a BRT system. The goal of these modifications is to carry more customers—while minimizing the saturation level at stations—and thereby ensuring good service speeds.

7.5.1 Increasing the Service Frequency

The service frequency refers to the number of vehicles per hour. The waiting time between vehicles, which is roughly the same idea, is known as the headway. Up to a point, simply increasing the vehicle frequency on a BRT corridor can increase the corridor capacity. However, at frequencies of more than sixty vehicles per hour, simple BRT corridors with one lane per direction tend to experience an unacceptably high level of vehicle bunching, or saturation. Therefore, the designer must turn to other alternatives, as discussed in the sections below.

The desired load factor may vary between peak and nonpeak periods. In Bogotá's TransMilenio system, typical load factors are 80 percent for peak periods and 70 percent for nonpeak periods. But as ridership levels grow in Bogotá, overcrowding becomes an increasing concern (Figure 7.9).

Figure 7.9. The Avendida Caracas corridor in Bogotá suffers from overcrowding at peak periods. *Carlos Pardo.*

7.5.2 Using Larger Vehicles

If a corridor is liable to reach saturation by way of the number of vehicles per hour, one solution is to increase the size of the vehicles. Replacing regular 12-meter vehicles with articulated 18-meter vehicles results in a dramatic increase in capacity—without causing a significant worsening in the saturation level. Determining the vehicle size should take into account the costs of vehicle operations against waiting times, as discussed in Section 6.4: Optimizing Vehicle Size and Fleet Size. Stations and service plan alternatives should adapt to use the optimal size to the required demand.

As has been noted, system designers have many vehicle size options. Table 7.12 summarizes the standard vehicle sizes available to system developers. Higher vehicle capacity can, in the right circumstances, increase BRT system capacity, but the right vehicle size is not always the largest vehicle. The main advantage of larger vehicles stems from reductions in operating costs, especially driver labor costs per customer carried. However, in lower-demand corridors, these large vehicles also tend to mean lower frequency, and hence longer waiting times for customers.

Table 7.12. Trunk Corridor Vehicle Options

Vehicle type	Vehicle length (meters)	Capacity (customers per vehicle)
Bi-articulated	24	240–270
Articulated	18	120–170
Elongated	15	90–120
Standard	12	60–80
Minibus	6	25–35

Increasingly, the 18-meter articulated vehicle is becoming the standard for BRT systems. The Curitiba system has utilized the larger bi-articulated vehicles, as have Mexico City's Insurgentes Avenue and TransMilenio in Bogotá. There are several reasons for the current dominance of the articulated vehicles (160-customer capacity) over the bi-articulated vehicle (270-customer vehicle):

- Large numbers of articulated vehicle orders have produced cost savings through economies-of-scale in manufacturing;
- Currently only a few manufacturers offer a bi-articulated vehicle, thus limiting the power of competition during the bid process;
- Heavier weight of bi-articulated vehicles reduces fuel efficiency and ability to accelerate rapidly;
- Length of bi-articulated vehicles (24 meters) can create difficulties with regard to available length of right-of-way at stations.

Figure 7.10. The 18-meter articulated vehicle has become standard in many BRT applications. *Image of Hangzhou, China, BRT vehicle Kangming Xu (http://www.brtchina.org).*

There may be instances where the operational and physical characteristics of a corridor would make a bi-articulated vehicle an appropriate choice. Chapter 20: Vehicles discusses vehicle technology options.

As vehicle length increases, there can be a diminishing return in terms of delivered capacity. If sub-stop capacity is reached and vehicle congestion occurs, then the additional capacity may not be fully realized. Figure 7.11 gives an example of this effect for a given set of parameters.

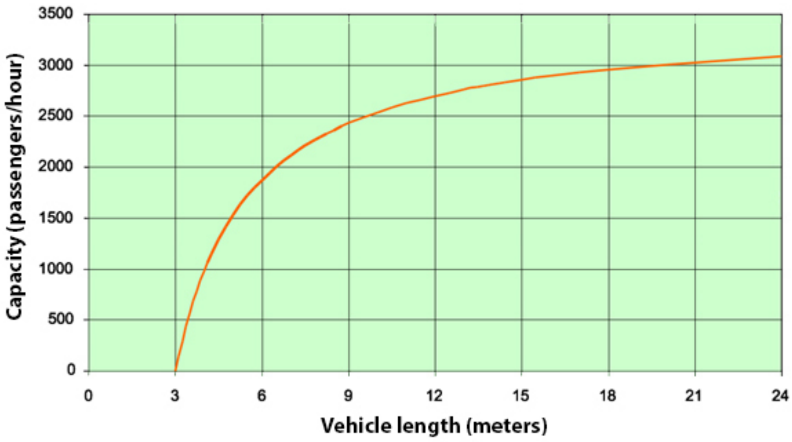

Figure 7.11. Relationship between vehicle size and capacity. *Graph Steer Davies Greer.*

While the vehicle size may optimize costs, very low frequencies can have a perverse effect. First, customer frequency translates into reliability, and this is one of the main drivers of transit use. Without sufficient frequency and reliability, customers may choose other options, and the system will lose ridership. Secondly, car drivers in traffic congestion will become frustrated from seeing an empty busway beside them. In turn, motorists will complain that the road is being under-utilized (Figures 7.12 and 7.13). Such complaints ultimately undermine political support for future busways. While a headway of a few minutes may not seem like a lot of time, a busway with a vehicle passing only every few minutes can appear to be empty most of the time. In Quito, pressure from motorist organizations led the national police to open up exclusive busway corridors to mixed traffic for a period of time in 2006. This conversion occurred despite the fact that each busway lane was moving three to four times the volume of customers as a mixed-traffic lane. Nevertheless, the perception of an empty busway next to heavily congested mixed-traffic lanes can create political difficulties.

Figure 7.12. The perception of a relatively empty busway next to heavily congested mixed-traffic lanes, as seen in this image of Quito. *Lloyd Wright*

Figure 7.13. Empty busways, as seen here in Hangzhou, may create political pressure to open up the lane to private vehicles. *Karl Fjellstrom*

7.5.3 Adding Passing Lanes and Multiple Sub-Stops

Measures such as vehicle size, vehicle-station interface, and doorway widths all contribute to higher-capacity and higher-speed systems. However, even together, these measures will likely only produce capacities around 9,000 pphpd. Thus, while systems such as those in Curitiba and Quito are high-quality BRT systems, their maximum corridor capacities are limited to this value.

A key innovation of Bogotá's TransMilenio system was that more capacity and speed was obtained because at each station, instead of having just one sub-stop, there were multiple sub-stops (Figure 7.14). In some cases, a single TransMilenio station will host up to three sub-stops (Figure 7.15). Each sub-stop represents a different set of services or routes (e.g., local services versus limited-stop services or routes with a different final destination). As a result, TransMilenio is able to handle capacities up to 45,000 pphpd, and there are good indications that values as high as 50,000 pphpd or even higher are now possible with BRT. Guangzhou achieves throughput of 27,400 pphpd, and new systems under construction in Rio de Janeiro promise to achieve even higher throughput levels than Bogotá and Guangzhou.

Figure 7.14. The use of multiple sub-stops and passing lanes helps minimize vehicle congestion in Guangzhou, China. Photo *ITDP.*

Figure 7.15. The use of multiple sub-stops, in this case three in each direction, has been one of the principal reasons Bogotá is able to achieve very high customer capacities. Photo *Akiris.*

At any given point on TransMilenio's corridors a vehicle passes every twenty seconds—a headway that would lead to significant saturation on a corridor without passing lanes. However, with passing lanes and multiple sub-stops and docking bays, the headway at *each* docking bay tends to be around one minute. Guangzhou similarly achieves very high frequency, and is, with Bogotá, the highest vehicle frequency BRT in the world, averaging around one vehicle every eleven seconds in the peak direction and peak hour. The Brisbane Busway achieves peak-hour vehicle frequencies of one vehicle every fourteen seconds in a single direction.

The presence of multiple sub-stops serves two distinct purposes. First, the multiple sub-stops permit many different types of services to operate from the same station, such as local services or limited-stop services. Each sub-stop represents a different set of services or routes. Second, the multiple sub-stops can dramatically reduce the saturation level at the stations. Since station saturation is typically the principal barrier to higher-capacity services, adding sub-stops is perhaps the cornerstone of any proposed system requiring higher capacity levels.

As noted earlier, to maintain a high level of service, saturation levels should be 40 percent or below. If saturation is over that, a second lane and a second sub-stop are likely to be required. As saturation increases, more sub-stops will be needed. In order to maintain a saturation factor of less than 0.40, services at each sub-stop must be properly scheduled and spaced to limit congestion. A saturation factor of 0.40 corresponds to approximately 60 vehicles per hour, but the specific sub-stop demand can reduce or increase this value. If 18-meter articulated vehicles are utilized, then 60 vehicles per hour corresponds to an approximate capacity of 9,000 pphpd, and this figure is a general limit for a simple one-lane operation. Since a lane will begin to congest once seventy vehicles per hour per direction is reached, a second sub-stop is recommended whenever volumes exceed this level.

Inclusion of Limited-Stop Services

With the inclusion of overtaking lanes, to increase capacity further, limited-stop services are likely to be the most relevant tool for planners. These services do not add to station saturation. In addition, they have higher commercial speeds. This way, stations with the highest demands can have services go directly to them. The potential of "express services" is limited for practical purposes, as the higher the demand, the easier it is to provide limited-stop services. One lane can serve up to 720 articulated-vehicles per hour. If 50 percent of this is used, that would be equivalent to more than 50,000 pphpd. Section 6.7.2 discusses how to implement direct service patterns. In the case of TransMilenio, approximately 50 percent of vehicles serve these types of routes.

Figure 7.16. Shidajida BRT station in Guangzhou, at the midpoint underneath the access bridge, has one lane carrying 27,000 people and one vehicle every 10 seconds in a single direction during the peak hour. This system has the world's highest BRT vehicle carrying frequency. Image *ITDP*.

Passing Lanes at Stations Only

The principal difficulty in including a passing lane is the impact on road space. Unless the corridor is highly saturated, passing lanes are usually not required beyond the stations. However, at station locations, the BRT system will occupy the width of the station plus two lanes in either direction, an approximate total of five lane widths for a station that serves both directions or a total of three lanes if the sub-stops for each direction are offset from each other. As discussed in Chapter 24: Intersections and Signal Control, if the BRT is in a section with intersections, narrowing mixed-traffic lanes will have no impact on the segment capacity if the station is at an appropriate distance from the intersections.

Other options for accommodating passing lanes in express roadways include making property purchases for widening. In some BRT cities, such as Barranquilla, Colombia, plans called for the purchase of properties near station areas. The road infrastructure was widened in these areas in order to accommodate the passing lane. This same strategy has been employed at some stations in the BRT system in Dar es Salaam, Tanzania, as shown in Figure 7.17. The viability of property purchases for this

Figure 7.17. In order to accommodate passing lanes at stations on the proposed Dar es Salaam system, the road infrastructure was widened. *ITDP*.

purpose depends on local property costs, as well as the existence of a well-designed compensation program for property owners.

7.5.4 Convoying

In general, multiple sub-stops are coupled with passing lanes in order to allow vehicles to pass one another and thus readily access the appropriate docking bay. However, if there is insufficient space for passing lanes, there is still a way to utilize multiple sub-stops without a passing lane. Some of the benefits of separate sub-stops can be achieved through the "convoying" or "platooning" of vehicles. Convoys involve two or more vehicles operating along the busway in a closely bunched pack. In some respects, a convoy system is similar to an extended set of rail cars. The order of the vehicles is typically set so that the first vehicle stops at the far sub-stop, and the next vehicle stops at the subsequent one.

A single lane operating with a single sub-stop per station can achieve a corridor capacity of approximately 9,000 pphpd. Convoys can increase capacity by around 50 percent to a maximum of 13,000 pphpd without any reduction in the level of service.

Unfortunately, the convoying or platooning of vehicles is difficult to manage and control. The vehicles must enter the busway in the right order or there will be delays and backing up of vehicles. Further, since customer boardings will vary for different vehicles, the dwell times will also vary. Some vehicles may needlessly wait behind others that have a longer boarding process. Thus, in a convoy system the slowest vehicle will likely set the speed for the entire fleet. For these reasons, multiple sub-stops are best implemented through the provision of passing lanes at stations.

Some conventional systems utilizing convoying have achieved corridor capacities over 20,000 pphpd. Both the Farrapos and the Assis Brasil bus corridors in Porto Alegre, Brazil, reach peak capacities of over 20,000 pphpd through convoying techniques. Nevertheless, the penalty for extending convoying to this level without reducing boarding and alighting times is a reduced level of service in terms of average speed.

Systems may operate as ordered convoys or non-ordered convoys. In an ordered convoy, the vehicles must approach the station in a set order so that the vehicles stop in the designated sub-stop. Signage at the station instructs customers which sub-stop corresponds with their intended route. To manage and control the order of the vehicles entering the busway, a control center in conjunction with automatic vehicle locating (AVL) technology will be essential. Communications between the control center and the drivers allow each vehicle to adjust its position in order to enter the busway at the right moment.

Figure 7.18. Convoying allows the Porto Alegre system to achieve peak capacities of over 20,000 pphpd, but at the same time this technique can result in busway and station congestion, and therefore slow average vehicle speeds. *Lloyd Wright.*

In a non-ordered convoy, the vehicles approach the station in any order, depending on the timing of each vehicle's entry into the main busway. In this case, customers will not know at which sub-stop their intended route will stop. Even if announcements give customers a brief warning, there is still likely to be some confusion. This situation implies that customers may be running from one end of the station to the other in search of their intended vehicle, or as mentioned previously, will have to flag down the bus to make a second stop at the station in order to pick them up.

7.6 Optimizing the Station-to-Vehicle Interface

> *"Let every man praise the bridge that carries him over."*
>
> — English proverb

Besides increasing the vehicle size, frequency, and number of sub-stops, there are several elements of the station-to-vehicle interface that can be improved to reduce boarding and alighting times, therefore reducing station saturation and increasing corridor capacity.

7.6.1 Platform-Level Boarding

To reduce boarding and alighting times, most state-of-the-art BRT systems have introduced platform-level boarding. With platform-level boarding, the docking bay platform is designed to be the same height as the vehicle floor. Besides fast boarding and alighting, it also allows easier access for persons in wheelchairs, parents with strollers, young children, and the elderly.

There are currently two different types of platform-level boarding techniques. In one case, a gap exists between the platform and the vehicle. The gap may range from approximately 4 to 10 centimeters, depending on the accuracy of the vehicle-alignment process (Figures 7.20 and 7.21). Such a boarding gap is comparable to or smaller than the gap present on many rail-based systems. Alternatively, a vehicle can employ a boarding bridge that physically connects the vehicle to the platform, thereby eliminating the gap completely. The boarding bridge consists of a flip-down ramp that is attached to the vehicle's doors or one that extends from the bus upon docking. As the doors open, the boarding bridge is released and covers the gap between the vehicle and the platform (Figures 7.22 and 7.23).

Figure 7.20. With well-designed infrastructure and adequate driver training, such as in Ahmedabad, India,BRT systems can reduce the boarding gap to under 10 centimeters *Shreya Gadepalli*

Figure 7.21. Reducing the borad gap, as seen here in Bogotá, Colombia, allows customers to safely board and alight faster, increasing system capacity. *Lloyd Wright.*

Figure 7.22. System in Curitiba, Brazil, utilize a boarding bridge between the vehicle and platform to facilitate easy boarding *Volvo*

Figure 7.23. Even bus approach to station being faster, using boarding bridges, as seen here in Guayaquil, Ecuador, usually increases dead time, while certainly decreases boarding time per passenger. *Lloyd Wright.*

Both techniques, gap entry and boarding bridge entry, have their advantages and disadvantages. Cities such as Curitiba and Quito have experienced much success with boarding bridges. A typical boarding bridge is 40 to 50 centimeters in width, meaning that the vehicle only needs to align within about 35 to 45 centimeters of the platform (Figure 7.24). Thus, there is much more room for error using the boarding bridge.

Figure 7.24. The presence of the boarding bridge means that the driver does not need to be as precise docking at the platform. In turn, this can significantly reduce the time lost at stations. Image *Lloyd Wright.*

The boarding bridge also provides boarding and alighting customers with greater confidence in placing their steps. The confidence means that customers will not have to look down at a gap to judge safe foot placement. Instead, customers confidently march forward. The small act of looking down slows each person's boarding and alighting time. While this lost time seems small on a per customer basis, the cumulative effect across all customers can be significant. The added customer confidence with the boarding bridge also means that two people can board or alight side by side. When a gap is present, customers are less likely to board simultaneously. The uncertainty imposed by a gap means customers are less likely to handle both the placement of the foot and the distance beside another customer at the interface point. A boarding bridge also is significantly more user-friendly to customers with physical disabilities, wheelchairs, and strollers.

Despite these benefits, the boarding bridge does bring with it a few disadvantages. The added cost of the boarding plate and the pneumatic system to operate it entails a modest increase in vehicle costs, as well as an increase in maintenance costs. As a moving part, the boarding bridge also introduces additional maintenance issues and the potential for malfunction. There is also one aspect of the boarding bridge that does not hold a time advantage. The deployment of the bridge itself takes about 1.5 seconds. Likewise, the retrieval of the boarding bridge at departure also requires about 1.5 seconds. While this deployment and retrieval roughly coincide with the opening and closing of the doors, they introduce a slight delay to the boarding and alighting process. However, the overall efficiency advantages of the boarding bridge tend to compensate for the deployment and retrieval time.

7.6.2 Fare Collection

In many conventional bus services, the driver is responsible for the collection of fares, as well as driving the vehicle, and customers are only allowed to enter through the front door. Thus, on-board fare collection means that boarding time is largely determined by the fare collection activity. If the fare collection process is slow, the whole public transport service is slow. Typically, customers take from two to four seconds just to pay the driver. If drivers also need to give customers change manually, this increases to fifteen seconds. Once customer flows reach a certain point, the delays and time loss associated with on-board fare collection become a significant system liability.

Figure 7.25. On-board fare collection and fare verification dramatically slows customer throughputs, as evidenced here in Harbin, China. Photo *Lloyd Wright.*

Most BRT systems since Curitiba have instituted external or off-board fare collection and fare verification. Customers pay their fare prior to entering the station, and then have their fare verified as they pass the entry turnstile or gate. Boarding and alighting can happen from all doors at once, and there is no delay in boarding and alighting related to the fare collection and fare verification. Pre-board fare collection and verification can reduce boarding times from 3 seconds per customer to 0.3 seconds per customer. In turn, the reduction in station dwell time greatly reduces vehicle congestion at the docking bay.

Figure 7.26. The Seoul busway system uses smart card technology for fare collection. *Lloyd Wright.*

The introduction of contactless smart cards and other modern payment systems can reduce on-board payment to two seconds per customer. Systems such as the Seoul busway make use of on-board fare collection using smart card technology. However, any time the driver is responsible for verifying fares, the speed of the service will be highly compromised, particularly if there is a large volume of customers. In the case of the Seoul busway system, customers must remember to swipe their smart cards both upon entering and exiting the vehicle. Delays can occur simply if a person enters the vehicle and must search through his or her belongings to find the fare card.

Figure 7.27. However, in Seoul, the on-board nature of the fare verification means that dwell times are negatively affected. A single customer searching through personal effects for his or her smart card can create a significant delay. *Lloyd Wright.*

In some cities, on-board collecting devices have been installed at all doors, and the average time for boarding and alighting has been reduced further. On the Geary Boulevard corridor in San Francisco, USA, the boarding times are 1.2 seconds per customer. However, these times are still several times higher than boarding times for systems with off-board fare collection.

In some bus systems, conductors sell tickets on board. While such an arrangement allows customers to board quickly and then pay once the vehicle is moving, it may introduce other forms of delay. For example, in some bus systems in India, it is common for the driver to halt the bus to make sure the conductor has finished selling tickets to all of the customers on the bus before it reaches the next stop.

In addition, if the conductor remains in a fixed position on the bus, and boarding happens through multiple doors, customers must make their way to the conductor, a potentially unpleasant ordeal if the vehicle is crowded. Some systems employ a reservoir area within the vehicle to hold customers while they go through the fare payment and verification process (Figure 7.28) at a turnstile. However, in this technique, the boarding is just through one door that is always less efficient than all-door boarding, especially when using large buses. In Brazil, the reservoir area is commonly small to prevent fare evasion (by getting off the bus through the same door). The first three or four customers need one second to board; the remaining need three to five seconds.

Figure 7.28. In Brazil, a "reservoir" space is provided within the vehicle where customers line up to verify their fare. With the use of this reservoir, the vehicle is able to proceed even before all customers have verified their fare. *The Municipality of Goiânia.*

With on-board fare collection and verification, alighting is usually faster than boarding. Typically, alighting times are approximately 70 percent of boarding times. In the case of off-board fare collection and verification, when vehicles are not crowded, there is no significant difference between boarding and alighting times.

Another method to avoid on-board fare collection and reduce boarding delays is to employ a proof-of-payment; customers must validate their own tickets that they purchase at shops and kiosks. Enforcement is then the responsibility of the police or contracted security personnel. Many European light rail systems utilize such a system.

Off-board payment collection is not necessarily the only way to reduce boarding and alighting times, but there are institutional reasons why this approach is generally more successful in the developing-country context. In particular, off-board fare collection and verification enhances the transparency of the process of collecting the fare revenues. When customers pay on board, and do not have to pass through a turnstile, there is no clear count of how many customers boarded the vehicle. Off-board fare sales to a third party make it easier to separate the fare collection process from bus operations. By having an open and transparent fare collection system, there is less opportunity for circumstances in which individuals withhold funds. This separation of responsibilities has regulatory and operational advantages that are discussed in more detail below. Further, by removing the handling of cash on board, incidents of on-board robbery are reduced.

Off-board payment also facilitates seamless transfers within the system. In addition, enclosed, controlled stations give the system another level of security, as security personnel can better protect the stations, thus discouraging theft and other undesirable activities. Off-board payment is also more comfortable than juggling change within a moving vehicle.

The main disadvantage to off-board fare collection is the need to construct and operate off-board fare facilities. Fare vending machines, fare sales booths, fare verification devices, and turnstiles all require both investment and physical space. In a BRT system with limited physical space for stations in a center median, accommodating the fare collection and verification infrastructure can be a challenge.

There is no one precise point at which a system's capacity will determine if on-board or off-board fare collection is more cost effective. Much depends on demand figures from individual stations, physical configurations of stations, and average labor costs. However, the advantage of off-board payment clearly increases as the level of boardings and alightings at the station increases and is part of the BRT basics of *The BRT Standard*. In Goiânia, Brazil, the local public transport agency estimates that an off-board fare system is cost justified when the system capacity reaches 2,500 pphpd. The development of a cost-benefit analysis may help determine this capacity point, provided the data is available. Figure 7.29 provides an example of this type of analysis.

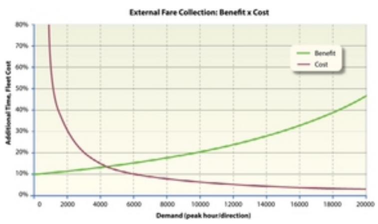

Figure 7.29. Cost-benefit analysis of external fare collection. Graph *Steer Davies Greer.*

7.6.3 Doorways

All the efforts applied to vehicle size, station design, and fare collection can be in vain if the vehicle's doorways inhibit smooth customer flows. With too few doors, systems experience bottlenecks due to conflicts between entering and exiting customers that increase the total boarding and alighting time.

The most successful BRT systems have employed multiple wide doorways dispersed along the length of the vehicle to ensure that platform bottlenecks are avoided. Having multiple wide doors accounts for a total of 3 points in *The BRT Standard*. These systems provide at least two separate sets of doors on 12-meter vehicles and three separate doors on 18-meter articulated vehicles. Each double door should be at least 1 meter wide, allowing two people to enter or exit the vehicle simultaneously. Table 7.13 compares observed boarding and alighting times for different combinations of doorway and platform configurations.

Table 7.13. Observed Boarding and Alighting Times for Different Configurations

Configuration characteristics				**Boarding and alighting times**	
Fare collection method	Doorway width (meters)	Stairway boarding or level boarding	Vehicle floor height	Observed; boarding time;	Observed alighting time
On-board, manually by driver	0.6	Stairway	High	3.01	NA
On-board, contactless smart card (no turnstile)	0.6	Stairway	High	2.02	NA
Off-board	0.6	Stairway	High	23	1.53
Off-board	0.6	Stairway	Low	1.5	1.2
Off-board	1.1	Stairway	High	1.5	1.0
Off-board	1.1	Stairway	Low	1.1	0.9
Off-board	1.1	Level	High	0.751	0.51

1. Colombia, Mexico
2. China
3. Brazil

NA – Not available

Doorway efficiency can also be closely tied to the interior design of the vehicle. The arrangement of the vehicle interior should provide adequate circulation space near the doors. In addition, some systems attempt to mitigate the conflict between boarding and alighting customers by designating some doorways as entry only and others as exit only. Curitiba utilizes this technique in some of its stations. This directional designation can improve boarding and alighting efficiency, but it can also cause customer confusion unless doorways are clearly marked.

The initial design of the Jakarta BRT system limited the system's capacity due to the decision to utilize only a single doorway for both boarding and alighting. As a solution to its capacity constraints, TransJakarta elected to increase its vehicle fleet. However, only a small number of the additional vehicles actually helped increase capacity before vehicle queuing at the stations dropped the level of service down to unacceptable levels. Table 7.14 presents potential solutions to TransJakarta's capacity problems. Shifting toward an articulated vehicle with multiple wide doorways would add the most capacity to the existing system, the analysis showed. TransJakarta has subsequently retrofitted stations and buses with additional doors and purchased larger vehicles.

Figure 7.30. The overcrowding of vehicles results in delayed boarding and alighting due to customer congestion around the doorway (Bogotá). Image *Carlosfelipe Pardo.*

Table 7.14. Scenarios for Improving TransJakarta's Capacity

Scenario	**Average boarding time (seconds)**	**Dwell time (seconds)**	**Average speed (kph)**	**Capacity (pphpd)**	**Required fleet size (vehicles)**

Present situation	2.5	45	17	2,700	60
Improving boarding	1.7	35	19	3,700	56
Vehicle with 2 doors	0.5	22	21	6,000	51
Articulated vehicle with 4 doors	0.3	18	23	9,600	26

Source: ITDP, 2006

7.6.4 Vehicle Acceleration and Deceleration

The time required for a vehicle to approach and then accelerate away from a docking bay also has an impact on station saturation and system speeds. If conditions require a slow, careful approach to the stations, overall speeds and travel times will suffer. The time consumed in the deceleration and acceleration process is affected by the following factors:

- Type of vehicle-platform interface;
- Use of docking technology;
- Vehicle weight and engine capacity;
- Type of road surface;
- Presence of nearby at-grade pedestrian crossings.

The vehicle deceleration time is greatly influenced by the closeness in docking required. Manual alignment generates variability in docking distances that can be improved somewhat through the use of optical targets for drivers along the face of the station. Mirrors can also improve the accuracy of manual targeting. Some other ways to help alignment include Kassel kerbs and flexible rubber lining the platform that allow the bus to come close to the station without damaging the bus or the station. All of the largest BRT systems in the world use manual alignment.

Alternatively, there are automatic docking technologies that try to increase the speed and accuracy of vehicle-to-platform alignment. Mechanical, optical, and magnetic docking technologies can all be applied for this purpose. In each of these cases, the vehicle is automatically guided into platform position without any intervention from the driver.

Mechanical guideway systems, such as those utilized in Adelaide, Australia; Essen, Germany; Leeds, England; and Nagoya, Japan, physically align the vehicle to the station through a fixed roller attached to the vehicle. In these cities, the fixed guideway is utilized both at stations and along the busway. However, a city could elect to only utilize the mechanical guidance at stations.

Optical docking systems operate through the interaction between an on-board camera and a visual indicator embedded in the busway. Software within the on-board guidance system then facilitates the automated steering of the vehicle. The Las Vegas, Nevada, USA, MAX system has attempted to make use of this type of technology (Figure 7.31). Problems have occurred, though, due to the inability of the optical reader to function properly when the roadway is wet.

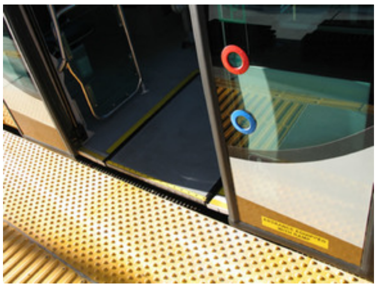

Figure 7.31. When operating properly, the optical guidance system employed in Las Vegas, Nevada, USA, can align the vehicle within a few centimeters of the platform. *NBRTI.*

A magnetic guidance system works on a similar principle to that of an optical system, but with magnetic materials placed in the roadway as the location indicator. The Philaeus bus, as utilized in the Eindhoven, Netherlands, BRT system, is capable of magnetic guidance.

Optical and magnetic guidance systems produce a highly precise degree of docking. However, due to current limitations with these technologies and their software, required deceleration and acceleration speeds can actually be slightly less than manual techniques. Further, the added hardware and software costs of an optically automated system can push vehicle costs well over US$1 million each.

7.6.5 Station Platform

The size and layout of the station platform will have a discernible impact on system capacity and efficiency. In some systems, platform size can even be the principal constraint on overall capacity. For many of the London Tube lines, it is the relatively small platform width that ultimately determines the total possible customer volumes.

The determination of the optimum platform size is based on the number of customers waiting to board and alight. If the platform hosts two service directions along one another, then the sum capacity requirements of both directions must be factored into platform sizing. Chapter 25: Stations details the calculation of platform sizing.

7.7 Route Distribution among Multiple Sub-Stops

"Even if you are on the right track, you will get run over if you just stand there."

— Will Rogers, social commentator and humorist, 1879–1935

Multiple sub-stops imply the existence of multiple services stopping at a single station. Which routes should be grouped near one another, and which routes can be separated by a longer walk? The guiding principle should be customer convenience. Ideally, the right distribution of routes along the sub-stops should minimize the walking distance covered by the largest number of customers. Thus, the most common transfers should be grouped together. This philosophy will not only improve customer convenience, but it will also improve overall station capacity. If large numbers of customers are forced to crisscross the length of the platform area, then customer congestion will ensue. This congestion can increase the overall trip time for the customer, thereby having a negative impact on the overall performance of the corridor. Often, the greatest efficiency in station transfers can be gained by placing together routes that have destinations in relative geographic proximity to one another.

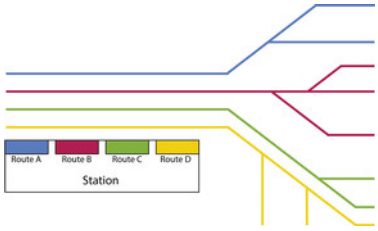

Figure 7.32. Platform order based on geographic proximity of routes. Image *ITDP*.

If frequencies are sufficiently spaced, some routes can even share the same docking bay. For example, a local service and a limited-stop service could share the same docking bay if the frequency levels make simultaneous arrivals unlikely. However, in such instances, sufficient space should be reserved for a vehicle to wait behind the docking bay, in case both routes arrive consecutively. The advantage of a shared docking bay is that customers changing from a local service to a limited-stop service (or vice versa) are not forced to walk to a different platform area. But if different routes share a docking bay, the risk of customer confusion increases. While route numbering, color coding, platform display messages, and platform audio announcements can all help minimize such confusion, some customers may unwittingly board the wrong vehicle.

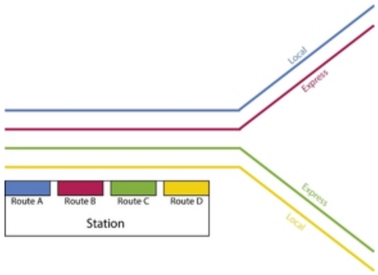

Figure 7.33. Platform order based on service clustering. Image *ITDP*.

8. Traffic-Impact Assessment

"A life is not important except in the impact it has on other lives."
— Jackie Robinson, first African American to play in Major League Baseball, 1919–1972

Any changes in a transportation network could result in changes to the operations of that network. This also applies to the introduction of a BRT system along city streets and arterials. The planning of a BRT system typically follows an iterative process to identify the best routes. One of the criteria to consider is the impact of the BRT on general mixed-traffic operations. For this reason, the traffic impacts need to be understood and quantified even during the planning and preliminary phases of a BRT system. The major reasons for conducting traffic-impact assessments are:

- Impacts of general traffic on BRT operations: Congestion at intersections that could have an impact on vehicle operations or queue spill-backs from neighboring intersections should be defined and mitigated, the main purpose being to ensure zero impact on vehicle operations during all hours of the day;
- Impacts of BRT on general-traffic operations: Departments responsible for general traffic require quantification of the possible traffic impacts of the BRT implementation and also, where necessary, assurances that negative impacts can be mitigated;
- Required environmental procedures: Many cities have environmental legislation, which requires evaluation of all impacts, and any proposed mitigation measures.

In many cities, the impact of public transit vehicles operating in mixed traffic on the operations of the facility can be severe due to the way the services are operated, such as the frequent starting and stopping in mixed-traffic lanes, pulling out and merging where stops are at the curb, and undisciplined lane changing and driver behavior. Introducing a BRT service with the focus of formalizing the public transit services into dedicated lanes will remove the disruptive operations of the current public transit services, and will improve the operations for mixed traffic. This could not only improve travel times for all private vehicles, but could also have a positive impact on business-travel and freight movements during all times of the day.

Figure 8.1. The Gangding conventional bus stop,in Guangzhou, China *Karl Fjellstrom, itdp-china.org.*

Figure 8.2. The Gangding BRT station in Guangzhou, China. Despite 24 meters being taken from the center of the roadway for the BRT stations and roadways, both capacity and speed of the road for mixed traffic and buses improved dramatically. Conditions for pedestrians were also greatly improved, with customers waiting in the station rather than on the side of the road. *Duan Xiaomei, GMEDRI*

Contributors: Chrsitoff Krogscheepers, *ITS Engineers*; Ulises Navarro, *ITDP Latin America*; Pedro Szász, *consultant*; Carlos Pardo, *Despacio*; Annie Weinstock, *BRT Planning International*

8.1 Requirements for a Traffic-Impact Assessment

Traffic-Impact Assessments (TIAs) could be required for several reasons. First, the planners and designers of the BRT system need to ensure that the system will work and that the possible adverse impacts on the general traffic are mitigated, or at least quantified and understood by all involved. Second, the authorities and/or departments within the authority that are responsible for the road network who need to approve the plans will often require the quantification of all transport-related impacts. Third, in many countries the environmental management legislation requires all impacts of new developments to be quantified and mitigated. This will require a full TIA. Last, the people, property owners, and business owners that could be affected by the proposed BRT will require details of the impacts and how they will affect their lives, properties, and businesses.

8.2 Data Needs

> *"Data is not information, information is not knowledge, knowledge is not understanding, understanding is not wisdom."*
>
> — Clifford Stoll, astronomer, 1950-

For any detailed traffic-engineering study, data representing the existing conditions will be required. This will form the baseline against which proposed alternatives can be compared, and which can be used for future traffic projections. During the planning stages of the project, data should have been collected with the focus on link volumes and distribution of traffic volumes during the day. This data would typically include classified hourly counts of both vehicle (classified by vehicle type) and customer volumes (occupancies in vehicles). Also from the planning stages of the project, data such as Origin-Destination patterns (OD Patterns), vehicle occupancies, existing public transit ridership, and an assessment of possible modal shifts should be available. This information should be sourced for input and evaluation in the Traffic Impact Assessment. Depending on the detail required for the TIA and the extent of the TIA, it could be necessary to collect the following additional information:

- Classified vehicle turning movement counts at all the major intersections;
  - These counts must be categorized in fifteen-minute intervals and done for at least two hours (preferably three hours) during each typical peak period of a typical day;
  - Where significant issues are expected during shopping peaks on Saturdays or Sundays, these peak periods should also be counted;
  - The counts must be classified by type, i.e., cars, buses, minibuses, paratransit, trucks, pedestrians, and bicycles;
- Turning-movement counts at the major accesses along the corridor with similar requirements for the counts as outlined above;
- Link-volume counts (between major intersections) classified by vehicle type on all the major routes in the proposed BRT corridors and also along important parallel routes. These counts should preferably be done for a full day in order to define the variation in traffic demand over a typical day, not only in terms of the total traffic volume, but also the variation in demand for each of the different modes;
- If not available from the local agencies or from the planning studies for the BRT, the following information must also be collected (see Chapter 4);
  - Vehicle occupancies;
  - Modal shift;
  - Public transit ridership;
  - OD patterns.

8.3 Study Area and Extent of Assessment

> *"All you need is the plan, the road map, and the courage to press on to your destination."*
>
> — Earl Nightingale, author, 1921–1989

Study areas for traffic-impact assessments are often well defined in local guidelines and are mostly based on the extent of the increase in traffic demand through the network and specifically through critical intersections. The introduction of BRT operations should not result in an increase in traffic volumes, but in fact should reduce the number of single-vehicle occupancy trips along a corridor. However, there will be impacts along the route and parallel routes as a result of:

- The possible removal of general-traffic lanes;
- The possible removal of parking lanes;
- The narrowing of general-traffic lanes;
- Signal-timing changes that could result in less green time for general-traffic operations;
- Restrictions and banning of certain turning movements at intersections and changes in local turning movements and access patterns;
- Diversions from the arterial along which BRT operations are planned due to capacity constraints to alternative parallel routes;
- Removal of local bus routes from general-traffic lanes.

The traffic impacts are not necessarily restricted to the corridor itself, but could also be introduced on alternative parallel roads. At a minimum, the study area should include the actual corridors along which the BRT is planned, with specific attention to all the major intersections. Ideally, the impact assessment would also include impacts to cross streets and along parallel alternative routes. The purposes of the impact assessment must always be clearly defined, and care should be taken not to introduce unnecessary mitigation measures along the corridor and along alternative routes. The BRT in itself can be argued as a major mitigation measure to improve the capacity of a corridor. Mitigation measures should be restricted to the route along which the BRT is planned unless there are compelling operational reasons to expand improvements to the road network in the immediate vicinity of an intersection where, for example, turning movements are banned and/or restricted as a result of the BRT system.

8.4 Level of Analysis

"The analysis of the thing is not the thing itself."

— Aaron Allston, novelist, 1960–2014

The impact analysis can be done at various levels of detail. This will depend on the specific needs of the planning and design team and on the requirements of the responsible authorities. The level of analysis can vary from a course *Planning Level*, to an *Operational Analysis*, and down to a very detailed *Microscopic Simulation* level. The purpose of the analysis should be to get a thorough understanding of the current traffic volumes and the current operations during all the critical time periods of a typical weekday. These will include at least the normal morning and afternoon/evening commuter peaks, but if necessary the midday commercial and possible weekend peak hours should also be evaluated. The three levels of analysis are not mutually exclusive but can be performed in steps or phases and can be described as follows:

- *Planning and Preliminary Analysis:* The first phase of analysis is normally a Planning Level analysis, which should be conducted during the planning phase of the project, but can also be applied during the detailed analysis phase of the project. The planning analysis allows for the use of default input values instead of using more relevant field-measured values. The results of the planning level analysis should be sufficient to clearly indicate which elements of the transportation network are currently, or with the future BRT system, at or over capacity and require mitigation, or which elements will be operating well below capacity and require no mitigation. Based on the results of the planning analysis, the project team and/or the relevant authority can then decide on doing a more detailed operational analysis of the network elements where the desired operational outcomes will not be met, i.e., those elements where the transport demand will exceed the capacity of the element;
- *Operational Analysis:* Following the planning analysis, the next level of analysis will be at an operational level. This is similar to the planning analysis, except the analysis of the critical elements is done in more detail, specifically refining the input assumptions, ensuring that the analysis is based on field-measured variables such as lane-widths, signal timings, gradients, etc. This level of analysis should also include a sensitivity analysis specifically to quantify variation in future operations based on the possible variation in input assumptions. For example, the future traffic demand will depend on the modal shift from private to public transport, and this could vary depending on the modal shift. The results of the operational analysis should, in most cases, provide sufficient detail to satisfy the project team and/or the relevant authorities. However, where additional detail is required for complex intersections or networks, a Microscopic Simulation will be necessary;

- *Microscopic Simulation:* This involves the computer simulation of the behavior and movement of individual vehicles, bicycles, and/or pedestrians on the transportation network. At this level, every detail of the operations based on the predicted demand and the simulated geometric conditions can be assessed. For this analysis to be accurate it needs to include actual field-measured inputs. There are several challenges with microsimulation, of which the most important is the validation of the model against field data. Without validation of the simulation model, the results should be questioned and interpreted with care.

8.5 Estimating Traffic Volumes

"If you have to forecast, forecast often."

— Edgar R. Fiedler, economist, 1929–2003

The changes in traffic volumes due to the introduction of new BRT corridors are not always simple to determine. BRT is typically introduced along existing public transport corridors where the demand is already serviced by buses or forms of para-transit such as minibuses. In some cities, these existing public transport vehicles can make up as much as 10 percent of the general traffic stream. Because of this, introducing organized BRT services in dedicated lanes, which might require reducing lane capacity for general traffic, might not necessarily have significant negative operational impacts.

The demand estimation on the network post-implementation of the BRT can be done in the following steps:

1. Identify all the design alternatives in terms of new infrastructure, route alignment frequencies, and BRT route capacities;
2. Remove all the relevant existing buses from the existing mixed-traffic lanes in the corridor. The traffic demand needs to be adjusted to account for the removal of the current public transport volumes on the network. This process should be informed by the planning and phasing of the BRT, since this will guide how many, if any, of the current buses will be removed from the network;
3. Add the proposed BRT vehicles back to the network, specifically along the corridors where the BRT will operate in mixed traffic;
4. Determine the extent of any modal shift from private automobiles to the proposed BRT. The modal shift should be defined by the BRT planners, and preferably supported by "Stated Preference" surveys (for more details, refer to Chapter 6: Service Planning). Reduce the private vehicle demand with the estimated shift away from private vehicles to BRT. The modal shift will depend on a variety of factors, one of which is the capacity and delay along the general traffic lanes. Therefore, the estimated network operations as determined in the next step should inform the modal split, hence there could be iteration between Step 4 and 5;
5. Estimate the possible changes in the capacity of the network for general traffic and determine possible diversions to other routes as a result of the capacity constraints. This could be a result of lanes being reduced due to the exclusive-use requirements of the BRT, or because of traffic-signal timing changes to accommodate the BRT;
6. Determine localized changes in traffic volume demands due to changes and/or restrictions to turning movements at intersections.

8.6 Methodologies and Performance Measures

> *"Our virtues and our failings are inseparable, like force and matter. When they separate, man is no more."*
>
> — Nikola Tesla, inventor, 1856-1943

Once the traffic volumes for all modes and for the different scenarios are determined for the target year, it is necessary to express the performance of the roadway facility using one or more quantitative measures that characterize the service experienced by the users. These measures are not only useful to the planners and engineers in evaluating options and impacts, but are also beneficial in describing operations to officials, policy makers, administrators, and the public. It is important that the selected measures are well defined and understood by all involved in the project. Performance measures must include all modes. Often an unwarranted focus is placed on the use of a single general-performance measure (i.e., level-of-service), but which is not necessarily universally applicable. The various available measures that could be used to evaluate the traffic impact of BRT systems can be classified into two broad categories: macroscopic and microscopic measures. Macroscopic level measures focus on:

- Throughput of the road, arterial, corridor, or wider system, measured in passengers per time unit, typically per hour;
- Average speeds along the road, corridor, or in the system;
- System and corridor door-to-door travel times;
- Vehicle emissions from all modes on the corridor or greater transportation system.

On the microscopic level, the measures relate to:

- Specific intersection or bottleneck capacities and demands;
- Average delay per vehicle;
- Number of stops per vehicle;
- The saturation levels of the individual movements at an intersection.

To successfully evaluate the impact of a BRT system, it is essential that not only the performance measures that will be used be defined and confirmed with all stakeholders, but also for the performance-measure criteria to be established and confirmed with all stakeholders. The methodologies and analysis tools that are used to define traffic impacts not only vary among states and provinces in one country, but also vary across the world. However, all methodologies include at least some measure of capacity and a comparison of the expected or current demand and how that relates to the capacity (volume-to-capacity ratio) of the facilities, and often also include operational descriptors such as average speed, average delay, densities, walkability, etc. The latter can be for a specific part of a route (intersection or link), a complete route, or even for a whole corridor or area.

A widely used reference for these types of analyses is the *Highway Capacity Manual* (*HCM*) developed by the USA Transportation Research Board (TRB). The 2010 edition of the *HCM* includes methodologies to estimate individual measures such as automobile travel speed, automobile stop rate, automobile traveller-perception score, pedestrian travel speed, pedestrian space, pedestrian-perception score, bicycle travel speed, bicycle-perception score, public transit vehicle travel speed, public transit wait–ride score, and public transit customer-perception score. It also provides a methodology for combining the individual measures into a single measure for the street, and it is often expressed as a level-of-service (LOS). LOS is also considered a performance measure, and can be computed individually for the automobile, pedestrian, bicycle, and transit travel modes. The individual measures can also be combined to collectively express a single measure for the facility. The latter, a collective approach to describing the performance of the system, is critical for a balanced evaluation of the impact of a BRT system. The *HCM* has evolved over the years from an automobile-oriented focus to a comprehensive multimodal focus, the multimodal focus only coming to the fore in the 2010 edition. The new edition puts forth principles and methodologies that are useful to consider for capacity analysis of any part of the transportation system and for most modes.

Although the LOS concept is very useful to describe operations with a single measure, the criteria used to define the various modes are based on North American data and standards. These are not necessarily universally applicable, except possibly the criteria for the automobile modes since they are based on performance measures that are field-measurable. Level of service at intersections is related to ranges of average delay per vehicle, in seconds per vehicle. That means that for a given average delay at a junction, the delay is equally experienced by the 1.2 customers in the private vehicle and the 60 customers in the transit bus. If average delay per customer is used as a performance indicator, instead of delay per vehicle, an improvement for transit vehicles will have a much higher impact on intersection average delay.

The criteria for the pedestrian and bicycle modes, which are based on scores reported by users indicating their perception of service quality, however, may vary from country to country. Similarly, the criteria for the public transit modes, which are based on measured changes in patronage due to changes in service quality, will also vary from country to country. This should be kept in mind, and where necessary adapted for local conditions. This is especially important when evaluating pedestrian and bicycle operations in countries where the behavior and prevalence of these modes are significantly different from that in the United States.

The table below summarizes the capacity methodology for the four major modes and the linkages between the modes and the infrastructure elements. Following the methodology presented in the *HCM*, the level of services of all four of the major modes can be determined.

Apart from understanding the relationship between the demand for a facility and the capacity of that facility, it is important to understand the acceptability of the operations. The latter is typically presented as a level-of-service, which is based on predefined criteria and as follows:

- Automobiles: travel speed as a percentage of base free-flow speed;
- Pedestrians: the density of pedestrians on the facility combined with a score which is based on several factors outlined below;
- Bicycle: a score based on the weighted average bicycle-travel speeds along the facility;
- Public Transit: a score based on the weighted average speeds of the services along the route.

Level-of-service is denoted by a number ranging from LOS A to LOS F, where LOS A represents the best operations and LOS F represents the worst operations where the demand typically exceeds the capacity of the facility. Table 8.1 illustrates the level-of-service for the automobile mode as a function of travel speed.

Table 8.1. Automobile LOS Criteria

Travel Speed as a Percentage of Base Free-Flow Speed (%)	LOS by Critical Volume-to-Capacity Ratio*	
	<= 1.0	> 1.0
>85	A	F
>67-85	B	F
>50-67	C	F
>40-50	D	F
>30-40	E	F
<=30	F	F

Note: * The critical volume-to-capacity ratio is based on consideration of the through movement volume-to-capacity ratio at each boundary intersection in the subject direction of travel. The critical volume-to-capacity ratio is the largest ratio of those considered.

Source: Highway Capacity Manual, 2010.

The pedestrian LOS presented below is a function of both density of pedestrians and a "score," which is based on several factors such as:

- Widths of the traffic lane, bike lane, shoulders, and sidewalk;
- Buffer presence of open space, on-street parking, and street trees;
- Volumes and speeds of general traffic and permitted turns on red at signals;
- Crossing distance and distance to the nearest cross walk;
- Pedestrian delay.

Table 8.2. Pedestrian LOS Criteria

Pedestrian LOS Score	LOS by Average Pedestrian Space (ft^2/p)					
	>60	>40–60	>24–40	>15–24	>8.0–15[a]	≤ 8.0[a]
≤2.00	A	B	C	D	E	F
>2.00–2.75	B	B	C	D	E	F
>2.75–3.50	C	C	C	D	E	F
>3.50–4.25	D	D	D	D	E	F
>4.25–5.00	E	E	E	E	E	F
>5.00	F	F	F	F	F	F

Note: [a] In cross-flow situations, the LOS E–F threshold is 13 ft^2/p.

Exhibit 16-5
LOS Criteria: Pedestrian Mode

As pointed out earlier, the values used for the actual scoring outlined in the *HCM* are not necessarily internationally applicable. However, the methodology provides a framework within which calibration for local conditions is possible. The operational requirements for pedestrians vary significantly from hot-dry or hot-humid climates to cold climates. In hot-dry climates, the availability of shade is important, while in cold climates protection against the cold and wind is important. Such factors can be included in the pedestrian scoring and hence the LOS.

The bicycle and public transit level-of-service summarized below is only in terms of a score that is based on a weighted average cycling speed and/or public transit speed. The average cycling speed can be estimated by using the methodology outlined in the *HCM 2010*, and depends on several variables such as bicycle and vehicle volumes, lane widths, number of vehicle lanes, heavy vehicles, and pavement conditions. The public transit average speed can also be estimated applying the *HCM 2010* methodologies, and is dependent on, among other things, running speed, acceleration-deceleration delays, dwell times, reentry delay, as well as the pedestrian scores.

Table 8.3. Bicycle and Transit LOS Criteria

LOS	LOS Score
A	<= 2.00
B	> 2.00-2.75
C	> 2.75-3.50
D	> 3.50-4.25
E	> 4.25-5.00
F	> 5.00

Source: Highway Capacity Manual, 2010.

Similar to the analysis for pedestrians, the local conditions related to cyclist operations can vary among different countries, depending on the local climate, the prevalence of the mode, and the mindset of motorists toward other mode users. The proposed methodology should be calibrated for local conditions.

The methodology provides a tool that can be used to compare routes based on the operation of all modes. The impact assessment should focus on all modes, and not just the public transit mode or the automobile mode.

What is often overlooked and not always explicitly considered in analysis methodologies and impact-assessment tools is the positive impact of the removal of existing public transit vehicles from mixed-traffic lanes in a corridor. This invariably results in a reduction in bus and general traffic volumes and even a possible increase in capacity along a route. Formal and informal bus and paratransit operations not only tend to stop in one or more curb lanes, blocking the lane for the duration of the stop, but also frequently merge and weave at will through the mixed-traffic lanes. The stopping and weaving movements have a negative impact on the capacity of the operations along a roadway facility. This behavior negatively impacts the automobile stream, and also negatively impacts transit customer safety and comfort, as well as cyclist and pedestrian safety and comfort.

8.7 Mitigation

> *"You can never protect yourself 100%. What you do is protect yourself as much as possible and mitigate risk to an acceptable degree. You can never remove all risk."*
>
> — Kevin Mitnick, consultant, 1963-

From the detailed engineering analyses, transportation engineers will be able to estimate the impacts BRT will have on all modes, based on standard practice and/or the methods outlined above. The impacts essentially will depend on:

- The amount of actual road space available to mixed traffic, including private vehicles, general public transit vehicles, and commercial vehicles;
- The extent of the space available for pedestrians and cyclists;
- The extent of road space that will be created for the BRT services;
- The time constraints at intersections where the different modes mix and or cross;
- The capacity constraints at bottlenecks in the system.

The illustration below presents a typical summary of such an analysis of a part of a BRT corridor. A summary is provided of the existing situation as well as the expected future situation with and without proposed mitigation measures.

Figure 8.3. Example of recommended improvements. *ITS Engineers.*

Defining impacts and the associated mitigation measures are closely linked to the expected future demand on the system, which depends to a large extent on the future mixed-traffic demand. In corridors where BRT has been successfully implemented, a reduction in general traffic demand often materializes. The reduced general traffic demand often negates the need for significant geometric improvements, such as adding more lanes. As pointed out earlier, the reduction in traffic demand is not always easy to estimate. Therefore, a practical approach to most impact assessments should be the evaluation of different scenarios based on different travel-demand estimates. The scenario analysis should present operators and decision makers with sufficient clarity on the possible impacts under different future demand scenarios. This applies specifically to the mode-shift scenarios from private vehicles to the BRT system.

Typical mitigation measures that could be considered along a corridor include the following:

- Removing on-street parking in order to maintain capacity for mixed traffic;
- Improving channelization and the separation of modes;
- Increasing the length of turning lanes to accommodate the design queues;

- Increasing the number of lanes by widening the roadway at stations and intersections. Lane widths must not be wide enough to encourage speeding;
- Reducing the number of signal phases by restricting low-volume turning movements;
- Increasing the enforcement of street-vendor activities that might have an impact on transport capacity;
- Implementing sidewalks and bicycle lanes alongside the BRT route, either on the same street or in a parallel corridor. This can often assist in improving the modal shift from an automobile to BRT and/or walk and cycling;
- Banning turning movements at priority-controlled intersections and forcing drivers to make right turns instead of left turns (when driving on the right) or left turns instead of right turns (when driving on the left);
- Implementing median islands to prevent unnecessary turning movements and providing shelter for pedestrians;
- Various signalization strategies to either benefit public transit vehicles and/or to improve the regulation of normal automobile traffic;
- In extreme cases, the implementation of grade separation of vehicles and/or pedestrians might be necessary;
- Consider parking areas near outlying BRT stations to allow park-and-ride. Parking areas could have negative land use impacts, specifically when compared to transit-oriented development, and should be considered with care;
- The BRT should always be considered as a mitigation measure in itself. It provides additional capacity along the corridor and provides an alternative mode for commuters, which will be more affordable than travelling by private car, at least as safe and possibly more comfortable, and with at least the same travel time as a car.

The implementation of a BRT system immediately emphasizes the NMT modes, since customers need to travel to/from the stations. Therefore, as a general rule, pedestrian and cycling space should be provided in and along the BRT corridors as much as possible, specifically where many short trips are being served.

VOLUME III

Communications and Marketing

Volume 3 details the necessary steps to building a communications strategy to be used for engaging the public with the BRT project, educating customers on how to use the system, and marketing the project to a wide array of potential users.

This volume is crucial to illuminating the benefits of BRT and establishing the distinction between BRT and less effective forms of transit.

Strategies can be crafted to address the concerns of specific stakeholders through a multitude of media formats, and these strategies' success should be measured in order to further increase their effectiveness (Chapter 9).

Outreach is also essential to spreading the word about BRT, but it is also important to engage the public through participatory meetings and workshops to get buy-in (Chapter 10). Once the public is actively providing feedback to officials on how the BRT system can best work for them, the public is then empowered to take ownership of the system and see it is as their transport system.

Marketing and branding (Chapter 11) is how the BRT project team can communicate that community ownership and unique identity of a system through its name, logo, color scheme, wayfinding, and customer service, all of which ensure that the system is user-friendly, attractive, simple, and easy to use.

9. Strategic Planning for Communications

> *"The greatest compliment that was ever paid me was when someone asked me what I thought, and attended to my answer."*
>
> — Henry David Thoreau, author, 1817 - 1862

Integrating communications into every aspect of the planning, launch, and operations phases is essential. Every communications plan will be different and should be tailored to address local concerns and challenges. The plan is not a static document; various elements may need to be tested and refined over time. This chapter aims to provide a roadmap for communications planning that outlines key steps for developing and delivering a comprehensive strategic communications plan.

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9.1 Define Goals and Objectives

> *"Our goals can only be reached through a vehicle of a plan, in which we must fervently believe, and upon which we must vigorously act. There is no other route to success."*
>
> — Pablo Picasso, artist, 1881 - 1973

Defining communication goals and objectives is the first step in planning. It creates the rationale for all activities, sets expectations, helps quantify needed resources, and provides a measure against which to track progress.

Goals and objectives should be as specific and targeted as possible and should guide decision-making as the process continues.

A common way to distinguish between goals and objectives is to think of a goal as an overarching principle that guides decision-making, and objectives as specific, measurable steps that can be taken to meet the goal. In short, goals are broader, objectives are smarter.

Goals for BRT communications planning typically include:

- To inform: Let interested parties know about the BRT project, with a focus on how it will benefit them and what they can do to help the project along. Use data to support your claims as available;
- To solicit feedback: Create opportunities for feedback from interested parties. This will improve planning and implementation, as well as help shore up support from these stakeholders when the project is criticized;
- To build understanding, support and attract ridership: This is particularly important if you are introducing BRT to a population for the first time. It will be necessary to engage new providers and to educate customers on how to use the system to get the most out of it;
- To mitigate risk: Big projects like these generate a lot of interest and potentially a lot of controversy. Even a small misunderstanding can create large problems, putting the project at risk. Open and transparent communications will significantly break down potential implementation barriers, such as NIMBYism (Not in My Back Yard) or bias against buses. Should there be unforeseen problems, there should be a communications "Plan B" in place that includes a decision tree for who is responsible for: a) developing a unified message and b) communicating the "fix."

Other, more specific goals may include ensuring that the dedicated busway is enforced, or incorporating informal public transport operators into the new system.

Once the goals are defined, a set of objectives should be developed that indicate how to measure whether the goal has been accomplished. Effective objectives are SMART: Specific, Measurable, Attainable, Relevant, and Time-bound.

For example:

- Goal: improve the quality of urban life with a world-class BRT system; Objectives: see a 10 percent mode shift toward public transport over two years. Maintain a safe and reliable system in a state of good repair. Support economic development along the corridor with a significant increase in street-level retail within a year of the system opening.
- Goal: improve public opinion on BRT; Objectives: Reach out to interested parties about the benefits of the BRT system. This may include how many people you plan to reach to and how you plan to reach them, in what manner, and how often. There are numbers that can be measured relatively easily, such as how many people are reached and how often. However, measuring public opinion shifts and whether your strategy helped to change it, is a complex and subjective thing to measure.

Some goals and objectives may require adjustment as the process goes forward. Such a shift can signal that the team is paying attention to the local environment, specifically the needs of stakeholders and target audiences. Constant evaluation should be encouraged.

9.2 Stakeholders and Target Group Identification and Analysis

> *"Building sustainable cities—and a sustainable future—will need open dialogue among all branches of national, regional and local government. And it will need the engagement of all stakeholders—including the private sector and civil society, and especially the poor and marginalized."*
>
> — Ban Ki-moon, diplomat and UN Secretary General 1944–

Throughout the planning, design, and implementation of your BRT, there will be many stakeholders and audiences to engage in order to create a system that works best for everyone. Taking the time to manage these relationships and understand the needs and concerns of these groups will facilitate effective communications, which, in turn, will help fuel the success of the project.

The best communications plans are those that are oriented towards target groups. This means identifying which people you want to influence, what you want them to do, and determining the best way to reach them with the message(s) that will have the most impact. It may be useful for planning, implementation, and messaging to segment into smaller groups who will have different concerns: for example, seniors, people with disabilities, people who are public transport-dependent (captive users), people on low incomes, minorities, students, people who prefer public transport to driving, and urban/suburban users.

Stakeholders are people, groups, or organizations with an interest in or a role to play in the BRT project. They can be internal (government/agency officials) or external (community groups, riders), and they can influence or be influenced by BRT activities.

Stakeholders will have varying opinions and interests with regard to a new public transport system, but if engaged and managed properly, they can all become important resources to draw upon for support of the project. In order for the project to be successful, stakeholders must be engaged throughout the entire process, beginning at the pre-planning stage.

Figure 9.1. A powerful stakeholder group, public transport workers, in Cuenca, Ecuador, protest against regulatory changes. *Image courtesy of El Comercio.*

In identifying stakeholders, think about whom this project will affect (both system providers and consumers), positively or negatively, and who might have reasons to want the project to succeed or fail. Some typical examples of stakeholder groups for BRT planning include:

- Government agencies;
- Political officials;
- Non-Profit or Non-Governmental Organizations, local and international;
- Community and neighborhood groups;
- Current public transport customers;
- Potential public transport customers;
- Drivers;
- Local business owners;
- Environmental groups.

The more clearly defined the stakeholders, the more strategic a communications plan to reach them can be. Identifying stakeholders is a local and specific process. If, for example, BRT is attempting to expand its support, then public health promoters and officials could be of interest, along with cyclists and walkers, neighborhood associations, women's advocacy groups, environmental organizations, consumer associations, and other relevant bodies. If specific services or destinations, such as education or health, are a focus, then involving school officials, parents and their organizations, health care and hospital users and employees should be a part of the participatory strategy (See Chapter 10 for more on outreach and strategic participation).

Box 9.1. Case Study: Rea Vaya

Figure 9.2. A typical minibus taxi in Johannesburg, South Africa. *Image courtesy of ITDP.*

The Rea Vaya BRT in Johannesburg, South Africa, has been working to manage an important group of stakeholders since system planning began in 2006: the informal taxi industry.

As in many places around the world, informal networks of taxi or minibus drivers are the primary providers

of public transport in Johannesburg, and transition to a formally run BRT system would mean massive change, and was sure to be controversial.

The city was proactive, engaging with taxi leaders at the outset of planning by taking them to South America to visit TransMileno, and meet with operators who were previously also operating informally. They held formal negotiations with representatives of the taxi industry, which resulted in the taxi drivers becoming directly tied to Rea Vaya as shareholders of the operating company, which the city contracted to run the BRT. This gave the city a formal way to relate to these stakeholders, and it gave the stakeholders a platform with which to advocate for themselves, in partnership with, rather than in opposition to the city.

Although the process is ongoing and many challenges remain, Rea Vaya has remained popular, and ridership continued to grow throughout the negotiation process. In their first customer survey, the majority of customers cited travel time savings, increased comfort, and reasonable pricing as the positive aspects of Rea Vaya.

9.3 Stakeholder Analysis

"Alone we can do so little; together we can do so much."

— Helen Keller, deaf-blind author and activist, 1880–1968

Performing a stakeholder analysis will help you to identify stakeholders and sort them according to their impact on the project, and the impact the project will have on them. The best time to perform a stakeholder analysis is during the preparation phase of the project, in order to shape your communications plan, and on a regular basis as the plan progresses. The survey process (detailed in Chapter 10) will help you to identify stakeholders you may not have previously considered, determine what they believe about your project already, and what is most important to them.

There are many ways to perform a stakeholder analysis depending on the level of depth you want and the resources you have available. The most common forms of stakeholder analysis is mapping—that is, gathering all the information you can about your stakeholders and creating a chart or map, which allows you to more easily see who the main actors are, and how you can provide what they need.

Using the data you collect from your surveys and focus groups, you can create a stakeholder analysis that will help you develop a communications plan aligned to each stakeholder's focus and concerns. The table below outlines a stakeholder analysis that was completed for a public transport project in Palmira, Colombia.

Table 9.1. Stakeholder Analysis for Palmira

Group; ;	Needs	Support and Influences	Perceived Problems
BRT; Customers;	To have a reliable, low-cost public transportation system	Willingness to pay for reliable bus transportation	Poor reliability of bus transportation; Public transport drivers drive recklessly; Frequent accidents; Frequent customer injuries; Frequent breakdowns of public transport; Public transport drivers are unprofessional;
Car Drivers	Reduction of traffic congestion	Reluctant to use public transport, but willing to try if system is reliable and fast	System would increase traffic congestion
Bus Drivers' Union	Better working conditions for bus drivers	Strong influence on bus drivers; membership is 100 percent; To represent the interests of its members in collective bargaining;	Low salaries; Extended working shifts; Vehicles in poor condition; Streets and roads in poor condition;
Public Bus Company	To provide a safe, cost-efficient public service	Fleet of buses; Operating budget, including municipal subsidy; To provide an essential, safe, and cost-efficient public service;	Vehicle fleet is old; Buses are poorly maintained; Fares charged cover only 75 percent of operating costs; Decrease in demand; Many customer complaints;
Public Works Department	Improve roads in Palmira	Annual operating budget allocated by City Council/Mayor; To build and maintain adequate roadways within Palmira city limits (including faraway neighborhoods);	Roads are in poor condition; Budget is insufficient for works needed; Increasing traffic congestion;
Mayor of Palmira	Re-election; To show success in reducing traffic congestion; To show success in implementing an efficient public transport system;	Commands popular support; Has veto power over City Council decisions; To serve the best interests of the City of Palmira; To serve as chief executive and city manager;	Increasing congestion; Many citizen complaints about transportation system; Costs of the system will be criticized if not considered a good investment;
Palmira City Council	Decreased congestion; To have a reliable public transportation system;	Approves and has oversight of annual Palmira budget; To serve the interests of the residents of Palmira; To make the final decision regarding all projects presented to be financed by the Palmira budget;	Increasing congestion; Political fallout from project criticism;

Source: http://www.iadb.org

9.3.1 Stakeholder Mapping

In general terms, stakeholders' positions on your project can be summarized along a spectrum. All these positions must be taken into account in a stakeholder analysis, since the goal of this exercise is to know what each stakeholder thinks about a project and to understand what each stakeholder may do to promote or stall it.

The first step in building any stakeholder map is to develop a categorized list of the members of the stakeholder community. Once the list is reasonably complete it is then possible to assign priorities and translate the "highest priority" stakeholders into a table or a picture. The challenge is to focus on the "right stakeholders" by identifying their readiness to act. The further to the ends of the spectrum the stakeholders are, the more willing they are to act — either on behalf of the project or to the detriment of the project. Both ends need to be accounted for in your communications plan.

This stage of the communications process emphasizes getting to know the population, rather than "convincing them" to take any particular action with regard to BRT. In many cases, the information from project opponents will be particularly useful for developing and disseminating messages. It is also important not to neglect groups that support the project, to maintain their enthusiasm, and make sure they don't feel taken for granted. Keep in mind that stakeholders may shift their positions during different project stages.

Typically, the dimensions of the map are the influence/power of stakeholders and their level of interest in the project, such as shown in Figure 9.3 below.

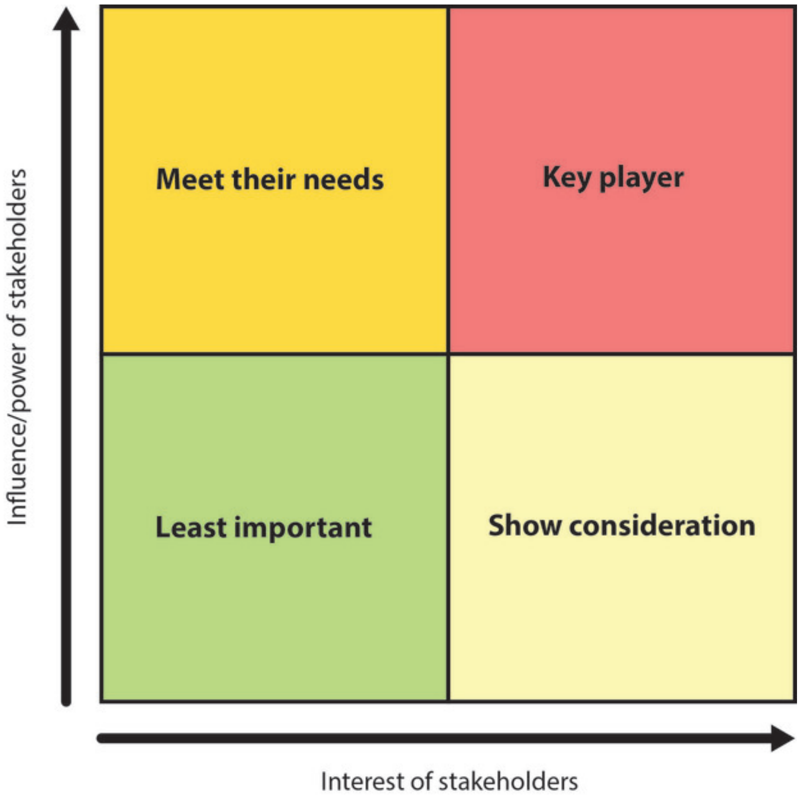

Figure 9.3. Stakeholder map that looks at both the influence/power and the interest of stakeholders. *Source: http://www.stakeholdermap.com/stakeholder-analysis.html.*

Some of the commonly used "dimensions" include:

- Power (high, medium, low);
- Support (positive, neutral, negative);
- Influence (high or low);
- Need (strong, medium, weak).

Once they are categorized in this way, the map can be used to determine strategies for dealing with each category of stakeholders. The type of mapping or analysis you do with this data depends on what the goals are for the particular group.

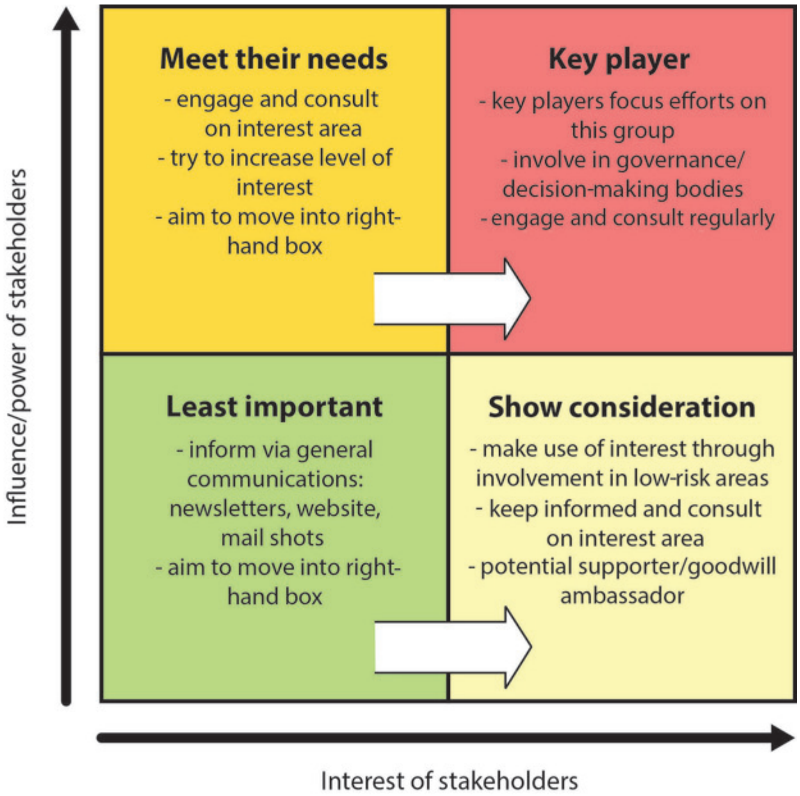

Figure 9.4. Stakeholder map that describes each type of stakeholder by both the influence/power and the interest of stakeholders. *Source:* *http://www.stakeholdermap.com/stakeholder-analysis.html*

9.4 Engaging Stakeholders

> *"The most basic of all human needs is the need to understand and be understood. The best way to understand people is to listen to them."*
>
> — Ralph G. Nichols, author

With a clear picture of who the stakeholders are, what their influence is, and what they need, the next step is determining how best to engage them. Generally speaking, they should be given an opportunity to voice their points of view. Stakeholder groups are already likely to be talking about the project so it is best to offer a more official managed venue.

Ideas for engagement include inviting participants to blog about the BRT on your website, participate in a public forum or roundtable discussion, or be interviewed for a video that you will release publicly. If the issue is more confrontational or sensitive, invite a representative for a sit-down meeting with a member of your team. If social media is an option, be sure to show your appreciation for the stakeholder's involvement by including them in your tweets and posts.

Box 9.2. Four Reasons to Engage Stakeholders Early and Often:

- By inviting stakeholder groups to participate in conversations relevant to you, you are forging positive relationships that will benefit the system in the future;

- Engaging stakeholders, especially those who may be in opposition to the BRT project, shows open-mindedness and transparency in a controlled way. Giving stakeholders a podium shows that the BRT operators are not timid about exposing audiences to other points of view;
- Offering an opportunity to stakeholders to share their points of view under the BRT system's brand umbrella helps promote the system to their networks, or people who would often be more skeptical of an appeal coming directly from BRT officials;
- Communications is a social ecosystem. More content from more providers means more opportunities to promote the benefits of BRT.

9.4.1 Communicating with Internal and External Stakeholders

Having done your due diligence around learning about individual groups of stakeholders' needs and concerns, the team is better positioned to think about how to communicate with both internal and external stakeholders, and to make use of these resources to communicate with them.

Internal stakeholders include employees of the public transport agency, board members, and other government agencies such as police, urban development groups, traffic agencies, public works, city council members, district politicians, and the mayor. For internal stakeholders, it is essential that there be a consistent message, especially when communicating with external stakeholders and target groups. Everyone needs to be saying the same thing, within reason, and the government must be perceived as a united front. Showing a clear understanding of the challenges and benefits of the project will help build political support from important external stakeholders, which will help with implementation.

Prior to any public communications launch, internal stakeholders must be brought together, and once a public communications plan is in place, internal stakeholders still need to be routinely engaged, or they may feel disenfranchised and pull out of supporting the project. It is not enough to consult these groups once; rather, it is important to give them space in the process to participate on a continuous basis, either through regular meetings, electronic communication, or other preferred method.

Box 9.3. Internal Stakeholder Example: Public Transport Owners

Figure 9.5. The public transport sector in Bogotá prior to TransMilenio was dominated by informal transport and private owners. *Image courtesy of ITDP.*

The most difficult negotiations for developing a BRT system will likely be with existing transit operators. Change is never easy and, regardless of the benefits, many will resist even if they are brought on board early and well.

In many countries, however, the sector is unused to official involvement, oversight, or taxation, and operators often distrust public agencies. In cities such as Belo Horizonte, Brazil, São Paulo, Brazil, and Quito, Ecuador proposed formalization of the transport sector sparked violence and civil unrest. In Quito, existing operators blocked the functioning of the new Trolé system, until the military restored public order.

It is essential that BRT be positioned as a positive business opportunity and not a threat. BRT can improve profits and working conditions for existing operators and drivers. The city government should carefully plan an outreach strategy that will build an open, trust-based relationship with existing operators. At least one planning staff member should liaise with existing operators on an on-going basis. Often, a former transit operator or someone with high personal credibility among operators may be ideal for this post.

Inclusion and outreach efforts to involve operators are essential. Visits to cities with existing BRT systems can be very helpful (see the Rea Vaya case study). Many operators' fears can be successfully dispelled with a first-hand view of a working system. Private operators are most likely to be convinced by their peers in cities that have already converted from conventional services to BRT. Discussions among different private operators are very effective in building an atmosphere of support and trust.

Internal communications within the project team and steering committee also require careful management. Generally speaking, the project team should be completely familiar with all critical information and require frequent updates to ensure that when project team members speak, they provide a consistent vision and an accurate description of the project. Up-to-date, coherent information for team members ensures they are prepared and prevents costly mistakes. If communications are infrequent, steering committee members may feel left out, and obtaining project approvals can become unnecessarily difficult.

External stakeholders are the people outside the government and transportation planning organization who have a vested interest in the BRT project. They include: public transport users, businesses along the corridor, existing operators, advocacy groups, employers, unions, and car drivers along the corridor.

Box 9.4. External Stakeholder Example: Private Car Owners

Figure 9.6. In cities with high car growth, such as Santiago, Chile, car owners are an important stakeholder group that should be made aware of the benefits of BRT. *Photo courtesy of Lloyd Wright.*

An external stakeholders group that nearly every public transit project has to consider is private car owners. In developing cities, although this is often a small minority of the overall population, they tend to have disproportionate influence. For any transit system to be successful, these stakeholders need to be managed well.

On the outset, the idea of giving priority road space to public transport may seem counter to private vehicle users' interests, and their first reactions to your plan may be hostile. However, there are many benefits of BRT to these stakeholders, and if they are properly communicated with, then you are much more likely to make them an ally of your project. Separating public transport vehicles from other traffic will, in fact, improve conditions for private vehicles. Since buses stop more frequently and may represent the majority of vehicles on the road in some countries, the separation of these vehicles from mixed traffic improves traffic flow and dedicated lanes allow drivers to bypass buses completely, reducing traffic congestion overall.

The specific impact on mixed traffic will depend on local circumstances. Getting accurate information to the motoring public can prepare motorists with reasonable expectations about the new system. If the system has been designed well, it is likely that there will be many positive impacts for drivers. If the new system does create negative impacts for motorists, then project proponents should be ready for criticism from this group, and they should create messages that both acknowledge the issues and respond to concerns as well as justify the project on equity or environmental grounds (Figure 9.6).

For some critical stakeholder groups, such as existing public transport operators, the project team may designate a representative to specifically handle those communications on a full-time basis. This builds mutual knowledge, a common language, and trust. This sector-specific spokesperson should remain in close contact with the political leader to ensure credibility and consistency all around.

See Chapter 10: Public Participation, for more strategies on engaging and managing stakeholders.

9.5 Message Development

> *"Words mean more than what is set down on paper. It takes the human voice to infuse them with deeper meaning."*
>
> — Maya Angelou, author and poet, 1928–2014

Having identified your internal and external stakeholders, the team is better positioned to think about the messages that will best reach these groups. For internal stakeholders, such as employees of the public transport agency, board members, or other government agencies, it is essential that there be a consistent message. Prior to any public communications launch internal stakeholders must be brought together and then routinely engaged.

As part of message development, it can be helpful to choose a theme. There may be one overarching theme or different themes for different audiences, depending on what the stakeholder analysis has revealed.

For example, in a BRT campaign, the objective may be the same as many others around the world: to increase ridership. But the themes are different depending on the different values of the audience. To an audience of parents, the theme may be safety, and messaging can convey how much safer they and their children will be in a more formalized bus system. To an audience of commuters, the theme may be speed, indicating how much time will be saved, and how much shorter they can expect commutes to be.

Tone plays an important role as well. An optimistic, positive message is always preferred whenever possible. Good message development is a key element to the success of both the planning and the implementation phases of BRT systems. Creating the "perfect" message is a complex process, but general guidelines include keeping messages:

- Honest: To the greatest extent possible, present issues as they really are or as they really will be. Deceiving customers will generate endless problems;
- Simple: Offer simple, easy-to-understand ideas. Too much information makes a message confusing and difficult to remember or relate;
- A call to action: Inviting stakeholders to act upon an issue. This gives people a role, letting them know how they fit in to the project;
- In sync with local culture: Messages should be well adapted to social mores, language, values, and norms;
- Illustrated with real examples: Use real-world examples to illustrate your stories as much as possible. This will enhance audience engagement and recall, and it will draw a picture for them as to why they, in particular, should support this project.

A basic and common aim of BRT projects is to familiarize the population with BRT. If this is the first BRT in your city, messaging should focus on educating your target groups on what BRT is, how it is different from regular bus service, and how this will improve their public transport experience.

Citizens who may consider using public transport, particularly those who may have the option to drive, may be deterred simply because they don't understand the system. You can overcome this hurdle with the right messaging, and the right placement, before the system opens. User education should help potential customers answer these fundamental questions about the BRT:

- What is it?
- Where does it go?
- When does it start?
- Who is affected?
- How do I use it?
- Why should I use it? What does it cost?

Box 9.5. Tips for messaging:

- Keep it clear: Don't use acronyms or jargon in your messages;
- Keep it fresh: A message is not a re-worded mission statement;
- Keep it consistent: All messages, for any target group, should support and not contradict;
- Keep it positive: Whenever possible, keep your message positive while being honest.

A commonly used tactic is to demonstrate through example, by using information from successful BRT systems, such as TransMilenio in Bogotá or the Guangzhou BRT in China. This can give stakeholders some good visuals and examples as to what the system will be like. Many cities have found success with a focus on educating children about public transport. If children get excited about a new system, they will share what they've learned with their families, and encourage their parents to try the system. For example, in Johannesburg, South Africa, they city hired a theater group to perform a play in primary schools, teaching children how to use the Rea Vaya BRT.

Figure 9.7. Creative approaches to outreach, such as using entertainers, can be highly effective for disseminating information in a memorable manner. *Image courtesy of Lloyd Wright.*

Consistency of messaging with the project's operating plan is critical, as these messages will be the first interaction users will have with the system and will set the tone for how they judge the system once it is operational.

For example, with regard to customer comfort/crowding in buses, although BRT promises high-quality service, ideally at four customers per square meter, public transport typically must find a financially sustainable model involving little or no subsidy, which will mean that customers' comfort may be reduced. If service is set at five or six customers per square meter, it is no longer valid to say that the BRT is comfortable, and messages should instead promote other characteristics, such as cleanliness, punctuality, speed, accessibility, and safety.

9.6 Targeting your message

> *"Talent hits a target no one else can hit; Genius hits a target no one else can see."*
>
> — Arthur Schopenhauer, philosopher, 1788–1860

Box 9.6. Example: Transantiago

Figure 9.8. The Transantiago BRT in Santiago, Chile. *Image courtesy of Wikipedia Creative Commons.*

When officials from the city of Santiago, Chile restructured the city's bus system, they unintentionally gave us a case study in how NOT to manage messaging to their system's users. User education concentrated on high-level messaging using celebrities, but it did not address the practical needs and basic questions of users, such as where the system would run, how much it would cost, or how customers would pay and transfer. The updated route map was released less than two weeks before opening day, and because it was poorly designed and promoted, the system was difficult for customers to navigate.

When the new system launched, residents were completely unaware of how the changes would impact their daily commutes. Confused commuters responded by avoiding the bus and crowded the city's metro, nearly crippling the rail system. The situation created such public outrage that the President of Chile issued a public apology and the Transport Minister resigned.

Transantiago's problems went well beyond communications — incomplete infrastructure and insufficient service were also major factors — but citizens who had been left in the dark made the chaos far worse.

Targeting messages effectively requires thinking about the issue from the target group or stakeholders perspective. The most effective messages are designed to meet your audience where they are and move them toward the objective. What does this group already believe about BRT? Are they supportive or opposed? It's important to be respectful of their existing beliefs on this issue and build a message platform that addresses them.

In so doing, it is important not to assume that if people know what you know, they would do what you do. For example, many people know that big cars have high emissions levels, but they choose to drive them anyway. Perhaps big cars make them feel safer. Perhaps smaller cars do not provide them enough cargo space. An effort to get people to switch to low-emissions cars must address these concerns. To connect with the target audience and make them an ally requires understanding how they think and determining what lens they use to make decisions.

The best way to persuade target audiences to support and use the BRT system is to make sure that the messages they are receiving explain how BRT fits with their lifestyles. If the messages resonate with people, they can be enormously successful in promoting the project.

One way to help ensure that messages resonate is to employ the best possible messengers. The people who deliver the message are as important as the message itself. The right messenger is one who has credibility with the target group. Determining who the stakeholders and target groups most trust should be part of the initial stakeholder analysis. For some groups, government officials will be trusted, while with others, community elders, celebrities, international experts, or representatives from NGOs may better convey your message.

Box 9.7. Example: LAMATA

Figure 9.9. The "BRT-Lite" system in Lagos, Nigeria. *Image courtesy of Wikipedia Creative Commons.*

Lagos, Nigeria, successfully implemented a bus project with a strong communications program. The Lagos Metropolitan Area Transit Authority presented the project as more than simply a bus system but about improving and facilitating movement within the corridor, positioning the issue as "congestion vs. flow" and "old-fashioned vs. modern". The program made good use of quality, professionally produced videos, websites, brochures, and regularly scheduled radio and TV programs.

This tapped into public frustration at the lack of transit options in the city, and created acceptance and pressure that was used to overcome resistance by skeptics within government and among the taxi and minibus industry. Key to stakeholder engagement was the support of the road transport workers union, which had been convinced that it was best for them if the city moved to a more regulated form of public transport.

LAMATA invited the best molue drivers to train to become "pilots" for the new system, conveying a sense of status and giving them a role in the transport revolution sweeping Lagos. This synergistic relationship helped to develop more respectful drivers, leading to a more compliant population that in turn could produce even more such drivers, and represented a catalyst for change.

9.7 Dissemination Tactics

> *"The two words 'information' and 'communication' are often used interchangeably, but they signify quite different things. Information is giving out; communication is getting through."*
>
> — Sydney J. Harris, journalist, 1917 - 1986

Having completed the stakeholder identification, analysis, and message development, the next step is determining how best to deliver the messages. Tactics include meetings, speaker's bureaus, websites, newsletters, press conferences, phone calls, earned media, and paid advertising. The best efforts use the most direct tactics that are appropriate for your audience. For example, to reach out to internal stakeholders, an internal newsletter or email may be most effective. If the audience is younger, using social media or mobile applications may be most direct; but, if senior citizens are the intended audience, a direct mail campaign may be more appropriate. Channels for communicating should always align with the objectives, theme, and tone appropriate for the target audiences.

Getting the timing of communications right is an important consideration as well. Be sure to consider natural communications opportunities first, such as back-to-school day, when parents and children will be taking buses, or Earth Day, when an environmental message would be welcome. Think about the opportunities for outreach through events, earned media, and other activities. Most importantly, the tactics should match system capacity and budget. It's much better to have a few smart, well-executed activities than to undertake so many that they cannot be done well.

9.7.1 Traditional Media

Traditional media includes print (newspapers, magazines), broadcast (radio, television), and the online versions of these. Depending on the culture and context, print media may still be the primary way that people consume news, or it may have shifted online. In either case, although the reach of traditional media has receded with the rise of the Internet, it still has considerable impact on public opinion and should be integral to any communications plan.

The team should pay special attention to relations with the media. A new BRT system will likely generate both negative and positive coverage. Engaging in the dialogue is encouraged as a means of spotlighting BRT, generating interest, and affording the team the opportunity to answer key questions from stakeholders.

The communications team should develop press kits containing basic and relevant information to the BRT. Depending on how media works in your city, this can be made available electronically, hard copy, or both. This will proactively provide media with up-to-date information on system operation, planning, management, financing, and technical specifications.

Holding briefings for reporters and editorial boards of both print and broadcast media with in-depth background on a project prepares them to cover the BRT-related issues in a more even-handed way.

In some cases, video is an integral part of the media strategy. An easily understood video can be more useful to some people than hearing about transportation. Videos can both describe the steps in a process and enliven presentations and online press releases. They can also be used at public meetings and on the BRT Web site. However, video production demands a high level of expertise and can be relatively expensive.

If possible, a press-access section on the BRT website, which can be accessed by approved media with a password, should contain up-to-date information when you are ready to release to the media. It should also contain press releases, embargoed or not, contact information for designated BRT spokespeople, data, photos, reports, video b-roll for broadcast media, and any statements from government that you wish to make available to the press. Keeping information easily accessible and transparent will encourage journalists to look to you for the final word on any rumors, or at least give you the chance to respond to them before they publish a story. These will both facilitate accurate transmission of information between the project team and citizens and help the project team control the messages.

In addition, it is useful to generate complementary communications, such as an insiders' newsletter or email list for people who like to be in the know and can transmit the information through their own networks of interested people and groups. LinkedIn affinity groups, or even simple listservs, can be useful for this purpose as well. These interactive formats can help to balance media coverage and provide fodder for independent supporters eager to defend the new system through op-eds, letters to the editor, or in conversation.

Developing relationships with journalists is essential. The more comfortable they feel contacting a public transport agency, the easier it will be to disseminate messages through a news medium, which is far more trusted than advertising. It

Figure 9.10. Bogotá hosts a range of innovative transport and public space measures, including closing streets to car traffic on Sundays. *Image courtesy of Lloyd Wright.*

Figure 9.11. In Jakarta, traditional media covered the Transjakarta BRT extensively, which has significant political ramifications for then Governor Sutiyoso. *Image courtesy of ITDP.*

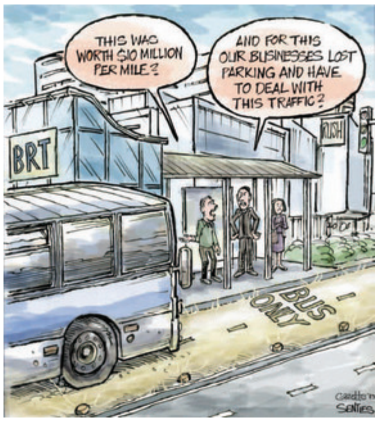

Figure 9.12. This editorial cartoon from Chicago, USA demonstrates a common negative perception of BRT. Building relationships with local media is extremely important to countering this perception. *Image courtesy of Chicago Gazette.*

is important to be as accessible as possible to journalists, otherwise, there is a risk they will either not get the facts right or be more likely to write a negative story. As a general rule, it's important to address problems and negative perceptions proactively, rather than wait to be called for comment on a reactionary story. Just as relationships with key stakeholders should not end when construction finishes; neither should PR and external relations efforts. Both should be closely tied to the daily operation of the BRT.

Box 9.8. Example: Rea Vaya

Figure 9.13. The Rea Vaya BRT is Johannesburg, South Africa. *Image courtesy of ITDP.*

The Rea Vaya BRT in Johannesburg, South Africa, made special efforts to reach out to the riding public in general and the disabled community in particular to ensure their support in the face of opposition from the taxi and minibus unions. Although there was promotion of Rea Vaya and consultations ahead of the system's launch, financial constraints prevented the project team from spending large amounts on communications and promotion strategies. In light of the funding issue, the Rea Vaya team and the project's political champions courted local media to provide as much positive exposure as possible.

Although two key minibus stakeholder groups agreed to cooperate with Rea Vaya, significant numbers of minibus taxi operators continued to oppose the system by holding strikes and protesting. The Rea Vaya team continued to engage with them, and their relationship with local media helped to ensure that the coverage included Rea Vaya's perspective, as well as the perspective of those unions that did support the project. This was essential in framing the issue as favourable to Rea Vaya, and they continued to enjoy public support during this phase.

9.7.2 Website and Social Media

Virtually every BRT system, as well as metro, light rail, and streetcar, has a website for users. The website should be thought of as the main portal of information for people who use the system, and it should contain reliable, accurate, and current information on the BRT. Although the way in which people access information has shifted almost entirely online in the last decade, many public transport agencies still don't have comprehensive online strategies. However, establishing a sophisticated online presence is relatively inexpensive and can have a massive impact on users.

The communications team should determine the content that will populate your website. While you will likely want to include every progress report, positive news story, performance evaluation, and plans for improvements, the material must be organized in such a way that the most commonly sought-after information is the most accessible, and that all content is accurate, current and user-friendly.

The most commonly sought-after information on BRT websites generally includes:

- System Maps;
- Trip Planner;
- Fares and Tolls;
- Schedules;
- Delays or changes to regular routes or schedules;
- Special schedules for holidays and events;
- Updates on service enhancements;
- Information for tourists (some systems provide this separately, as tourists generally want to know how to get to specific locations and don't have knowledge of the system as locals do).

Figure 9.14. The website for Bogotá's TransMilenio BRT focuses on trip planning, which is the most common reason for a visit to a public transport website. *Image courtesy of TransMilenio.*

Other information, while less commonly sought, but expected to be available on the website for public use, includes performance, cost, user data, press releases, and information about the city agency and public transport organization. In some cities, BRT websites include a "transparency" section of the website where the public can see who is receiving contracts for construction and operation, how the project is progressing, and what the cost is to taxpayers beginning from the development phase. Keeping the process open and transparent to the public is often the best way to head off criticism and allegations of corruption as the process continues.

As the general public will know little about BRT at first, a package of visual materials, including renderings, may be an effective mechanism for introducing the concept. Some excellent renderings of the planned Las Vegas BRT stations show how the system will incorporate traditional neon signs evoking the glamour of Las Vegas and connect the planned system with a sense of local pride. Showing people how their city can be transformed by the new BRT system can generate lots of enthusiasm for the project.

The future route map is a fundamental part of the BRT public relations campaign. The route map creates a sense among stakeholders that the new system is really going be implemented. Getting a mayor or a governor to publish a proposed route map for a BRT network, particularly using a subway-style map signals political commitment and creates a sense of inevitability critical to winning over stakeholders. The route map shows commuters how they, personally, will benefit from the new system. For this reason, it is important to indicate Phase I and subsequent routes for the whole completed network.

Just as important as your website containing accurate and up to date information is the ease with which the desired information can be found on the site. In order to be useful to your communications efforts, the website must be user friendly, well designed, professional, and conform to brand standards.

Nearly all mass transport systems now also maintain a presence on social media, through Facebook and Twitter, and some also use formats such as Instagram or Flickr to promote their systems and engage with customers. Twitter in particular can be a valuable tool to engage directly with customers by providing real-time service information and soliciting feedback. Like your system's website, your social media presence should be maintained consistently and professionally. More information on social media can be found in Chapter 11: Marketing and Customer Service.

Mobile phone applications are another innovative practice that cities are adopting to make public transport more attractive. Through applications like NextBus, city dwellers in places like New York, Washington, D.C., and Los Angeles can check the real-time location and projected arrival times of buses from their mobile phones. This type of information reduces the uncertainty of using public transport.

Even in cities where public transport agencies have not opened their data, entrepreneurs are coming up with innovative ways to share public transportation information. For example, Mobile 4 Mumbai used data collected by social media to build a mobile application allowing users to find bus routes in the city. While entrepreneurs like those that run Mobile 4 Mumbai continue to innovate, it's important for public transport agencies to view them as allies and support them by making data open to the public.

For more examples of promotional materials and branding, see Chapter 11.

Box 9.9. Example: Transjakarta

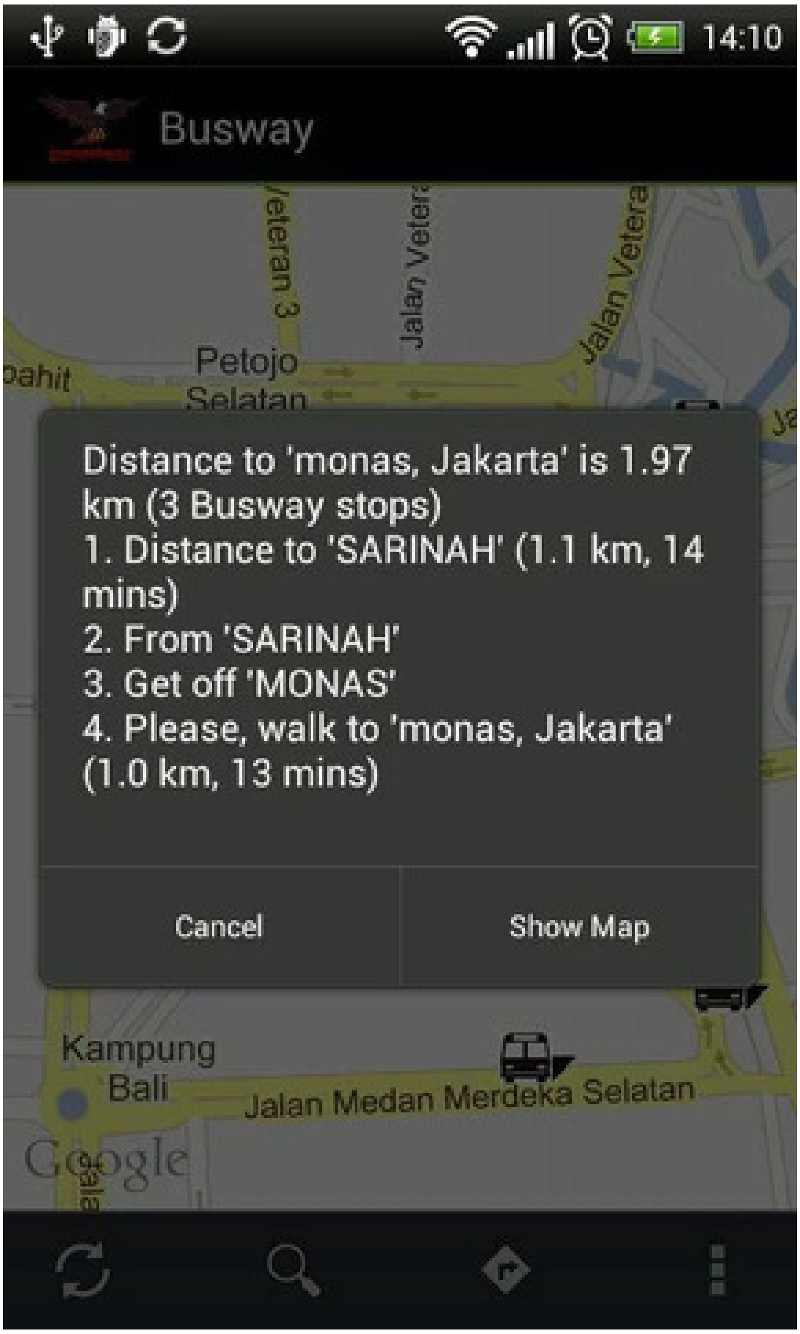

Figure 9.15. A mobile application provides public transport directions. *Image courtesy of Transjakarta.*

Figure 9.16. Transjakarta's website showing the route map for Jakarta. *Image courtesy of Transjakarta.*

Transjakarta BRT in Jakarta, Indonesia operates a professional, well-designed website with a route planner, links to Facebook and Twitter pages, route and system maps, forums for comment, rider polls, and even a live station security camera. It also includes an interactive map with service updates, making it easy for everyday rider use.

Transjakarta has several mobile apps. The most popular, called Busway Transjakarta helps users navigate the city with Google maps. Users type in the name of the street or building of their destination, and are given step-by-step instructions of the shortest route with the fewest transfers.

9.7.3 Budgeting

Defining a discrete marketing budget for a BRT system can be a challenge, particularly if it hasn't been specified very clearly in any of the existing documentation, and system managers are not entirely sure about the amount of money that has been spent on marketing for their system. In many cases, this is an afterthought of system operations, and so far there has generally been no marketing division as part of system staff.

For instance, when asking two system managers about the percentage of investment being spent in marketing for their systems, one reported 1 percent while the other responded by saying that all work related to the system was marketing, thus 100 percent of their budget was spent on this issue. Whether the budget for marketing is separate, or integrated throughout the other budgets, it should be taken into account in planning, and system staff should be provided with enough resources in order to work on this issue.

A comparison from the automobile sector is useful here. According to a recent study (EMBARQ, 2010), major auto companies spent US$21 billion in 2009 specifically on advertising (General Motors spent 3.2 billion by itself that same year). If a BRT system is expected to gain ridership from those citizens who are choosing between cars and public transport, it is very important to counter those efforts by considerably strengthening the importance, visibility, staff, and budget of a BRT system.

Generally, as part of the initial team of people working on this, a communications professional should be on staff to manage the budgeting process, as well as deal with media and press around this project. If this is a new service in a city without a public transport agency or other formal services, hiring a PR and/or marketing firm to help with developing the brand, develop key messages, and liaise with the media will significantly improve outcomes.

9.8 Measuring Success

> *"Some artists claim praise is irrelevant in measuring the success of art, but I think it's quite relevant. Besides, it makes me feel great."*
>
> — Chris Van Allsburg, illustrator and writer, 1949–

An often-neglected, yet critical part of any communications plan is measuring the success of the plan. While measurement is useful for satisfying funding requirements, the most important reason for measuring success is to ensure continuous learning and improvement. Identifying both quantifiable and anecdotal evidence to measure success helps demonstrate the system's progress to internal audiences such as public transport staff and external audiences such as funders, policymakers, and the media.

The communications planning process should include identifying what "success" looks like for each stated objective. From that definition, a set of benchmarks can be developed to measure against. The plan should include allocating resources necessary to conduct research for reporting progress toward these benchmarks. The purpose of developing a communications strategy is to ensure that key messages are getting to the right audiences and influencing their behavior. It is important to correct course quickly if the strategy isn't working. Ongoing revision of the communications plan is a reality of nearly every communications effort, and not a sign of failure. Plans should be adapted and modified as often as is necessary.

Measures of success should be a mix of outputs and outcomes. Outputs for example, can include things like positive news coverage, advertising, or meetings held with stakeholders. These should be straightforward to measure and are quantifiable. How many press hits were there? How many public meetings were held?

Outcomes are the changes that occur because of these outputs. For example, did positive press coverage lead to a positive shift in public opinion? Did stakeholders choose to become more involved in the project because they were happy with the meetings they attended? While measuring outcomes is more complex, it is essential to do so regularly to determine if the outputs are having the desired effect.

If, for example, your goal was to get all public transport riders on a specific corridor to use the system, ridership data can be collected. If, however, an objective is more qualitative, such as "build support", a more sophisticated measurement system, and/or anecdotal information and analysis may be required. To illustrate how to measure success, consider the sample goal and objectives from the beginning of this chapter.

Goal:Improve the quality of urban life with a world-class BRT system.

Objectives:See a 10 percent mode shift toward public transport over two years;

Maintain a safe and reliable system in a state of good repair;

Support economic development along the corridor with a significant increase in street-level retail within a year of the system opening.

As we discussed in the goals and objectives section, the goal is a broad statement of your vision rather than a measurable one, while objectives should be SMART: Specific, Measurable, Attainable, Realistic, and Time-bound. The objectives we've set for our broad vision goal should be broken down into metrics to measure progress, and these should be evaluated throughout the process. Some examples of metrics for each objective:

Objective: See a 10 percent mode shift toward public transport over two years.

Setting metrics for modal shift can be complex, but most use some form of regular surveys. Data should be collected before the opening of the system and at regular points throughout the first two years of operation, tracking the number of trips, trip type and characteristics, and mode of travel used.

Objective: Maintain a safe and reliable system in a state of good repair.

This objective is somewhat more complex than the first, but it still fits the SMART requirements if broken down properly. Define what you mean by "safe and reliable" and "state of good repair". Possible metrics include low or no annual customer injuries, a low percentage or overall number of service delays, or how many days it takes for a repair job to be completed. As this is an ongoing objective, the time bound part of the objective could be met with progress being measured quarterly, monthly, annually, etc.

Objective: Support economic development along the corridor with a significant increase in street-level retail within a year of the system opening.

This objective could be measured in many different ways. The most obvious way would be to compare how many retail outlets exist before the corridor versus how many are open within a year of the BRT. But what this objective is really measuring is how the BRT is leveraging transit-oriented development along the corridor, so the measures will need to take that into account. "Significant increase" should be defined as is realistic for this area. Twenty percent more stores? Fifty percent more pedestrian activity? Also, does street-level retail contribute to a more pleasant environment, with places for people to walk and sit? Or is it taking away from this with compound walls and anti-loitering policies?

Also, since the objective contains "support", that will also need to be defined. Progress toward the objective can include changes in zoning and land use policy that allow for higher densities along public transport, or tax breaks for desirable businesses opening along the corridor.

In cases where success is not achieved or not clearly determined, having as much data as possible helps to understand why, and what can be done differently in the future to gain the support of the stakeholder group or stave off negative press you may have received. There is no substitute for experience, and a good system for measuring success will help to leverage resources efficiently.

9.9 Promoting BRT System Progress

> *"Never measure the height of a mountain, until you have reached the top. Then you will see how low it was."*
>
> — Dag Hammarskjold, former UN Secretary General, 1905–1961

New public transport systems most commonly release a report of success measurement immediately after implementation, and then they follow that up with a more extensive report once the system has been in place for a year. Beyond that, annual reports are a commonly used vehicle for reporting progress. There are many reasons to monitor and report on progress, but for communications purposes there are two that are most important: to maintain transparency and to promote your progress.

As discussed earlier, maintaining transparency improves relationships with journalists, and helps you to control the narrative. These reports also provide an opportunity for positive press and continued engagement with stakeholders. The most common way to promote BRT progress is to release a report when the system has been open for one year. It is likely that there will be some, but not complete, progress toward achieving objectives, and the report offers an opportunity to highlight the positive and explain the negative.

For example, let's say the team finds that it is not on track to meet mode shift targets, as not as many people are switching to public transport as hoped, but against another set of benchmarks, the performance is excellent, i.e. the system has been maintained in a state of good repair, or development is increasing along the corridor.

The report could lead with "One Year On, BRT System Increasing Safety and Development", and highlight all of the progress to date and then segue onto a discussion with a hypothesis on why the mode shift is not as high as it could be, and what plans there are to improve those numbers in the next year. This type of narrative can increase confidence in the system, by offering a whole picture of progress.

It is also advisable to include anecdotal evidence of progress in your report. Interviews with people who take the BRT daily, and who have seen their quality of life improve with shorter and safer commutes, add an important "human touch" to reports. It also reminds both internal and external stakeholders that although there may be challenges, improving transportation is making a real difference in your city.

9.10 Conclusion

> *"Taken out of context I must seem so strange."*
>
> — Ani DiFranco, musician and singer-songwriter, 1970 -

Throughout this chapter, we have described some basic components of a strategic communications plan and provided suggestions and examples of strategies relevant to BRT planning. It is important to remember that this is simply a guide, and that communications plans should reflect the local context as closely and specifically as possible. Just like every other type of BRT planning, a communications plan is only as good as its data.

The next chapter in this volume builds on the stakeholder engagement that began with the surveys and focus groups used to learn about them, and it delves deeper into ongoing engagement with ways to increase public participation and outreach. Chapter 11 then picks up with details on developing the system's brand, integrating marketing and customer service.

10. Public Participation

> *"Tell me and I'll forget. Show me and I'll remember. Involve me and I'll understand."*
>
> — Confucius, philosopher, 551 - 479 BC

In Chapter 9: Strategic Planning for Communications, we reviewed stakeholders and target groups, and how they should be considered as part of your overall communications strategy. A comprehensive communications plan facilitates the interaction between project leaders and the stakeholders, including transport providers, passengers, and the general public. It is also a helpful tool for reviewing entrenched ideas and perceptions of public transport.

This chapter takes a more in-depth look at public participation and the outreach necessary to achieve it, reviewing research on participation methods, tools and tactics, and desired outcomes. The purpose of this chapter is to highlight the importance of participation and engagement as strategies for BRT realization and success and to offer some best practice guidance for effecting a participatory process. Participation as a whole is more than "information-sharing," "communication," or "marketing," although a well-thought-out strategy will integrate all these elements.

Public participation in the transportation field is the process through which transportation agencies inform and engage people in the decision-making process. The benefits of engaging the public include community ownership of policies; better, more informed decisions that are sustainable, supportable, and reflect community values; increased agency credibility; and faster implementation of plans and projects.

The most effective transport planning draws on specific insights from the public, civic organizations, existing operators, private sector firms, and other government entities to complement the knowledge of planning staff and consultants. To achieve community ownership of the project, BRT proponents must engage with people's needs, fears, and interests. Public input on corridors and feeder services can be invaluable, as can insights from existing transport operators. Moreover, incorporating public views on design and customer service features will help ensure that the system will be more fully accepted and utilized by the public.

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10.1 The Importance of Participation

> *"We always hear about the rights of democracy, but the major responsibility of it is participation."*
>
> — Wynton Marsalis, trumpeter and composer, 1961 -

Early development and implementation of a formal strategy addressing the spectrum of stakeholders and their concerns are fundamental to the success of BRT. The best participation strategies are built on the strengths of the situation on the ground and develop a widespread sense of project ownership while managing resistance to change. When done well, this will enhance the legitimacy of the project by providing stakeholders with a sense that they are being listened to, and it will improve the quality of the decisions made by the public transport agency, as they will better reflect the interests of the general public.

In most countries, transport-system management suffers from some form of bias. Planners are primarily professional men from twenty-five to fifty-five years of age, who often do not use the public transport systems they are creating, and lack both firsthand knowledge and credibility with many stakeholder groups. This can lead to a biased system design, focusing on just one kind of commute that benefits professional adults working standard business hours, but excludes students, parents with small children, the elderly, the disabled, people who use the system for shopping and may have large bags, workers with their tools, or people who combine multiple errands such as work, shopping, and child care into one trip, also known as trip chaining (discussed in more detail in Chapter 4: Demand Analysis and Chapter 6: Service Planning).

Proper management of stakeholders and public involvement increases the chances of a project's success because they result in improved understanding of issues on the part of proponents and increased buy-in and appreciation among other stakeholders.

Although agencies sometimes fear that participation could exacerbate the disapproval of a service, the reality is that a well-developed participatory strategy will bring people on board—literally and figuratively. Participation should be seen as a long-term strategy that can provide:

- Useful instruments for framing BRT positively, getting it on public agendas, and keeping it there for the time necessary for successful implementation;
- Knowledge and support for BRT among the key stakeholders and target groups, including opinion leaders and politicians;
- Crucial input regarding users' needs and preferences that can offset age, ethnic, socioeconomic, and gender biases, often built into the urban transport planning system;
- Innovative perspectives that can enhance the usefulness and public perception of existing and new BRT routes, often based on relevant experiences from walking and cycling advocacy networks;
- Credible citizens' initiatives and organizations capable of advocacy, education, campaigning, and other work to build and maintain long-term support for BRT.

To optimize these potential contributions, the project's management will need to take an "integrative approach," weaving together the input received from an array of engagement venues. Specific activities include traditional approaches based on one-off events (public hearings, formal and informal consultations, surveys, and focus groups) as well as methods based on civil society initiatives, which typically involve activities like campaigning, education, organization-building, and other initiatives.

For an innovative approach like BRT, building support among residents contributes substantially to putting it on public agendas and keeping it there throughout the typical turbulence of implementation. Citizens involved in participatory events can offer uniquely detailed, contextual knowledge of the urban spaces (and life systems) that are in design or under intervention. Moreover, in rapidly democratizing societies, their opinions influence politicians.

Finally, citizens' organizations are able to contribute crucial BRT-related information in a timely and credible way through a vast network of contacts. For example, a participatory process that creates a very BRT-literate neighborhood association executive enables that person to become an effective conduit as well to his/her local religious institution, health clinic, planning advisory board, or parents' group at the local school.

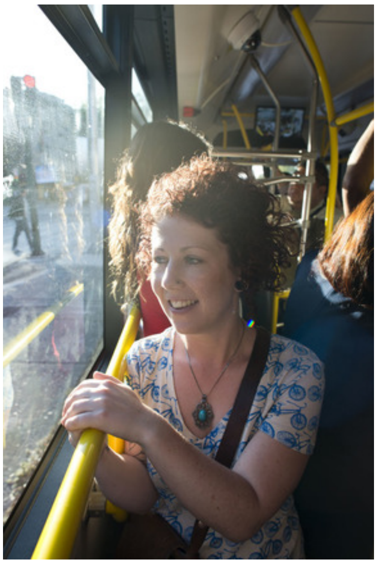

Figure 10.1. Building support among residents and customers paid off well for Mexico City's Metrobús BRT, which has enjoyed popular support during major expansions. *Image courtesy of ITDP.*

Table 10.1. Factors influencing Goals and Objectives of Participation

Factor	Observations
Political Priorities	Support through participation may focus on breadth—lots of people across different constituencies—or depth, key spokespeople willing to support, or a combination of both.
Agency Priorities	Keeping these in line with current and potential users' preferences can save money and reduce risks.
Level of Controversy	Thinking outside the box, consultation, and bringing key citizens' groups on board can help improve a difficult decision or build a better understanding of it.

Reducing Risk Exposure	Participation helps to "learn from the future as it emerges."; ;
Project Schedule	Participation can reduce delays due to unforeseen controversies or barriers.
Environmental Justice Issues	A legal requirement in the United States, other cities should still consider them as they influence perceptions of BRT.
Safety Issues	Detailed knowledge from citizens of their micro-environments can avoid costly errors and loss of lives.
Legal Requirements	It helps if participatory requirements are built into laws and regulations, so all companies are subject to the same rules.

Source: Giering 2011

10.2 Industry Standards of Practice

"Those are my principles, and if you don't like them...well, I have others."

— Julius Henry "Groucho" Marx, comedian and actor, 1890 - 1977

Public participation strategies are as diverse as the communities, locations, and agencies they serve. Specific public involvement techniques and the methods by which public transport providers execute public involvement strategies are constantly evolving. There are, however, some overall generalizations about the elements of agency public participation strategies and the process for creating them.

Although this chapter focuses primarily on agency-government-user/civil society interactions, the principles of participation outlined here apply to other stakeholders including operators and drivers (addressed more comprehensively in Chapter 16: Vehicle Operator Contracting and Industry Transition).

Figure 10.2. This design charette in Rio de Janeiro brought together government, civil society, and private sector representatives in preparation for the TransOeste BRT. Image *ITDP*.

Governments, private sector, and civil society actors have diverse and sometimes contradictory views of what citizen participation in urban transport planning should be. Maximizing success in participation requires a fundamental shift from viewing public engagement and participation as an obligation to understanding it as an opportunity to improve and build the short- and long-term viability of the system. A well-designed participatory process can also strengthen the long-term credibility and viability of organizations that build civil society.

10.2.1 Goals and Objectives

Just as in communications planning, goals and objectives play a key role in public involvement strategies. They guide the entire process, influencing who will be engaged, the level of participation desired, the type of information that will be needed, and the techniques to be used. Goals and objectives also set expectations about what the public participation effort will achieve and provide a basis for measuring outcomes.

The goals themselves should be based on the specific needs of the project. What are the questions that need to be answered? What are the missing pieces of information? What type of public buy-in is desired? Below are common project-specific goals from the International Association of Public Participation.

- Inform: To provide the public with balanced objective information to assist them in understanding the problems, alternatives, opportunities, and/or solutions;
- Consult: To obtain feedback on analysis of alternatives and/or decisions;
- Involve: To work directly with the public throughout the process to ensure that public concerns and aspirations are consistently understood and considered;
- Collaborate: To partner with the public in each aspect of the decision, including the development of alternatives and the identification of the preferred solution;

- Empower: To place final decision making in the hands of the public (IAP2 2010). As with communications planning, each goal should be followed by specific, measurable objectives. For more information on defining goals and objectives, see Chapter 9: Strategic Planning for Communications.

10.2.2 Principles of Participation

An essential part of having a well-designed participatory process is setting clearly defined principles that all participants agree to abide by, which are enforced by leaders or coordinators of participant groups. The Community Development Society () suggests the following five principles of good practice in community development:

- Promote active and representative participation toward enabling all community members to meaningfully influence the decisions that affect their lives.
- Engage community members in learning about and understanding community issues, and the economic, social, environmental, political, psychological, and other impacts associated with alternative courses of action.
- Incorporate the diverse interests and cultures of the community in the community development process; and disengage from support of any effort that is likely to adversely affect the disadvantaged members of a community.
- Work actively to enhance the leadership capacity of community members, leaders, and groups within the community (so that they may be ambassadors for BRT).
- Be open to using the full range of action strategies to work toward the long-term sustainability and well-being of the community.

There are many versions of these good practice principles, and they may be adjusted for local context and to address specific concerns.

10.2.3 The Passive vs. Active Approach

In the past, agencies have offered suggestion boxes, toll-free telephone numbers, leaflets, or advertising campaigns as examples of “participation.” While these offerings are not without value—high-quality collateral and information is a precondition for participation—they do not constitute a participatory process.

Public transport providers must often make complex decisions about the type and amount of information to provide to the public, balancing the risks of providing too little information and too much. This can be further complicated by the often technical nature of the data and the risks of it being confusing or misinterpreted. However, information sharing is important not just for meaningful public involvement, but also for building trust within the community, creating transparency at the agency, enhancing advocacy efforts, and proactively guiding the public conversation instead of allowing others (including the media or other stakeholders) to dominate the debate.

Equally important for shaping the public involvement process is the agency’s determination of what information it wants from the public. The survey results support the idea that for public transport providers, public involvement provides the agency with critical missing information. When asked about the type of input agencies typically want from the public, respondents noted that they want to know about community issues that might impact public transport service, as well as chronic customer service problems.

Informational campaigns take place along a spectrum. At one end, you have one-way communication, which means providing information, usually to a broad public with no ability to receive feedback from the audience. This is what is known

Figure 10.3. Fig.10.4 A community workshop in Rio de Janeiro, Brazil, asked participants to give input on the future of transportation in their city. *Image courtesy of ITDP.*

Figure 10.4. Surveys, which are discussed in more detail in Chapter 9: Strategic Planning for Communications, are an important and simple way to begin public outreach. *Imagecourtesy of ITDP.*

Figure 10.5. Results from an interview of thirty public transport providers about the type of input agencies typically wanted from the public. *Graph courtesy of Transportation Research Board.*

as a “passive approach.” Further along the spectrum are limited two-way communications processes, such as feedback surveys or Internet voting on preferences, which tend to be more sophisticated and have more of an impact on people’s thinking, although usually not on their behavior. At the other end, you have a genuine participation process or an “active approach” that involves more complex two-way or multidirectional communication, usually referred to as deliberation.

Generally speaking, the more active the approach, the better the results. For example, in deliberation, groups are engaged in an intense form of facilitated communication meant to bring crucial information to the surface, including the participants’ knowledge, interests, feelings, and fears. In the urban sphere, deliberation occurs in formal or informal spaces as preferred so people can hammer out agreements in a more relaxed, trusting environment. It can involve being active in the spaces being planned by conducting walking, cycling, or neighborhood access audits and reviews. This should happen in planning phases and be facilitated by the BRT team in conjunction with community groups. A well-organized participation process can transform people’s thinking and, more important, their actions.

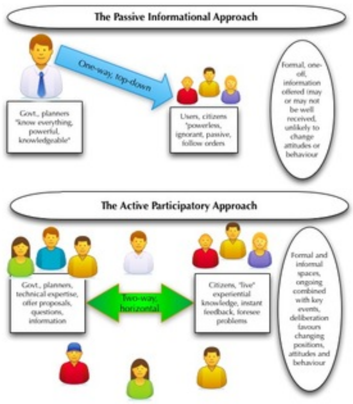

Figure 10.6. A passive approach to participation as information versus an active approach, where bidirectional communication, feedback and change foster optimum results. *Courtesy of Carlos Felipe Pardo and Lake Sagaris.*

10.3 Challenges to Public Participation

> *“We are like islands in the sea, separate on the surface but connected in the deep.”*
>
> — William James, philosopher and psychologist, 1842 - 1910

Public transport providers face many challenges when engaging the public. These challenges arise from specific issues within the agency, such as inadequate resources, or from the public, such as feelings of cynicism and distrust, lack of time, and lack of awareness. These challenges are magnified when trying to engage traditionally hard-to-reach populations such as people with limited language proficiency and low-income and minority communities. Responses to these challenges have varied among agencies, as has their success at rising above them. What has worked for some agencies has not always worked for others; however, many have been successful and there are common themes that have tended to lead public transport agencies to greater success in public involvement (TCRP Synthesis 89—Public Participation Strategies for Transit: A Synthesis of Transit Practice. Transportation Research Board. 2011):

- The more public involvement, the more likely an agency is at having successful outcomes;
- Determining the “right” questions to ask is important;
- Dedicating resources to public participation is important, but these do not have to be strictly financial resources;
- The value that an agency places on public involvement is critical to success;
- Openness and transparency matter, and in many cases are the most important as far as the public is concerned;
- Understanding, partnering with, and empowering communities can significantly benefit public involvement efforts and the agency.

Figure 10.7. Proposed increases in bus fares led to violent protests in Quito, Ecuador. *Image courtesy of Diego Pallero, El Comercio.*

10.3.1 Internal Challenges

A survey by the Transportation Research Board in 2011 showed that the biggest internal challenges to public participation are inadequate financial and staff resources, difficulty in getting elected officials interested, and lack of time for public participation. Other challenges included lack of support from upper management, lack of public involvement training for staff, and lack of coordination among agencies.

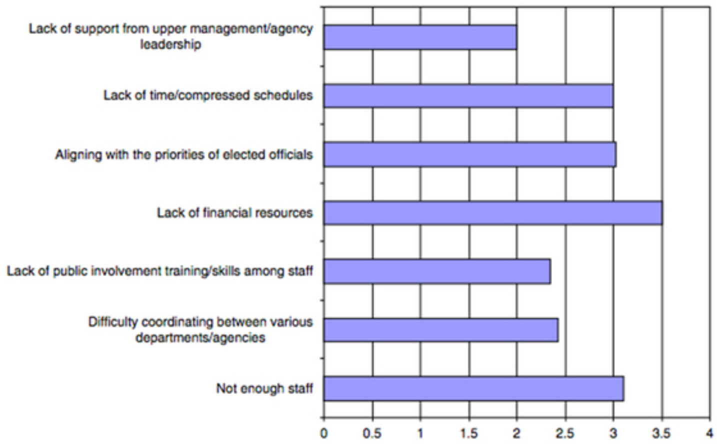

Figure 10.8. Average transit rating of internal challenges for public involvement. Note: Average rating of responses where: "Not Significant" = 1, "Somewhat Significant" = 2, "Moderately Significant" = 3, "Very Signficant" = 4, and "Highest Significance" = 5. *Graph courtesy of Transportation Research Board.*

A lack of resources is almost always a major challenge for public transport agencies. However, there are many ways to ensure successful public involvement that can be done with a modest budget. The best way this can be managed is to integrate public engagement into all of the agency's public transport activities, rather than rely on a separate budget. Even informal conversations among drivers, riders, agency staff, and community members all provide important information that can be taken back to the agency.

Building partnerships with community organizations can also address the resource problem. It is an effort that takes time and commitment, but it can reap rewards for an agency in both the short and long term. For the Hiawatha LRT project in Minnesota, USA, the Metropolitan Council reimbursed community organizations for costs associated with distributing information about the project, an action that saved the agency money (e.g., labor costs) and allowed it to tap into local distribution channels. Maintaining these relationships rather than having to rebuild them for each project will also provide efficiencies for future efforts.

Most of the other internal challenges have to do with the failure to prioritize public participation in the overall BRT process. This is a common problem that does not have a simple answer. We recommend that public participation plans be built into the system planning from the outset, including in the very first funding proposal (see Chapter 9: Strategic Planning for Communications on the importance of public participation).

10.3.2 External Challenges

There are many complex challenges to overcome in managing external stakeholders, such as feelings of cynicism and distrust, lack of time, and lack of awareness. Agencies are best able to succeed when they (1) have taken the time and effort to understand the challenges and their causes; (2) have a firm understanding of community issues, needs, and local support networks; and (3) approach projects and planning efforts in a collaborative fashion with communities.

Public cynicism and distrust of the process can arise from a feeling that participation is not worth the effort—that decisions have already been made and the opportunity for public input is merely a formality. Overcoming these feelings among the public requires building trust within the community. The best way to counteract this is by being as open and transparent as possible.

Some agencies have found that by structuring public meetings to allow participants to work through and identify solutions to specific problems, they have helped participants feel as though they have a meaningful impact on the planning process. In addition, demonstrating exactly how public involvement is used to inform the planning process can reduce levels of distrust.

All opportunities for public involvement must compete with the other obligations of people's lives. Finding time to participate in a community meeting is not generally high on the list of priorities for working people. Providing multiple opportunities for participation, including outside of regular business hours, and offering opportunities that are not dependent on time and place, such as online and mobile engagement, can help increase participation levels. In addition, active engagement, such as going out and meeting people where they are, is essential. These are discussed later in this chapter.

Lastly, making your financial information and audits available for public review demonstrates that you can be trusted with public funds.

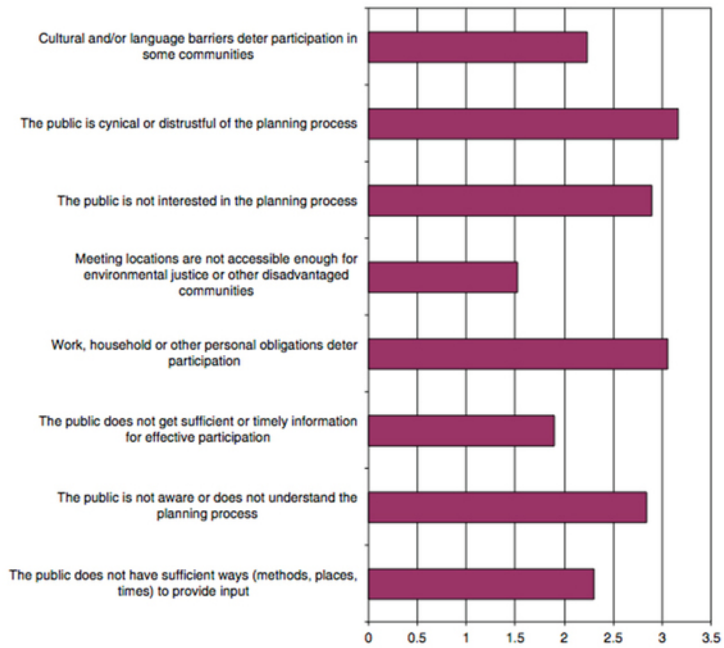

Figure 10.9. Average transit rating of external challenges for public involvement. Note: Average rating of responses where: "Not Significant" = 1, "Somewhat Significant" = 2, "Moderately Significant" = 3, "Very Signficant" = 4, and "Highest Significance" = 5. *Graph courtesy of Transportation Research Board.*

10.4 Tools and Tactics

> *"Do not wait; the time will never be 'just right.' Start where you stand, and work with whatever tools you may have at your command, and better tools will be found as you go along."*
>
> — Napoleon Hill, author, 1883 - 1970

Methods of public participation range in type, and they reflect the specific characteristics of each place. Thus, while the basic toolbox for participation is relatively similar everywhere, how these tools are combined and how each tool is used can and should be adapted to local conditions and needs. Indeed, they should evolve constantly along with local conditions and be limited "only by the creativity of their practitioners" (Giering 2011, p. 2).

Table 10.2. The Main Participatory Tools

Tool	Quality	Type	Uses	Risks	Examples
Surveys, data collection	Consult	Information	Minimal input	Superficial	Online vote on location of cycle parking, new line, etc.
Public forums and large public meetings	Consult	Information exchange	Receiving inputs from broad audience	Superficial, formulaic, meaningless, frustrating	Public hearings when written briefs can be submitted, must be considered and receive response
Small group meetings	Involve	One-off or short-term deliberation	Generate new ideas, problem solving, planning along corridors	Irrelevant, high energy waste	Charettes, working groups, manual development
Focus groups	Consult	Information gathering	Traditional research and analysis	Difficult to identify capacity for change, potential	User intercept, statement of choice, user satisfaction
Committees	Collaborate	Long-term relationship building and deliberation	Generate new ideas, problem solving, strategic development, earning broader support	Procedural, no real influence, no access to decisions	Advisory committees at the system-wide, corridor/neighborhood levels
Civil society initiatives and local networks	Empower	Two-way, extensive, deep	Building users' and others' knowledge into the system	Too small, potentially high conflict	Users' associations, cooperation with neighborhood, environmental and other groups
Online engagement	Inform	Information	Offering up-to-the-minute, user-specific information	Superficial	Informational websites, plan-your-route, SMS texting of schedules for specific lines
Corporate social responsibility	Collaborate	Two-way, but tends to be paternalistic, hierarchical power relations	Community outreach, bridge building, greater understanding	PR, "greenwashing," no real change	Sponsorship car-free days, cycling Sunday routes, cycle parking, cycle taxis for users
Community engagement	Involve/collaborate	Short-term deliberation	Gain new insights into community issues and how to make BRT more relevant to needs, interests, aspirations	PR, no real change	Speaking at local fairs, services, meetings, events

Categories based on Giering 2011 and other sources. Classification based on IAP2 Spectrum of Public Participation: http://www.iap2.org.

When it comes to choosing between a bus-based system and rail, politicians and citizens alike tend to prefer surface and underground rail systems. Thus, being careful to frame a new BRT with a name and a set of associations relevant to the specific project and the lives of potential users is important.

BRT can learn from nonmotorized transport modes that have attracted powerful advocates in groups, movements, and among key planners and politicians who have organized to push these modes onto policy agendas and keep them there as banners for friendlier, more socially just, and sustainable cities. Enrique Peñalosa, the former mayor of Bogotá, has played this role in the case of BRT, but even in his home city efforts have flagged relative to other priorities in the face of recent political turnover and a lack of an engaged civil society that could offer continued support through the mercurial nature of politics.

As a rule of thumb, large-scale efforts will reach more people, but will impress them less. Small-scale efforts, especially ongoing work with a relatively small group of diverse but representative individuals, require more work, but can produce deep change.

10.5 Surveys

> *"USA Today has come out with a new survey—apparently, three out of every four people make up 75% of the population."*
>
> — David Letterman, former television host and comedian 1947 -

The process of identifying stakeholders should result in a long list of individuals and groups. There are a variety of ways to determine your stakeholder groups' positions. Reviewing discussion in local press, on public transport blogs, or on social media can be a good place to start, but any information gleaned that way should be confirmed with more direct outreach. The most common method is through the use of surveys. Surveys are a great way to initiate a dialogue with stakeholders that will continue throughout the public participation process outlined in this chapter.

Surveys are administered to a representative sample of the population and, if properly designed, will elicit answers that provide an overview of the group's attitudes, knowledge, or practices. Surveys are a qualitative instrument with quantitative properties: their results are numbers that can be examined through statistical analysis. They produce massive amounts of qualitative information (many peoples' opinions, fears, desires) using quantitative tools. For the data to be accurate, however, a large and representative sample of the population must be obtained.

Since the quality of any survey will determine the accuracy of the information it yields, working with a trained professional to design a survey is recommended. Local universities can be great resources for this.

Another consideration is determining which of the many options for survey dissemination to use. Methods include personal interviews, telephone or mail surveys, or surveys distributed in person, via e-mail, or on a website. Choice of survey method will depend on several factors, such as:

- Speed: E-mail and web page surveys are the fastest methods, followed by telephone interviewing. Mail surveys are the slowest;
- Cost: Personal interviews are the most expensive followed by telephone and then mail. E-mail and web surveys are the least expensive for large samples;
- Internet usage: Web and e-mail surveys offer significant advantages, but you may not be able to trust the data enough to generalize for the population as a whole;
- Literacy levels: Illiterate and less educated people tend not to respond to mail surveys;
- Sensitive questions: People are more likely to answer sensitive questions when interviewed directly by a computer in one form or another;
- Video, sound, and graphics: A need to get reactions to an image or sound limits your options to in person or online.

Source: Creative Research Systems advice for survey design—.

10.5.1 Public Forums

Public meetings, open houses, town halls, and hearings are examples of the most prevalent forms of public participation. Public forums can serve as "curtain raisers," places to present a lot of basic information about a new corridor or project, or changes in an existing system. They can also serve as "lightning rods," bringing out potential opposition, criticisms, and critics, and these forums can often become very contentious. In some countries, the law requires these kinds of meetings to discuss fare and service changes.

In a study by the Transport Research Board (TRB), public transport agencies heavily criticized these kinds of meetings, however, as "ineffective at engaging and interacting with the public, failing to attract sufficient numbers of participants, encouraging only the most vocal opponents of a project or plan to attend, ignoring the time and financial constraints that limit the public's ability to participate, and serving as an agency formality to meet legal requirements rather than an honest and open forum to gather meaningful input" (p. 15, Giering 2011).

These sentiments are supported by research that indicates that public forums on their own are not only largely unsuccessful at achieving genuine participation, but they can also have negative impact on the planning process for the reasons stated above. In addition, the often-negative tone of the events discourages so many people from attending that it is unlikely that officials are hearing from a representative sample of the public.

Some public transport agencies have tried to improve the effectiveness of these meetings by changing their venue and have found some success. By holding small public meetings at bus stops and stations, including creative visual and audiovisual elements, they have been able to reach out directly to riders who may not have otherwise attended a public forum.

Figure 10.10. Small group meetings are often more useful for gathering information from the public than a public forum, which can be an intimidating experience for some. *Image courtesy of ITDP.*

10.5.2 Small Group Meetings

There are other options for direct public participation that have often proved to be more useful than the standard public forum, and one of those is the small group meeting. Mechanisms that involve smaller groups of people, including focus groups, charettes, and workshops, allow for more discussion and interaction among stakeholders, target groups, agency staff, and officials.

Charettes and workshops involve a range of stakeholders coming together to review, assess, or make plans. Like focus groups, they provide a forum for ideas, but also offer the unique advantage of giving immediate feedback to the designer. Charettes typically consist of intense and possibly multiday meetings, involving small groups of municipal officials. A successful charette promotes joint ownership of solutions and attempts to defuse typical confrontational attitudes among project designer and end users.

Charettes require considerable preparation and good facilitation, but have become a popular way of finding win-win solutions and building strong networks and positive support for innovative initiatives.

Finding a representative group of participants—in terms of age, sex, socio-economic level, ethnic background, or religious background, for example—may be an initial challenge but is important to finding solutions that work for the broadest possible group of those affected. A participatory strategy could get more out of these resources by creating an ongoing panel and bringing it together regularly to discuss new ideas, problems, issues, and their potential solutions.

10.6 Focus Groups

> *"I believe in accessibility. I believe in honesty and a culture that supports that. And you can't have that if you're not open to receiving feedback."*
> — Mindy Grossman, CEO of the Home Shopping Network (HSN), 1958
> -

Focus groups can provide significant qualitative information quickly and in depth, based on a group discussion guided by an interviewer. A delicate science of complex interactions with ethical implications, focus groups should be facilitated by social science professionals to encourage full discussion among all participants, usually six to twelve people, and to provide useful data. A typical session lasts about two hours.

The main components to consider for any focus group, however, are:

- Participant selection: It is essential that participants be representative of the groups you are targeting with respect to ethnicity, age, income, and any other relevant factor in the local context;
- Rapport with group: It is important for whomever is guiding the discussion to establish a good rapport with the group, such that the group feels free to give their honest opinions on the topic;
- Mix of targeted and free questions: Participants should be guided toward providing the information needed, but also encouraged to speak freely, as they can introduce opinions and ideas that had not occurred to the group previously;
- Equality of attention: All individuals in a group should be heard. It is a good idea for moderators to give priority to those who have not spoken, to avoid a tendency for one or two outspoken individuals to dominate, or get into lengthy debates. Ground rules should be laid out in advance, explicitly to the whole group, and the group should acknowledge and accept them;

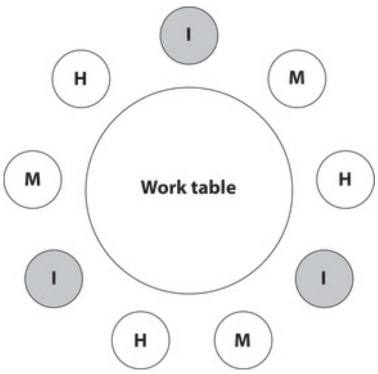

Figure 10.11. Fig.10.12Spatial setup of investigators and focus group participants (I = investigator, H = man, and M = woman). *Image courtesy of Lake Sagaris and Carlosfelipe Pardo.*

Figure 10.12. Focus groups should be held at a convenient and comfortable location for participants, such as this focus group held in a village in Jagatpur of the Chitwan District in Nepal. *Image courtesy of Save the Children, Image*

- Reports and conclusions: The focus group leader should provide an extensive data set on responses and analysis, including conclusions and suggestions for achieving communications goals;
- Knowledge of BRT: Ideally, the social science professionals involved should have experience with transport planning and know the specific BRT project well. Ideally, the team should include core project team members who have full and up-to-date information of the project;
- Horizontal process: It is also essential that any communications process be handled as a horizontal process, where there is no expectation or indication of powerful and powerless actors. That is, meetings should not be held in a way that emphasizes or creates a sense of "the knowledgeable versus the ignorant" or "powerful versus powerless." This includes such details as setup of tables, chairs, and in general an atmosphere of horizontality, with no differences in level between participants and group moderators.

10.6.1 Committees

A particular form of the small group meeting, which usually lasts and evolves over a much longer period, is the advisory committee made up of civic, private, and government representatives. Committees have become so relevant to public transport planning in the United States that the Transportation Research Board (TRB) commissioned a specific study of how they function (Hull 2010). Key lessons included:

- Clear expectations about committee roles and responsibilities contribute to an advisory committee's success;
- For committee membership, the need for representation of all viewpoints can be balanced with the need to maintain a manageable committee size;
- Agencies find value in the input provided by advisory committees and think of them as an indispensable part of the public involvement process;
- Many agencies employ professional public involvement staff to support committees and other outreach activities;
- Committee evaluation can lead to improved effectiveness (pp. 1-2, Hull 2010).

These committees may function at the regional or local level, on a project basis, or they may simply be standard practice for all aspects of public transport planning and operations, including monitoring contractor activities and financial incentives.

Training of members is an integral part of the process in most cases. Often a standing committee that functions at the regional level forms subcommittees to deal with specific projects. This permits greater precision, while still maintaining the panoramic view of the whole.

The TRB study identified several core characteristics of community-based advisory committees:

- Interest groups from the project study area are represented;
- Meetings are held regularly;
- Comments and participants' points of view are recorded;
- Consensus on issues is sought, but not required;
- The committee is assigned an important role in the process;
- Representatives truly represent users and are accountable to them.

Often, governments or agencies think first of selecting people they feel comfortable with, but this is usually counterproductive and can undermine the benefits of participation. One way of selecting people to encourage a more representative, accountable advisory committee is to have interested groups and organizations register with the organizing body. These groups then nominate potential committee members, and vote to select them. Typically, highly respected individuals or organizations

Figure 10.13. Fig. 10.14Dar es Salaam BRT project team leaders discuss the proposed DART BRT system with an association of Daladala owners. *Image courtesy of ITDP.*

win many of these slots, as they would probably do in a situation where the authority selects them, but a vote-based system increases the legitimacy and therefore the credibility of advisory committee members.

The most effective committee representatives not only attend meetings and offer their opinions, but they also take what they have learned back to their community, group, or broader constituency for discussion and additional input. This helps spread the learning acquired through expanding networks of people and also expands the catchment area of the data/feedback received through participation. Clear articulation of their roles and good training can ensure that this happens.

Having participants who genuinely represent functioning organizations also improves results. Many neighborhood associations or federations have their own publications, for example, that can spread the word about new BRT programs more effectively than can an individual.

These kinds of participants function as information transmitters. They tend to be gatekeepers for particular communities: when they agree and support a policy, their credibility, won through years of work and immediacy, can greatly enhance acceptance throughout an entire territory

Advisory committees must have demonstrable impact on BRT decision making. It is no good trying to win women cyclists' support for BRT, for example, if suggestions to include cycle parking at key stations or permit cycles on vehicles during off-peak hours are never formally integrated into projects. If committee members see integration of at least some of the ideas they put forth, they are more likely to believe in and support the participatory process.

10.6.2 Civil Society Organizations

Building civil society organizations is a complex task that largely falls outside the mandate of BRT initiatives. Nonetheless, it can be the single most relevant factor in generating strong political support for an existing or new BRT system. BRT initiators should learn as much as possible about the civil society environment in which their projects are located and make an effort to ensure that their project is functioning optimally.

In practical terms, this means ensuring solid communication, especially with neighborhood or other citizens' organizations, providing training to improve the knowledge of BRT, and planning charettes or other kinds of activities that effectively integrate proposals for improvements. Incorporating skilled citizen representatives (neighborhood leaders familiar with the various issues surrounding BRT) can greatly enhance effectiveness and build a sense of mutual respect and solidarity among different system players who might otherwise generate considerable friction.

Civil society representatives should be included in advisory committees of the BRT agencies, if they exist, and should also be involved in additional activities, such as visiting other BRT systems around the globe. One of the ways that cities and countries have found to do this with regard to other sustainable transport modes, particularly walking and cycling, is to earmark funds that encourage civil society development in general and/or specifically for neighborhood associations. These funds enable NGOs to develop studies, training, education, and other programs; to support corporate social responsibility initiatives; and to coordinate with other funders to make focus on transport-related issues part of the criteria for awarding funds.

10.6.3 Engaging Local Networks

While the above processes all offer opportunities for interested members of the public to engage with the planning process, having a truly representative public participation process also requires proactively endeavoring to meet people where they live, work, and play.

Proactive or collaborative engagement can take many forms: attending festivals, farmers markets, local fairs, flea markets, or other special events; speaking at community organizations, resident or business associations, or clubs; engaging the public at public transport centers, malls, and other gathering places; canvassing neighborhoods; engaging elected officials; or partnering with other agencies, organizations, institutions, or places of worship. The concept is to take the message of the agency directly to the public and broaden the number and diversity of people reached by using established local communication and support networks. This type of engagement offers agencies the chance to interact directly with their customers, learn about neighborhoods, and build relationships for future outreach.

One example of proactive engagement that has been particularly useful in other planning processes and before the system has been launched involves installing a prototype station in areas of heavy pedestrian traffic. This allows users to familiarize themselves with the BRT concept in advance and also generates excitement for the new system. In Ahmedabad, India, the city built a sample station a year before operations began on the Janmarg BRT. The prototype allowed the city to showcase the station design and help educate the public about how it would operate. At the same time, the prototype allowed the city to test and tweak certain design elements.

In Bogotá, the city used a program known as "Mission Bogotá" to reach out directly to members of the public. The city trained and employed more than three hundred young people from low-income communities as "ambassadors" for the proposed system. The campaign began six months before the city's BRT TransMilenio started up and took place mainly at bus stations and on board regular buses, along with civic gathering places and local schools. The outreach team of Mission Bogotá would discuss the project directly with the public and personally answer any questions or concerns. Many cities now use these techniques to impart transport information in a friendly, lighthearted manner.

Online Engagement

Public transport agencies have embraced the Internet as a means of communication with the public since the 1990s. Internet-based communication can be broken down into two phases. The initial phase was dominated by one-way communication, where agency websites were geared primarily toward marketing their services online, much like an online brochure. These websites allowed customers to retrieve information such as maps, schedules, guides, and fare information, but provided little opportunity for interactivity (Morris et al., 2010). Today, websites are more interactive. Project websites routinely offer customers the ability to submit comments. In some cases these comments are shared on a discussion board or blog. For its 2035 long-range plan update, the Virginia, USA, DOT developed a web-based workshop to mirror the information and interactive opportunities available at its in-person meetings held throughout the state. The convenience afforded by the Internet in allowing users to participate from the location and time of their choosing helped push online participation above the total combined participation at all of the in-person meetings (VTrans2035).

Box 10.1. Example: Showcasing Janmarg

Figure 10.14. Janmarg BRT station in Ahmedabad, India. *Image courtesy of ITDP.*

The Ahmedabad, India, Janmarg BRT was very successful with proactive engagement in the lead-up to the launch of the system in 2010. The Janmarg communications team took advantage of many options to showcase the system by developing and displaying prototypes and offering free trial rides over an extended period of time. This made it easy for people to become familiar with how to use the system. It also alerted systems planners to user-interface problems, giving them a chance to resolve these issues before customers started paying for their rides, thereby heading off many potential public relations problems before they began.

The rise of social media tools and mobile phone and tablet applications offers a host of options for multi-directional communications, reaching people in their preferred way of receiving and interacting with information.

Many public transport providers have discovered the benefits that social media offers for public participation. It also allows direct communication in real-time and unfiltered by the media, which can help foster an interactive dialogue with the public (Eirikis and Eirikis 2010). Social media can provide an easy and accessible forum for public participation, but it should be used to supplement, rather than replace, other more personal options for participation. Although it may be easy to solicit feedback on Twitter, the responses you receive are very unlikely to represent an accurate sample of your population. (See more about social media in Chapter 9: Strategic Planning for Communications.)

10.7 Measuring Success: Process vs. Outcomes

"Failure is the condiment that gives success its flavor."

— Truman Capote, writer, 1924 - 1984

As with communications planning (see Chapter 9: Strategic Planning for Communications), it is important to define what a successful public participation program will look like as you plan your outreach. There are no consistent methods for defining success in a public participation process for BRT, although there are both quantitative and qualitative methods available for evaluating public involvement. The threshold that defines "success" is dependent on the complex mix of variables including the size, reach, and level of controversy surrounding a given project, the resources available for a project from the organization, the community in question, and the overall intent of the public participation effort.

Criteria for measurement are set by the goals and objectives of the project. While measuring things like numbers of meetings and participants is relatively straightforward, outcomes are more complex to quantify. The International Association for Public Participation offers guidelines for evaluating participatory processes. Basic criteria regarding the process of participation includes whether:

- The public had access to appropriate resources and clear information to allow them to meaningfully participate;
- The purpose of the participation tasks were clearly defined;
- The decision-making process was structured appropriately to allow for and incorporate public input;
- Efforts were cost-effective;
- Views were diverse and representative.

Measuring success of outcomes is trickier to quantify because of the diversity of preferred results. For example, an agency might consider public support or ease of implementation as an appropriate outcome, while the public might consider the extent to which the community can achieve its goals or block decisions as better measures of success. Outcome-based success measures can include:

- Project or decision acceptability;
- Project efficiency;
- Cost avoidance;
- Mutual learning and respect;
- Improved understanding;
- The amount of conflict resolution required;
- The degree of consensus achieved;
- Influence on decision making;
- Participant satisfaction with the results of the process.

Preestablished metrics, including performance indicators, benchmarks, and performance standards, set beforehand and based on key project goals, can help gain upfront agreement on what to measure. These metrics can also be integrated into the project plans. Regardless of the evaluation method used, it is essential to keep evaluation in mind as part of public participation planning from the outset. While some approaches will be more fruitful than others, clearly delineating expectations at the beginning will help determine what needs to be changed as the project develops, and what you can do differently in the future. Public participation, if managed properly, is a gold mine of information and a source of knowledge that cannot be achieved in any other way.

11. The Case for Marketing and Customer Service

> *"We're obviously going to spend a lot in marketing because we think the product sells itself."*
>
> — James Allchin, former Microsoft executive, 1951 -

Marketing is a broad term that encompasses everything from branding and market research to public relations and advertising. It is difficult to overstate the critical role that marketing and customer service play for BRT, given the often-negative image of bus-based public transport in some cities around the world. Just as with communications planning and public participation, marketing is sometimes seen as an add-on, rather than a core function, of the BRT plan. In reality, marketing and customer service make up a BRT system's public image. The first impression that most people will have of your system, whether or not they are users, depends on how well you position and promote your system's brand. Good public transport is a hallmark of a world-class city, and a positive image of a system can spur economic development, revitalize neighborhoods, and improve quality of life. A better public image attracts riders and investors, increasing the likelihood of service expansions and improvements. A good marketing campaign demonstrates professionalism and modernity, and will not only "sell" the new service, but will also help instill pride in it and, by extension, in the host city. This chapter will review some basic components of branding, marketing, and customer service for a BRT system. The first section covers branding, from logo to typeface to uniforms to communicating a brand. The second section then reviews ways to reinforce and market that brand with taglines, messaging, and a summary of the outreach steps outlined in the previous chapters. The third section focuses on customer service, which is the service portion or "face" of a marketing plan. Good customer service will elevate a brand, while poor customer service will undermine it.

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11.1 Branding

> *"Make it simple. Make it memorable. Make it inviting to look at. Make it fun."*
>
> — Leo Burnett, advertising executive, 1891-1971

There are many definitions of branding. Like marketing, it is a broad term. Marty Neumeier, marketing expert and author of The Brand Gap, describes an organization's brand as "a person's gut feeling about a product, service, or company." A strong, coherent brand can showcase a BRT system as modern, efficient, rapid, reliable, convenient, comfortable, and safe. It should also incorporate positive local values, best determined by extensive market research.

A system's branding, that is, name, logo, and tagline, should be crafted with great care by a professional marketing firm. They constitute the basic building blocks of the brand. However, a brand is more than simply graphics: the constituent parts of the BRT service, from the vehicles and livery, the BRT terminal, the stations and stops, the signage, to the uniforms, the messages, and the communications, are integral elements of the brand. These should create a recognizable, seamless, and cohesive statement about the BRT, expressing three interrelated themes:

- A clear and comprehensible presentation;
- A symbol of the service;
- The values of the service.

On a functional level, the brand must also be:

- Distinctive;

- Recognizable;
- Transferable across different media;
- Reflective of the local area;
- Enduring.

Durability of the brand is an important quality, particularly if it is taxpayers who are funding the program. Design solutions that are too contemporary or ephemeral run the risk of becoming outdated, and while all brands need refreshing in time, re-branding too often, such as every few years, is counterproductive to the entire point of a brand, which should be a consistent symbol. While there are plenty of branding examples to look to in everyday life, it is important to remember that what is acceptable in the commercial arena is not necessarily appropriate in the public sector, and what might be clever and witty today may quickly become stale.

There are generally five stages to developing a brand:

- The brief: This is a document produced by a requesting party to be used by such as advertising agencies to produce a visual design, a promotional video, advertising copy, a web site for promotion via the Internet, or other collateral and physical materials;
- Concept and research: The concept is the elemental visual realization of the brief's objectives, the logo, colors, typography, that is, informed and verified by customer and peer research;
- Design development and research: Having established the concept, it is then developed to ensure it can be physically applied to the services media and infrastructure. Any evolutions of the concept need to be reviewed to ensure that it remains true to its original values;
- Consolidating the brand architecture: This stage is primarily to bring together the various elements generated in the design development into a single resource; often referred to as a "Design Guide" or "Brand Guidelines" for use both internally and by third parties responsible for applying the brand;
- Implementation: With the guidelines in place the brand can be physically applied to the various media channels and infrastructure, that is, website, print, communications, liveries, and stops, etc.

Source: http://www.businessdictionary.com/definition/creative-brief.html

There are, of course, varied approaches to creating a brand, but these elements are fairly universal.

11.2 The Branding Brief

> *"You now have to decide what 'image' you want for your brand. Image means personality. Products, like people, have personalities, and they can make or break them in the market place."*
>
> — David Ogilvy, advertising executive, 1911–1999

The brief sets the agenda for the brand and subsequently informs the creative process. The brief's author will, of course, vary according to ownership structures and other factors; but whomever the responsibility falls to should ensure that the brief is developed using a collaborative process. Creating the brief offers the chance to build consensus among the stakeholders about the goals and purpose of the service and the message that the brand needs to convey. A collaborative process will also help develop allies in enforcing the brand during implementation. Finally, the brief must provide a clear guide to the graphic designer, copywriter, and other creative professionals who will use this as a road map to develop the brand elements.

Figure 11.1. Fig. 11.1The Janmarg BRT in Ahmedabad, India, is branded as "the people's way," which gives the system an inclusive feel. *Image courtesy of Meena Kadri, Flickr.*

When composing the BRT brief it is vital to keep in mind that BRT differs from most commercial brands in that BRT is a universal offering: it should appeal to the old, young, rich, poor, able-bodied, and disabled. There may be situations where it is beneficial to appeal to a target group—for example, low-income commuters—but it can be done in a way that is still appealing to a larger constituency. For example, in Ahmedabad, India, the Janmarg BRT was branded as "the people's way." This makes it clear to low-income groups that they are welcome, that this is a system for them, but is general enough to appeal to the majority of residents.

Briefs can vary in levels of prescription in terms of how much has been predefined through either the stakeholder consultation or the visual proximity the service should have with other transport modes. The system may perhaps be completely new in an area where there has historically been little or no public transport in the conventional sense, or it may be a new mode as part of a mature and highly developed network.

11.2.1 The Elements of a Creative Brief

A creative brief is a document created through initial meetings, interviews, and discussions with BRT system officials and designers, and it is informed by stakeholder research. When developing a brief, less is more. This is a simple, clear, and concise document that only needs to contain the essential details. A good creative brief should answer the following key questions:

- What is the project?
- Who is it for?
- Why are we doing it? What needs to be done? By whom? By when?
- Where and how will it be used?

Too much information can be confusing, interpreted differently, and can set the team on the wrong path, wasting time and money. Instead, focus on defining and articulating the basics:

- The situation: What is the context? What concerns need to be addressed? Do a SWOT (strengths, weaknesses, opportunities, and threats) analysis;
- The objective: What are you trying to accomplish with this?
- The audience: Who is the audience and why should they care? Which target groups and stakeholders should be prioritized?
- The core idea: What is your brand's promise or values that address the needs of your audience?
- The strategy and messages: How can you explain what you are offering in a way to which your audience will respond?
- The tactics: What tactics will best support sharing the core idea and strategy?
- The creative tone: What is your brand's personality? What values should it convey?
- The budget: This determines the strategy and options for dissemination;
- The time line: Set a realistic time frame to develop, refine, test, and launch the brand.

Source: http://lrxd.com/blog/how-to-successfully-position-a-brand-the-essentials-of-a-creative-brief.

It is important to include input from both the planning team and stakeholder research in the brief. If the design and service standards across a system are both high, the customers will respond. However, it is important to remember that even great branding cannot mask poor service.

11.3 Concept and Research

"Business has only two functions—marketing and innovation."

— Peter Drucker, writer and consultant, 1909-2005

Customer research is an important part of the process, and it should be aligned with the public participation process discussed in Chapter 9: Strategic Planning for Communications and Chapter 10: Public Participation. As with the design process, there are many different methodologies as to how and when market research should be used. Perhaps the most important thing to bear in mind is that research should be used to inform the design process—not dictate it. The makeup of this working group usually involves someone from the client side, marketing, and operations. Where there is no in-house expertise, the professional advisers are sometimes advertising and PR agencies or design and branding consultancies.

This process will generate a long list of potential ideas. These should be reduced to three to five "contenders." These contenders are then used as the basis for the initial design concepts that explore logos, colors, and typography and sample applications of these. These concepts are then tested on focus groups representative of the target markets. From these groups, a consensus should emerge as to what is the most preferable direction for further development.

An early understanding and identification of who to involve in the branding process is key. Chapter 9: Strategic Planning for Communications takes a detailed look at stakeholder identification, but the following groupings are typical:

- Politicians;
- Planners;
- Transport user groups;
- Disability groups;
- Civil societies;
- Chambers of commerce;
- Customers, that is, women, men, parents and children, mobility impaired, car users, students, commuters;
- Planning and development authorities (where there are environmental and infrastructure considerations).

With these thoughts in mind, we can look at the brand's building blocks in more detail.

11.3.1 Naming

In the case of BRT, some systems, such as TransMilenio, have moved away from the conventional bus mode, dispensing with the word bus altogether. However, some, such as Brisbane, Australia, and its "busway" have demonstrated that it is possible to have a well-executed generic solution.

The word bus is, after all, part of the lingua franca of transportation along with other words such as trans, express, metro, line, and so on. Coupling these words with a place can turn the generic into the local. This is particularly pertinent to systems that expect high numbers of foreign visitors.

There are many different categories from which a brand name can be derived, but they tend to fall into one of five categories and can be generic, local, or abstract. This is best demonstrated by using airlines as examples:

Figure 11.2. The Busway BRT in Brisbane, Australia, embraces the bus name, as some cities choose to move away from it in branding their BRT systems. *Photo courtesy of Neal Jennings, Flickr.*

Figure 11.3. In London, the descriptive approach can be seen with Transport for London (TFL) buses and the London Underground. *Photo courtesy of ITDP.*

- Descriptive: British Airways (the airline of the United Kingdom);
- Abbreviated: Pan Am (short for Pan American);
- Initials or acronym: Qantas (Queensland and Northern Territory Aerial Services);
- A made-up name: Allegiant (a low-cost, US-based carrier);
- An analogy: Garuda (mighty Garuda is the lord of the birds in Indonesian mythology).

Figure 11.4. A great example of the analogy can be found in Orlando, Florida, USA with the LYNX bus system where routes are referred to as links, an effective play on the words links and lynx and the system uses the memorable paw print logo. *Photo courtesy of gillphoto, Flickr.*

Figure 11.5. Acronyms can be either generic or local. The Las Vegas MAX (Metropolitan Area Express) is a good example of first finding the word you want, and then creating the acronym. *Photo courtesy of ITDP.*

Other acronyms may appear to be less exciting, but it is more important that they be aligned with their context. Curitiba, Brazil, for example, is not Las Vegas, and its Rede Integrada de Transporte (RIT) name should not be discounted because it is not perceived to be a "fun" or "exciting" brand. The high design standards and quality of the Curitiba system tell people much more than the name ever will. If the service delivers what people want, creative and adventurous advertising campaigns can be built around the brand to communicate with different target markets across multi-media platforms. RIT works because the name RIT is associated with an excellently conceived and executed system, and so in many ways the name has less importance attached to it.

Figure 11.6. Curitiba, Brazil is the birthplace of BRT. *Photo courtesy of ITDP.*

The greatest name in the world will quickly become tarnished and ridiculed if the service it represents is poor or promises more than can realistically be delivered.

Another good example of an abbreviated brand name is NWM, Network West Midlands, the public transport brand of Centro, the West Midlands Passenger Transport Executive (PTE) in the United Kingdom. A BRT system is currently being considered for integration into the NWM for the area and an icon will subsequently be developed as a part of the NWM branding.

Figure 11.7. An interesting example of a made up name can be seen in Cleveland, Ohio where the BRT is sponsored by the Cleveland Clinic and University Hospital and is called the "HealthLine." Here there is a synergy between health care providers and the positioning of the BRT as a greener, and therefore healthier, way to travel. *Photo courtesy of ITDP.*

11.3.2 The Logo

The logo is the most recognizable piece of branding. A logo can be a symbol, a word or words known as a logotype, or a combination of both. Logos can be, but do not have to be, literal interpretations or representations of what they represent. Although commercially the majority of logos are abstract, in the public realm it often makes the most sense to stick with the principle of simplicity. Since BRT is a service for the public supported by taxes, rather than an optional product, its symbol should be easy to understand.

Basically, a good logo must be:

- Simple;
- Memorable;
- Timeless;
- Versatile;
- Appropriate.

Some of the most recognizable BRT logos are shown in Figures 11.8 through 11.11.

11.3.3 Colors and Typography

Although it may seem like a minor decision, advertising research tells us that color influences brand recognition by up to 80 percent; it also tells us that people will make a subconscious judgment within ninety seconds, and the first thing they notice is color. Colors influence public receptiveness to the system as well as reinforce the system's meaning to the community. There are, however, practical considerations to be taken into account with BRT, such as climate in relation to livery (or uniform insignia), for example. The livery is a vital part of the brand and an important touchstone, so weather conditions and cleaning measures will influence appropriate colors. Therefore, the colors used within the logo and the physical system should be carefully considered for both practical and promotional uses.

Figure 11.12. The BRT in Lima uses orange and green to stand out from other transport in the city. *Image courtesy of Fundación Ciudad Humana.*

Figure 11.8. Logo for Transjakarta BRT. *Image courtesy of Transjakarta*

Figure 11.9. Logo for Transmilenio BRT. *Image courtesy of TransMilenio.*

Figure 11.10. Logo for Guangzhou BRT *Image courtesy of Guangzhou BRT.*

Figure 11.11. Logo for Janmarg BRT. *Image courtesy of Janmarg.*

Figure 11.13. The BRT running from Pune to Pimpri-Chinchwad in India has the name "Rainbow." This is a great example of assigning a made-up name with positive associations locally and allows for colorful and positive branding. This logo and typeface works well both in English and Sanskrit. *Photo courtesy of PMPML.*

Once selected, the color scheme should be applied consistently across different media, understanding that print colors such as Pantone do not always have matching colors in, say, powder coating systems where RAL colors—a standardized set of colors used in Europe—are prevalent, and the colors you see on a computer screen are not the same colors you see in print.

In choosing colors the design team should review literature on color theory (for example, http://www.colorcom.com/research/consumer-color-preferences). The use of color, particularly in branding, is a well-studied science, which has proven that different colors produce different reactions. For example, yellow and orange and some variations of red have been shown to make people hungry, which is why most fast food chains, such as McDonalds and KFC, have chosen colors from this spectrum. As with all elements of branding, however, local context and culture are important, so ensure that any use of color theory is backed up with local expertise.

Given the broad constituency BRT systems need to reach, including different languages and levels of literacy, typography also should be applied with the same principle of simplicity and universal appeal.

Font type, size, color, and background all need to be taken into account. Generally speaking, sans serif and lowercase fonts are more legible, and color contrast is also important. However, this also depends on the local language context.

Figure 11.14. Mexico City's Metrobús. *Image courtesy of Hook89, Wikimedia Commons.*

In some cases, research may show that a hyper-local approach, using the local language primarily, will work best. In others, and increasingly common in world cities, using English in place of, or in addition to, a local language can give the system a more modern and international look and feel.

The image (colors, logo, and typography) for Mexico City's Metrobús is an example of an inclusive and integrating brand. It was important to the city to establish a strong statement of the project, since there was initial social resistance to it, from former operators and public transport users alike. The color red, the simple solid logo, and the clean type supported the idea of an energetic, modern, and efficient mode of transportation. Since the system was competing with microbuses, which were not nearly as attractive, having this strong image helped the city promote Metrobús as a serious, professional product.

11.3.4 Core Communications: The Route Map

The most practical and essential element of the overall visual communications package is the route map. As previously discussed, visual renderings and station prototypes of a new system are a standard part of any marketing efforts. Sophisticated renderings of a system can do much to stimulate public enthusiasm for the project. In addition, simulation videos that highlight current problems with the transportation system, followed by a visual portrayal of the future system, can also be an effective marketing tool.

Regardless of the complexity of the route or routes, the route map should strictly adhere to the brand guidelines in terms of presentation, color, and typography.

Figure 11.15. The TransJakarta route map is an example of a complex system that is streamlined by a route map encompassing the logo, system colors, and typography to maintain consistent branding. *Photo courtesy of TransJakarta.*

Figure 11.16. The system map for the Metrovía system in Guayaquil, Ecuador, shows a more detailed version of the BRT line. *Photo courtesy of Lloyd Wright.*

The route map can be a stand-alone piece of collateral and can be assimilated into a network map comprising other modes. In the latter case, it is likely that the visual parameters will be determined by the structure of the network.

11.3.5 Core Communications: Wayfinding

Another key component is signage and wayfinding. Particularly in a dense city center with other transport, good signage can be essential in increasing and keeping your ridership high. This is particularly important for visitors, who, depending on your fare structure, may pay more to ride the BRT than do local residents.

Figure 11.19. Transport for London is well-known for its effective wayfinding in a complex and sprawling city. *Photo courtesy of TheIntrepidTraveller, Wikimedia Commons.*

TFL's four design rules for their interchanges offer guidance for other systems and are good governing principles for all user-information systems:

- Efficiency: Place user information at decision points where pedestrians can easily read it without obstructing the movement of others;
- Usability: The design and placement of signage, maps, kiosks, and ticket machines should make the public transport system easy to use for all customers, including people with limited mobility. Information should be illuminated at night;

Figure 11.17. Large and well-placed signage helps customers find the public transport they are looking for quickly in this Nagoya, Japan, multimodal terminal. *Image courtesy of Lloyd Wright.*

Figure 11.18. Signage in a station in Quito provides clear guidance to customers. *Photo courtesy of Lloyd Wright.*

- Understanding: Facilitate navigation and movement by designing information systems that are intuitive for all users and well placed. Post signage and information where customers need it;
- Quality: Use high-quality and well-designed materials to help improve the user experience and enhance a public transport system's values of modernity, cleanliness, and quality. Wherever possible, use vandal-proof material.

11.3.6 Core Communications: Livery

Livery is an integral part of the brand architecture and one of its most visible manifestations. It is the common design scheme or identity a company uses on its vehicles and uniforms. Livery is more than simply how the vehicle is wrapped or painted, it is also the interior design, the driver's uniform, and it can appear on many other branded pieces. Liveries should be used to convey the overriding brand values of the BRT system. For example, the main attribute might be speed, safety, local, premium, or generic, depending on the needs and expectations of the local context.

Figure 11.20. Advertising can be a significant revenue stream and can take many forms, from complete wraps to partial wraps and hoardings. *Photo courtesy of Strauss of Orlando LYNX.*

There are a number of factors to consider when designing a livery, such as consistency with the branding, vehicle design, climate, and advertising. The livery should, whenever possible, follow the brand color and carry the logo and any tagline. Where vehicles can be dedicated to a particular route, the inclusion of a visible route map or list of key destinations can be a powerful way of promoting the service.

Often a color-coding system is used to brand and differentiate routes or "lines." While this is helpful to the customer, there is a trade-off; it may limit the flexibility of both the public and contracted fleets to operate on different lines as needed.

Figure 11.21. Visual clutter from hanging advertisements in Japanese rail systems can hamper the customer's ability see other information, such as system maps, as well as reduce outside visibility. *Photo courtesy of Lloyd Wright.*

Climate and weather can also play an important part in the livery design. In a hot and dusty environment, the vehicles may quickly become discolored. This is obviously unavoidable, but if it is the prevalent condition then a distinctive livery can mitigate the effect (as can a routine cleaning and maintenance program).

The vehicle and its design will dictate the livery parameters to a large extent. Today's vehicles have large areas of glass all around, usually with solar control that darkens the overall appearance of the vehicle. Many vehicles are now using perforated vinyl that allows advertising and branding over windows, but this limits visibility, and safety issues should be well reviewed.

In other transport modes, accessibility is highly regulated in terms of livery, particularly around the visibility of doors. Designers often like to have minimal visual interruption to their liveries. However, greater accessibility is a goal that all operators must aspire to and the challenge is to create a design that works for everyone.

Figure 11.22. An example of how uniforms can reflect the "personality" of the brand: In Japan, the Keihan railways system reflects a professional and formal branding. *Image courtesy of Keihan Railways*

Advertising can be a source of much-needed revenue for BRT systems, but careful consideration must be given to the amount of advertising a vehicle can reasonably handle. The more of the services "real estate" that is given over to someone else's brand, the more it undermines your own. If advertising is a critical part of the business plan, it is advisable to look for products or organizations that align with the system's own brand values. Some transport systems, such as the MTA New York City Transit, offer discounts to advertisers whose ads are transport-themed and adhere to MTA branding guidelines.

Uniforms

Uniforms, a component of livery, are an important part of the brand and communicate a great deal to your customers and potential customers about the people and the business behind the service. While the uniform is an effective advertisement for the BRT and helps build the brand, it also enables employees to feel part of a unified, professional team.

Figure 11.23. An example of how uniforms can reflect the "personality" of the brand: In Bogotá, TransMilenio staff are casual and approachable. Each reflects the intended personality of their respective brands. *Image courtesy of Lloyd Wright.*

As with all elements that combine to make a brand identity, uniform design should take into account the following questions:

- How will the uniforms reflect the personality and values of the brand?
- Should the uniforms reflect local or national traditional forms of dress or should the forms be purely “international”?
- What are the climactic working conditions for the range of jobs and activities, including those who spend more time outside than in, vice versa, or both? What fabrics make sense?
- What is the age range of the staff across gender?
- What are the trade union requirements?

Compare a polo shirt to a “military” style shirt. If an airplane pilot turned up in a baseball cap and polo shirt, one might question the seriousness and professionalism of the airline. A bus driver is just as responsible for safety as a pilot; but a BRT system may want to convey a friendlier face, as the driver is generally more accessible to customers than is a pilot. Station attendants or customer service representatives, likewise, may want a casual look that will make them more easily approachable, especially since their jobs require more freedom of movement.

Cultural and social conditions will also influence what makes for the most appropriate uniforms for your particular service. For example, in an urban service, security may be an overriding issue so it may be appropriate to feature military styling to convey a sense of authority. In a relaxed, leisure-oriented location, a more casual uniform might be more effective branding.

11.3.7 Copyright

Trademarks and copyrights should protect the new system’s image, brand name, logo, and tagline, as they will be important assets for the system. The copyright should be held by the public authority and not by any of the related private sector firms, such as the vehicle operating companies or the marketing firms.

A successful system will likely generate some imitation. For example, various businesses in Bogotá have adapted the name of TransMilenio in order to cash in on the system’s success. Within a week of opening the Metrovía system in Guayaquil, Ecuador, businesses started expropriating the system name. As is often said, imitation is a form of flattery, and this is particularly the case for a city service.

Figure 11.24. When the Guayaquil Metrovía system opened, the “Metrovía Delicatessen” followed. Using the system name for commercial purposes should be a concern for authorities, who should seek copyright protection for the system name to ensure that branding guidelines are followed. Photo *Lloyd Wright*.

Others will only try to expropriate the system’s name if the name is perceived to have substantial value. To some extent, small-time borrowing of the system name should not be a significant concern, and in fact, can aid in marketing the system. However, if an outside firm is making a significant gain from the use of the name or image, or if the outside usage of the name or image could lead to a degradation of the system’s public image, then legal action should be considered on a case-by-case basis.

Illegal borrowing of the name or image can be a particular concern with merchandising. As noted in Chapter 17: Financing, merchandising T-shirts, toy vehicles, and other items with the system name and logo can be a modest source of system revenue. If private companies take the lead in doing this type of merchandising, then the system forfeits revenue. In Bogotá, at first, street vendors sold many TransMilenio toy vehicles until TransMilenio itself took action to intercede and finally begin merchandising efforts itself.

Joint marketing efforts with corporate or other organizational partnerships can be an effective way to broaden the reach of the system’s message. For example, the favorable response to the TransMilenio system and its positive image among the general public attracted a lot of requests for sponsorship and co-marketing from the business community. A prestigious bank, for instance, offered a generous advertising budget to promote the system in exchange for permission to display its support for landmark ventures like TransMilenio in its official logo.

11.4 Design Development: Feedback and Adjustments

> *"The business of the advertiser is to see that we go about our business with some magic spell or tune or slogan throbbing quietly in the background of our minds."*
>
> — Marshall McLuhan, philosopher and public intellectual, 1911 - 1980

Once the concept and core communications have been developed, they will need to be reviewed, fine-tuned, and tested. This is the time to go back to the stakeholders and target groups that were previously engaged in the process to solicit their feedback. This is also the time to present options for adjustment to the project group to review and approve.

It is important to remember that feedback loops are part of the process. A negative reaction to a logo or color scheme should not be seen as a failure, but rather as an opportunity to create a better brand that better suits your audience. It is also an opportunity to ensure that your brand has remained true to the original values set forth in the branding brief.

Once there has been a consensus on the brand that has been tested and approved, you can move on to bolstering your brand with complementary messaging, targeting your audiences, and preparing for implementation.

11.4.1 System Tagline/Slogan

Figure 11.25. The marketing announcement for the Orange Line BRT in Los Angeles highlights the time-saving aspect of the service. *Image courtesy of Los Angeles County Metropolitan Transit Authority*

Figure 11.26. The public transport system of Ottawa, Ontario, Canada focuses on the universal use of the system for all your public transport needs. *Image courtesy of OC Transpo*

Creating public recognition of the system can be bolstered by a slogan or tagline that accompanies the name and logo. The message from such a slogan may highlight an aspect of the system that is of particular value to the targeted audience. For example, the message may stress the time-saving aspects, the level of convenience and comfort, or the modernity of the system. Above all, the slogan should be inspirational in motivating customer usage of the system. Some sample BRT slogans:

- Rapid transit for everyone;
- The fastest way around the city;
- Relax and leave the driving to us;
- Not just another bus;
- Wherever life takes you;
- Connecting people to life;
- When you need to get there;
- The easy way to work;
- Never sit in traffic again.

Not every system has a tagline, but when used, taglines should be visually integrated into the design sometimes as part of the logo, sometimes independently, in the same way as the logo, name, and livery.

11.4.2 Market Segmentation

The market segmentation process will be informed by the stakeholder analysis (see Chapter 9: Strategic Planning for Communications) and the communications team will develop messages as well as devise strategies and tactics for reaching individual audiences. Determining what messages and modes of transmitting them will appeal to which group is the key challenge for and job of the communications team, as described in Chapter 9.

Table 11.1. Potential Marketing Messages for Market Segments

Market Segment	Potential Messages
Students	• Availability of student discounts • Mobile phone payment and apps • Social atmosphere of system • Independence

Parents	• Security and safety for children • Cost-effectiveness of system • Off-peak services that cater to errands • Young children enjoy riding the bus
Professionals	• Work or relax while commuting • Travel time savings • Technological aspects of the new system • High-quality image/status of the new system • Comfort and convenience
Existing Public Transport Users	• Improvement in system quality and information • Increased time savings • Higher frequency of service
People with Disabilities	• Accessibility of the new system • Helpful and courteous staff

Marketing techniques have increasingly drawn on psychology as a basis for understanding personal decision-making processes. It is one thing to simply inform a person of a new public transport option, and it is quite another to convince people to change their behavior to use the system for the first time or to interact differently with this public transport system if they have used it previously. In the case of a BRT replacing an informal bus network, for example, intensive outreach is vital to educate customers on how to use the new system, and to explain to them how it will improve their quality of life.

An individual may undergo many stages of realization before moving from awareness of a new transport option to actually trying out the new system. It may take further conditioning and persuasion to move the person to a long-term commitment to a new form of mobility.

It is important to account for existing brands in a city or country when designing a brand so as to avoid unintended conflicts or unwelcome associations. If the brand of a new public transport line or system embodies local values and context, potential riders will be more likely to relate to it.

Box 11.1. Example: Metro Orange Line: It Beats the 101

Figure 11.27. Orange Line vehicle. *Image courtesy of ITDP.*

Through a unified brand and clear messaging, Los Angeles Metro has proved that it can capture the attention of riders in the most style-conscious of cities. The team employed several taglines in the launch of the Orange Line BRT that informed users about the new service, as it was the first BRT in the state. The taglines were locally focused, referencing congested Highway 101, for example ("the valley's new shortcut"), and referencing their market research, in which they determined that a barrier to using the BRT was that people's experiences on crowded buses made them think they would not find seating.

11.5 Consolidating the Brand Architecture

> *"No matter what your product is, you are ultimately in the education business. Your customers need to be constantly educated about the many advantages of doing business with you, trained to use your products more effectively, and taught how to make never-ending improvement in their lives."*
>
> — Robert G Allen, investment advisor, 1948-

Once you have finished the arduous process of brand development and approval, it is essential to document and consolidate the various elements generated by your brand process into a single resource, often referred to as a design or branding guide.

Figure 11.28. This page from the Transport for London branding guidelines shows an example of an ad and some of the various versions of the logo to indicate different lines or modes of public transport. *Image courtesy of Transport for London.*

This document essentially reflects everything someone representing the brand needs to know. Although there are specificities to different systems, most branding guidelines for public transport systems include the following:

- Basic elements: This is your logo and symbols in all the forms they can be used, and guidance on when certain logos should and should not be used. This also includes typography and colors;
- Print materials: Any standard print materials such as posters, brochures, timetables, notices, and window displays. It is best to provide templates for these whenever possible;
- Architecture and signs: External signs, platform signs, station equipment, service notices, and advertising spaces;
- Liveries and lettering: For buses, this includes uniforms and any standards around them;
- Road vehicles: Liveries and branding for official vehicles other than BRT vehicles, such as maintenance vehicles, that may use the busway;
- Stationery: Letterhead, business cards, and forms for official communications;
- Miscellaneous: Anything that will carry your brand not mentioned above.

11.6 Implementation

> *"Mix a little foolishness with your serious plans; it's lovely to be silly at the right moment."*
>
> — Quintus Horatius Flaccus, Roman poet, 65 - 8 BC

With a fully developed document in place, the next step is implementation. Effective marketing involves identifying the best channels for communication, such as direct outreach, print, radio, television news and advertising, and social media. These tools, which are discussed more extensively in Chapter 9: Strategic Planning and Communications and Chapter 10: Public Participation, should be integrated into a comprehensive marketing campaign strategy that reaches different constituencies with targeted messages.

At the outset, the implementation strategy will likely focus on educating users about the new system and entice users to give it a try. At later stages, the strategy may play upon the initial successes, learn from mistakes, and target groups that may lag behind in terms of usage, such as motorists. It is important to remember that all the best technical planning can be undone if the system is not presented appropriately to the general public. The remainder of this chapter will cover the (very) basics of a marketing campaign, which is, essentially, the introduction of the brand to the public.

11.6.1 Marketing Plan Project Phases

Every BRT marketing campaign must have a clear, realistic, and coordinated plan and time line that includes the following phases:

- Inception: Launch website, issue press releases, create the action plan, gain political support, develop a marketing campaign, and conduct market research;
- Routes finalized: Begin high-level user education, launch corridor-targeted marketing, issue press releases, and finalize corridor-specific brand elements;
- Construction: Host groundbreaking event, explain benefits, and identify and articulate what the problem is, including how the BRT will solve it; launch feedback systems and provide construction/disruption updates. Release final route maps, build sample station, display vehicles at events, and get feedback for user-information systems;
- Business plan finalized: Deliver internal brand training, establish internal feedback methods, and publicize business model;
- Launch: Begin media/PR blitz, build external events presence, finalize pre-opening marketing campaign, develop specific user education, for example, school outreach, and begin targeted marketing;
- Operations begin: Host press event, give free trials, identify station ambassadors, and increase targeted marketing.

Once you have a timeframe and a process list, you can plan to incorporate the branding and identity of the system into each one, ideally building the identity in the minds of the users with every step.

11.6.2 Outreach Tools

The creative process to produce a marketing message or advertisement varies with each marketing professional. The basis, though, should be the stakeholder analysis as defined in Chapter 9: Strategic Planning for Communications and an identification of the themes that will be important to target audiences.

A range of outreach tools and channels are available, each with different costs and different levels of effectiveness. For reaching a wide swath of people, costly mediums, such as television, may offer the greatest message exposure. For others, personal outreach, such as street interviews, can be effective, albeit costly. There are also several non-costly, creative ways of reaching audiences. The gamut of outreach tools, defined and discussed in more detail in Chapter 9, include:

- Television;
- Radio;
- Print advertisements, such as newspaper or magazine;
- Social networks;
- Telephone marketing;
- Web sites;
- Online video;
- Billboards;
- Flyers/brochures;
- Fact sheets;
- Newsletters;
- Street kiosks;
- Group seminars;
- Personal interviews;

- School programs;
- Social media/mobile applications.

The content of any message—the imagery, the voice, and the color—all should adhere to a uniform visual identity. Typically, a professional public relations or advertising firm should be employed to develop and implement outreach, coordinating closely with the in-house project team.

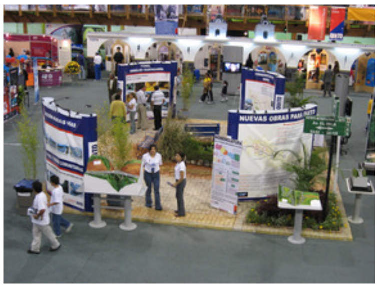

Figure 11.29. In Quito, a public exhibition with details of the new BRT system expansion. *Image courtesy of Lloyd Wright.*

Though television can be prohibitively expensive, because BRT is a public service it can use public service announcements (PSAs) for free on television and radio. In many countries, public and private broadcasters are required by law to provide a certain amount of airtime for such messages.

The best advertisement for the system should be the system itself. The sight of a public transport vehicle whizzing by motorists stranded in traffic is hugely effective marketing. Visual messages on the exterior of the vehicle can heighten the impact: for example, "You would be home now if you had taken the BRT" can really make motorists take note. Messages that particularly note the time gained with one's family and loved ones are often used in BRT advertising to firmly highlight what is at stake with travel time savings.

Marketing efforts should not end with the opening of the system and should not be limited to getting people to use it. Reassuring new customers that they have made the right choice is also a critical part of the process. Regardless of the product, there is always the specter of "buyer's remorse" in which a person can regret their choice. Thus, advertisements inside the system can be effective in reassuring the customer that they have chosen wisely. The messages can remind customers about the time and money that they are saving, as well as other benefits such as environmental protection.

11.7 Customer Service

> *"Well done is better than well said."*
>
> — Benjamin Franklin, author, politician, and scientist, 1706-1990

Customer service is the communications face of the BRT and the ultimate implementation of the brand. Every employee who comes in contact with the public should be thought of as a "brand ambassador" to the public. These interactions are important opportunities to reinforce the brand. Customer service employees need to understand the brand, and have the resources they need to represent it well. They should be trained in and furnished with talking points and practices that reinforce the brand values. Having a useful and accurate website, social media presence, and outreach will help customers and customer service personnel be better informed and better able to assist customers. Yet it is still the case that nothing beats personal contact at stations, in terminals, and in neighborhoods. The system must provide specific locations where users can share feedback directly without having to go online. This is especially true for cities with little Internet use in low-income areas. These locations should have staff trained to answer users' queries and offer information on routes, stations, services, disruptions, or other system information.

The overall BRT communications plan should include a process for communicating with customer service representatives regularly so that they can both provide assistance to customers and feedback to system operators. They also need to be able to answer inquiries and manage communications if there are any service problems. Ideally, the system will be designed in such a way that direct customer service is not always necessary but is available for anyone who needs extra assistance.

Figure 11.30. A TransMilenio staff person provides in-person assistance to customers. *Image courtesy of Libros al Viento.*

BRT transport systems are particularly complex environments and need a way to transmit to users the best way to travel according to their needs. Users will always need to know, at a minimum, how to get to their destination. Ideally, travelers should not have to spend a lot of time figuring out how to reach their final destination; instead they should have a seamless travel experience. The information system needs to provide users with the right information in the right place at the right time.

The rest of this chapter will briefly describe how people receive information, and what rules must be taken into account when designing information for travelers. There are different types of information in a BRT system that can guide travelers, and the best mix of these will provide riders with a useful and effortless way to navigate through the system, even if they are first-time users or foreigners.

11.7.1 User Information

The development of a user-information system is a process that is determined by the nature of each BRT system, technical and operational features, users, and physical and cultural context. It is useful to understand the role of each information element as part of a whole. Generally, user information falls into two categories: system information and service information.

Different users (and different situations) need different information. Nobody travels for the simple pleasure of sitting in a bus, but for a purpose: going to work (frequent trips), to the hospital (occasional trips), or sightseeing (leisure trips), for example. This context determines what type of information a person requires. While experienced travelers focus on making more effective use of their daily commutes, an elderly person, for example, may prefer to avoid crowded environments and seek a more comfortable, if longer trip. Defining what type of information users require, acknowledging the wide range of needs they may have, and providing only that information simply and easily, is the core of the user-information design challenge.

System Information

- Network: Where can I get to using the BRT system? How does the system relate to the city? How can I reach areas of the cities outside the BRT coverage?; Before entering the system, maps and network diagrams are usually placed at station entrances (outside the paid area).;
- Ownership: Who is responsible for the system operation? How can I contact them? Is the BRT part of a wider integrated system?; Visual identity (branding) application and clear distinction need to be included between the system brand, the transport authority, the local authority, and the operators. Contact details through various media need to be made available for users.;
- Behavior and rules: What are the rules? What is mandatory and what is desirable? What are the penalties?; On entering and throughout the journey users need to be reassured about what is allowed/disallowed in the system. National regulation and statutory notices need to be incorporated into the information system from scratch.;
- Fares and payment options: How much does it cost? What are the fare alternatives? How do I pay?; Users need to understand what they are paying for and how to choose the right fare: a single ride, a given time allowance. Payment options are equally important, in particular when the use of cash is restricted. The latter also contributes to enhancing customer movement.;

Service information

- Destinations: What is the nearest or most convenient stop to my final destination?; The nature of the network map could aid in understanding this issue, but consistent naming of stations, neighborhoods, and points of interest is key. Linear route diagrams could display more detailed stop information.;

Figure 11.31. This information kiosk in Brisbane, Australia, helps answer basic questions as well as begins the awareness-raising process. *Image courtesy of ITDP.*

Figure 11.32. Real-time information is displayed along a platform of the Brisbane Busway System. *Image courtesy of Queensland Transport.*

Figure 11.33. This time-based route map in Nagoya, Japan, allows customers to gauge the time required to travel to their destination. *Image courtesy of Lloyd Wright.*

- Routes (journey planning): What services are available from A to B? What journey option is more convenient for me?; BRT can sometimes provide different options to perform the same trip (i.e., express and stopping services). Users' priorities depend on the purpose of their trip and their personal abilities.;
- Schedules: What are the operation times and days? What is the frequency?; This could include a number of details on the operation of a given service or route: operation times and days, frequency, first and last service, and special schedules. Depending on the complexity of the operation, this level of information could range from being redundant (i.e., very frequent services) to essential (i.e., irregular or special services, such as weekends, night, and peak-only).;
- Time (travel and waiting): How long do I have to wait for the next service? How long will my total journey will take?; Electronic information is generally preferable and more intuitive for users than fixed schedules. Countdowns at stations reduce anxiety and provide key information for experienced users. Electronic information also can respond to system disruptions.;

One very important issue is that all information must always be accurate and updated periodically (monthly, annually, etc.). Information that is likely to change more often is better placed in flexible, cost-effective structures, such as poster holders, or presented digitally in the station. Periodic changes fall to the maintenance staff and will depend on the materials chosen for the structures, as well as the level of vandalism or wear that these receive. Digital information platforms allow a great level of flexibility and can be updated to display short-term information such as service disruptions and countdowns. Information must always be accurate, especially regarding travel and waiting times, service stops, and disruptions. Inaccurate system information is one of the most common customer service complaints regarding public transport.

11.7.2 Effective Visual Information

Information must be presented in the most effective, easiest way for everyone to understand and act on quickly. Ideally a user should not have to spend more than thirty seconds deciphering information. Careful positioning of these types of elements (such as information panels) is important so that they are visible and readable on the one hand but do not obstruct passing customer flows on the other.

11.7.2.1 Best practices for visual, customer information

Simplicity: The first and most important rule is that information must be presented as simply as possible. One can make use of design techniques and color contrasts in order to provide the simplest and most effective visual presentation. An arrow, for instance, if well placed and properly designed, can convey almost all needed information in some cases (e.g., showing where to walk in order to arrive at an exit). The basic rule is less is more. It may be tempting to include more information than necessary with the intention of being comprehensive, but this is almost always counterproductive, confusing the customer.

Unity: All visual information for customers must be based on a consistent set of design rules, which in turn are part of the corporate image of the system. This is especially true when using colors, since these will convey messages in themselves if used as part of a coherent whole. For instance, a BRT system that uses the color yellow to mean "this is an entrance" will not need to write the word entrance if visual information is designed coherently and as a whole.

Figure 11.34. After just a few weeks of operation, stations along the Parajitos busway in Santiago, Chile, are covered with graffiti, making their information areas unusable. *Image courtesy of Lloyd Wright.*

Figure 11.35. Information displays at a BRT station in the Jinan, China, system provide the real-time position of BRT buses along the corridor. *Photo courtesy of ITDP.*

Coherence and integration: All visual information must be coherent with existent signaling systems and codes. For instance, it is commonly understood that the color red means “stop” or “caution,” while the color green means “go.” Each country or city will have its own particular and historical visual information systems, which must be respected when developing a new traveler information system.

Colors versus numbers/letters: A common question among designers is whether people understand colors better than numbers or letters, and if information should be conveyed exclusively through one or both. Some cities are used to complex numbering/lettering systems in their streets or other urban information systems, while other cities have used colors and even pictograms to present information. The right answer depends on the population being served, but in general, any option can work as long as the system is clear and consistent.

People versus machines: When given the option between relying on printed information or a person, users generally prefer to ask the person rather than looking into the details of the map. This tendency is so strong that, in many cases, people will prefer to ask other travelers rather than checking the map, even if those travelers are not necessarily well informed about the system. Obviously, official staff of the system (or police guards, or anyone with some relation to the BRT system) will be preferred over asking a fellow traveler. This is much better for concerned travelers because they know that they must only ask “what service do I need to get off at X station,” and they can also ask follow-up questions based on the answers they receive. With most visual information, none of these are options.

Ask users: This entire volume describes different ways of collecting information from users in order to know how the system should be planned and to gather information about their concerns or comments regarding system performance. This also applies to traveler information systems. Despite the fact that information design is a well-established discipline that has standard rules on how to develop information and present it properly, no piece of information can be confirmed until it has been validated by users. It must be clear that users have various groups (depending on age, level of schooling, special needs), and that users can be either frequent (i.e., those who use the system daily) or sporadic (i.e., those who use it once every now and then, or foreigners who will use the system only for a few days). These users must be integrated into consultation because a customer information system is most useful especially to those who are using it for the first time rather than those who have used it for a considerable time. This could also have a positive impact on ridership of the system.

Integrating customer information into BRT system design: Though customer information is normally seen as a complement of system planning, it can also work the other way around: in some BRT systems, operations are so complex that users fail to fully understand them regardless of the efforts of the designers. If this is the case and designers find that users cannot understand some features of the system, it means that the system will not necessarily be used to its fullest potential. Thus, whenever users express their confusion regarding specific operational characteristics of a BRT, system planners must reflect upon the usefulness of having those features and consider removing them completely if no solution is found. The more intuitive the system is to use, the less need there is for additional information.

Get the experts: In the same way that experts must design BRT operations, customer information systems are also very complex in terms of their design. Graphic designers, communication experts, and social scientists should be hired to develop the customer information system in close cooperation with system planners.

Adapt design to local legislation: National and city legislation is normally very specific with regard to what can be presented in and outside of transport system stations, and on how information must be presented in terms of colors, materials, sizes, etc. Of course, this legislation must always be followed, but if the design team judges that some elements should be modified to convey information better, they should decide if it is worth making a formal appeal to the authority, and if there is sufficient time to incorporate any changes into the design of information systems.

11.7.3 Types of Information

Figure 11.36. The Quito Trolé line provides an area map and a detailed map of the individual line stops at each station. *Image courtesy of Lloyd Wright.*

Information can be provided in many ways in a BRT system. Technological options have been increasing, while costs are plummeting. The most important consideration is that information be provided when and where travelers need it. In some cases digital information will work best; in others, print will be more useful.

In general, information that must be modified or updated frequently (e.g., the service that a vehicle is providing at a given time or the upcoming vehicles that are arriving at the station) should be presented digitally. Information that must be studied more carefully by travelers and that has greater complexity of graphics and information lends itself better to print form. This is also related to information that is static or dynamic as described below.

The typical set of information that should be included in any BRT system:

- City/area maps with system indications: Maps of the city or the area of the city with the station and nearby stations indicated. These should be large and located inside or outside of the station near the exits;
- System maps: Schematic maps (i.e., not in geographic scale) with all stations and integration locations. These can be printed out in small sheets and given as leaflets or placed in strategic locations of stations in large size;
- Trunk line schematic presentations: Specific trunk line drawings specifying stops and integration points. These can be located inside vehicles and in stations;
- Service details: Information on specific services (stopping or express) regarding their schedules or stops;
- Digital information displays: These can have all types of information depending on their complexity, and they can be located anywhere from outside the station to inside vehicles; they are especially useful for providing short-term information on service delays, disruptions, and wait times;
- Pocket guides: Guides with all necessary information on the system, which should be provided to users at no cost in system terminals or stations. These should clearly indicate the date when they were printed on the cover so that users can estimate when they need newer versions;
- Signage: Generally provide directional information helping users to find their way around the transport facility and improve customer movements;
- Web and mobile applications (as discussed in Chapter 9).

How the information is presented depends on the type of information. Generally, printed information is static, composed of maps of the system or of specific routes, and consists of anything that has greater level of detail and is modified with less frequency. Dynamic information that is modified frequently should be presented in digital displays. This includes real-time information on upcoming services, service disruptions, or general messages from system management. This information is generally "simple" in the sense that it will not need interaction from users and will only provide information in letters and numbers.

Figure 11.37. The BRT in Guangzhou, China, provides dynamic real-time information digitally on vehicle arrivals. *Image courtesy of ITDP.*

There is also dynamic information that is complex, meaning that users will need to interact with a screen or information panel in order to request and receive further information. This is the case of route planners (via websites, mobile phones, or machines at stations), where users will provide their origin and destination (or only their destination, when they use a machine at a station) and will receive information on the most appropriate services that can be used for their particular trip.

This is the most flexible of all systems of information. It is particularly complex to design, manage, and operate from the "back end" of the service, especially when machines are provided at stations. They must have very robust operation systems and software structure to avoid blocking or disruption when they are used heavily (e.g., at system terminals).

11.7.4 Locations of Customer Information

The placement of information in a BRT system requires careful planning. The following is a set of common locations where BRT planners should consider posting information as they attempt to address the individual concerns of each locale.

11.7.4.1 Everywhere: System Staff

As was described above, customers prefer asking system staff or even other users for information regarding the best way to get to their destination. System staff should be located in proximity to both users and system information maps. This will aid travelers in understanding information systems and allow them to request additional help if needed. Access to system personnel is also very important for people with special needs who will request help from people to get to their destination, as described later in the chapter.

11.7.4.2 External Venues near the Station: Printed Information

External venues, such as a shopping mall or a park, should have information about nearby BRT stations. People, especially tourists who will visit these venues, will want to access general information regarding the location of the nearest BRT station, and what service is available at that station. If customers can take the BRT from this location to another public attraction, then information should be clearly posted at exit points.

11.7.4.3 Outside the Station Entrance: Station Map

Since users must pay to enter the station, it is crucial to provide information on the system and the services that stop there right outside of the station. A station map would be useful here with a specific "you are here" indication and some level of detail of the specific services that can be taken there and the general destinations that can be reached through the system (and, more specifically, the trunk line that passes through that particular station). Generally, large totems are used for this purpose.

11.7.4.4 Inside the Station: Service Signs

The station interior may be long and have various sections or wagons depending on the extension and service complexity of the BRT. If the station has multiple doors in both directions, it must indicate where customers can find particular services and how they are grouped (by final destination, specific location, local and express services, etc.). In this case, travelers will want to know where they should look for more details about their service.

11.7.4.5 Inside the Station: Information Panels, Maps, and Digital Information

The location of information on more comprehensive panels, including maps, should be placed strategically. A station map will attract crowding around it and can negatively affect circulation in the vicinity. In general, having more than one map that can provide all necessary information to users throughout the station is a good idea.

As an alternative to information panels, interactive kiosks work well to provide specific information regarding system services and will respond to specific requests from users (i.e., what service they must take to go to their destination), although only one person at a time can use them.

11.7.4.6 Inside the Station in Front of Boarding Doors

Information regarding the specific services and schedules can be posted on doors that lead to the vehicles.

11.7.4.7 Outside of the Vehicle

Information regarding the specific service that a vehicle is operating should be presented outside of the vehicle (preferably on the side, rear, and front). Since vehicles can change services more than once a day, digital displays are recommended. This is also useful at nighttime when it is difficult for customers to read without proper illumination.

11.7.4.8 Inside of the Vehicle

Once inside the vehicle, customers must be alerted to upcoming station stops. In express services, it is advisable that users are informed of the next two or more stops. Synchronized digital displays and audio announcements can provide this information about the next stop, interchange options, and are also suitable for the visually impaired. Dynamic maps of routes are also useful for presenting a list of all upcoming stations. Again, frequent service changes imply that digital information may be a better choice than printed information.

11.7.4.9 Between Vehicle and Station

Before leaving the vehicle, travelers must ensure that they are alighting at the station they expect. This can be confirmed by the information inside the vehicle when approaching the station, and it should also be indicated clearly on the outside of the station, e.g., on station doors with station name. Travelers can also confirm where they can find the exit(s) of the station depending on their final destination (when stations have more than one exit). This information needs to be carefully positioned at window-height so it can be seen by seated and standing customers from inside the vehicle.

11.7.5 Accessible Customer Service Systems

An important constituency to consider when designing customer information and customer service systems is that of individuals with special needs. This includes customers with physical and mental disabilities, language barriers, and those who are visually impaired. Incorporating the needs of these users is essential to providing a fully accessible BRT system. Information for special needs groups may be either incorporated into the "main" information system or delivered through alternative media, implying in many cases the development of a parallel customer information system.

Remember that developing accessible information systems benefits everyone, not just those with special needs. In many countries, making your system accessible to everyone is required by law. Engage with representatives of this community in designing your system. Full details on the topic of universal access are available in Chapter 30: Universal Access, of this guide.

11.7.5.1 People with Physical Disabilities

There are many forms of physical disabilities, some requiring the use of wheelchairs or walkers. The location of an information panel must be evaluated based on the average height of the population but also based on the heights of people in wheelchairs so that they can read all information presented. Complex dynamic information systems must also be adapted for people who cannot use touch screens, possibly by means of sound sensors or other technology.

11.7.5.2 People with Language Barriers

Depending on the population the BRT will serve, it may be necessary to display information in symbols or images in addition to one or several languages. This will also be useful to foreigners and in countries where official languages are not necessarily those which are spoken by the entire population. A combination of symbols and sentences may also be useful for quick comprehension for everyone.

11.7.5.3 People with Visual Impairments

For the blind or partially blind, availability of tactile and/or audio information from station entrances through the station and until arriving at the vehicle can be helpful. As a rule, blind customers require audible or tactile information such as tactile guideways, tactile warning strips, and Braille (if desired), or more sophisticated Remote Infrared Audible Signage (RIAS) or other navigation aids. For those who have some level of vision, but may not be able to read small print or complex diagrams, including the elderly, it is important to evaluate whether font size and type are adequate for reading. Another group with visual difficulties includes the color-blind, who may not be able to discern different colors in a map. This is also why contrast is so important in presenting routes and line colors in maps.

11.7.5.4 People with Hearing Impairments

Like visual impairments, hearing impairments take many forms. These customers require text information or the use of various, more advanced technical solutions. To begin with, there should always be full information in written form, and if audio cues signal the approach of a vehicle, there should also be a corresponding visual cue, like a blinking light.

11.7.5.5 People with Mental Impairments

Those with mental impairments may have particular difficulty understanding complex maps or large amounts of information that include many steps, but keeping information simple is also good practice for the general population. Though this has more to do with operational planning specifically, traveler information systems can also help in providing more adequate information for this group. For example, complex dynamic systems may be clearer containing only essential information, or staff should be available for assistance.

In addition to the design requirements for accessibility, customer service staff must complement these systems. No matter how well a station or system is designed, there will be cases when human help is needed. Customer service station staff should be available to guide members of these groups in entering the station, choosing the right service, and boarding and alighting the vehicle. It is important to remember that most people, especially those with disabilities, would generally prefer to be able to navigate the system on their own, so help should only be offered when it appears necessary or in response to questions.

In general, the entire field of travel information for those with disabilities is growing and becoming more complex. It is important to refer BRT planners, engineers, etc., to the literature that is available, and to details in Chapter 30: Universal Access, of this guide. Some useful resources to start with are and .

11.7.6 Online Customer Service

Although customer service should not be limited to online interactions, providing service through a website or mobile app is increasingly necessary and can be very convenient for those customers who prefer go to online. Online customer service is often called the user interface.

The most commonly used web tool for transport systems is the route planner. Users must be able to easily and quickly identify how they can get an answer on the most appropriate service they must take to arrive at their destination. The interface should be as simple as possible, asking users where they are starting their trip (address, landmark, or station), and where they want to arrive. When using a smartphone that is GPS-enabled or if the device is located inside a station, the first step can be avoided.

Customers should be able to click or tap on these locations or have the option to write only a portion of the station or landmark name and have the system fill in the rest to ensure that they are choosing the right station. Software developers must always integrate a system that is flexible in interpreting information, meaning that customers should not need to have perfect spelling and should not be expected to write accents, and the system should integrate an auto-complete function in the query.

The ideal web-based route planner should have software that is able to recognize what the closest station is to where the customer is located, what is the current scheduling that applies (off-peak, peak, nighttime, all day) and which is the best, or shortest, route to arrive at the desired destination. The system should have default/user-specific values for:

- Transfer preferences (generally, none are preferred);
- Duration of trip (shortest is generally preferred);
- Use of local or express services;
- Availability of bicycle parking/bicycle taxis/feeder routes/public bicycles;
- Desired level of comfort (i.e., crowded or being guaranteed a seat).

These default values should be updated based on current settings and on complex queries given by travelers, or on users' own registered values, if the system has a registration service.

The web-based system can also include traveler registration, where users will provide their general demographic details if they choose and their preferred mode of travel according to the values specified above plus their typical origin or destination. Thus, every time they log in to the system, they will not have to provide full information on any of these variables. Mobile integration is essential, as most people will want to use the route planner when they are out and when their plans change.

In addition to the route planner, there should be options for customer questions, complaint, and feedback. This is a valuable way to collect information about your system from the people who actually use it.

11.7.7 Customer Complaints and Feedback

It is important to continuously take in and review comments and complaints regarding the system in terms of its operations, maintenance, staff behavior, and any other issue that is of interest to customers and system planners. There are many different methods that can be used to collect suchuser feedback and use it to improve the system. It is gratifying for participants in that feedback loop when they see their concerns addressed. More information on the methods of collecting information is described in Chapter 9: Strategic Planning for Communications.

In general, user feedback is one of the most useful ways to improve system services and should be actively sought. Regardless of the level of aggressiveness with which users present their complaints or comments, any information that is provided by users will be crucial to understand how the system is operating and how it can be improved. The fact that system managers are actively seeking such information will also generate very positive reactions from users, especially when their comments have specific responses from system management in terms of explanations or specific solutions that are given to them in return. This also has linkages with the use of social media as described in Chapter 9, since it is very easy to receive and give almost immediate feedback to social media users when they are indicating their concerns by those means.

There must always be a system in place for dealing with customer complaints, whether they are received online or in person. Staff should be trained on the protocol for addressing complaints and be equipped with the ability to offer solutions. This includes offering free rides or priority boarding if that will solve the problem or being aware of the process of issuing a formal complaint to the system operators. The most important thing to remember is that those who complain, no matter how polite or aggressive they may be, all simply want their complaints to be heard and taken seriously by customer service staff. If a customer is being disruptive, there should also be protocols in place to deal with that situation.

Despite the fact that users may not have a complete understanding of how the system is managed, who is in charge of operations, vehicles, or fare collection, or even who is in charge of maintaining stations, the customer service representative must represent the brand by being professional and courteous. Some simple ways to address customer complaints include:

- Providing accurate information to users regarding solutions being sought (or which have been accomplished) regarding their complaint;
- Forwarding information to the appropriate parties promptly (system management, operating companies, infrastructure developers, station management, fare collection);

- Systematizing all information and feedback that is provided and distributing it to system managers and planners for immediate or future improvements of the service;
- Including remarks or issues in the system website FAQs, guides, maps, or other locations.

An important issue when collecting users' feedback or comments on the system is time. For instance, a ten-minute survey will not be responded to by someone who has a twenty-minute ride to work in the morning. Methods like riding in the vehicle with users and collecting information from them can be done, though this poses a challenge if vehicles are crowded and collecting formats are large (i.e., A4-sized sheets of paper).

If these measures to collect feedback are not kept short and easy, the results of surveys can be biased since the only users who will respond to long surveys may be those who have arrived at a station much earlier than usual or those who do not have a specific time of arrival (generally unemployed or elderly groups). Thus, these responses cannot be generalized to all users of the system. As with the beginning of this process, it is valuable to consult with professional service organizations that specialize in conducting surveys.

VOLUME IV

Business Plan

Volume 4 looks at the necessary planning required to ensure the financial stability and success of the business of running a BRT system. This includes looking at the institutional and business structure as a whole, the contracting for different aspects of the system such as operating vehicles and operating the traffic control center.

A number of varying institutional structures have been used to run BRT systems, and this volume discusses the basic and administrative tasks required as well as some of the pros and cons inherent in varying setups in taking on those tasks (Chapter 12).

Furthermore, this volume includes guidance on the business of operations, contracting, and competitive tendering (Chapter 13); financial modeling (Chapter 14); setting up the systems fare policy and structure (Chapter 15); and finalizing a finance plan (Chapter 16).

12. Institutional Planning

> *"In the infancy of societies, the chiefs of state shape its institutions; later the institutions shape the chiefs of state."*
>
> — Charles de Montesquieu, politician and philosopher, 1689–1755

The quality of a BRT system depends as much on the system's "software" (e.g., institutional, business, and regulatory structure) as it does on more traditional "hardware" considerations (e.g., vehicles, stations, busways, and other infrastructure design). All government services require a competent team to manage them. Who is on the team, where it sits in relation to the rest of the government, and the degree to which the team is independent of—or integrated with—other government functions is the *institutional structure* for that service. Each government service has its own set of needs, and the best institutional structure may vary from one service to another. The institutional structure of a BRT system has a profound impact on its efficiency, the quality of service, and the cost of operations.

While there is a growing consensus as to what constitutes "best practices" in the area of physical design, as is reflected in *The BRT Standard*, there is only an emerging consensus with respect to optimal institutional structures for a BRT system. Empirical evidence suggests a considerable divide between the appropriate administrative structures in a higher-income versus a lower-income economy context, and under different legal frameworks.

This chapter first outlines the basic functions required to design, implement, and operate a high-quality BRT system. It then reviews the key issues to be considered when establishing an administrative structure for a new BRT system. This consists of the different administrative structures currently used to manage various BRT systems around the world. It only anecdotally provides preliminary observations with respect to the pros and cons of different institutional structures in different contexts. This chapter provides a baseline of comparative information on different administrative structures, with the hope that future research will be able to link these differences to empirically observable differences in performance, and eventually articulate clearer guidance with respect to best practices. Setting up the right institutional structure for a BRT system should start with understanding the key functions of a BRT system.

Contributors: Walter Hook, *BRT Planning International*; Edgar Enrique Sandoval, *consultant*

12.1 Basic BRT Functions

> *"Nature uses only the longest threads to weave her patterns, so each small piece of her fabric reveals the organization of the entire tapestry."*
>
> — Richard Feynman, theoretical physicist, 1918–1988

No matter how the administrative responsibilities are divided up among government agencies and departments, and among private sector contractors, there are certain basic tasks that need to be accomplished for a BRT system to be successfully designed, built, and operated. Figure 12.1 is an organigram that depicts the multitude of tasks involved in implementing and operating a BRT system. Every BRT system needs a government agency or one of its contractors to accomplish each of these key functions. They can be divided into those tasks that are integral to providing the BRT services ("BRT Services"), those that are integral to getting the BRT infrastructure built and maintained ("BRT Infrastructure"), and those that are critical to how the BRT system relates to general traffic, to competing road-based public transport services, to cycling and walking infrastructure, and to rail public transport services ("BRT Integration").

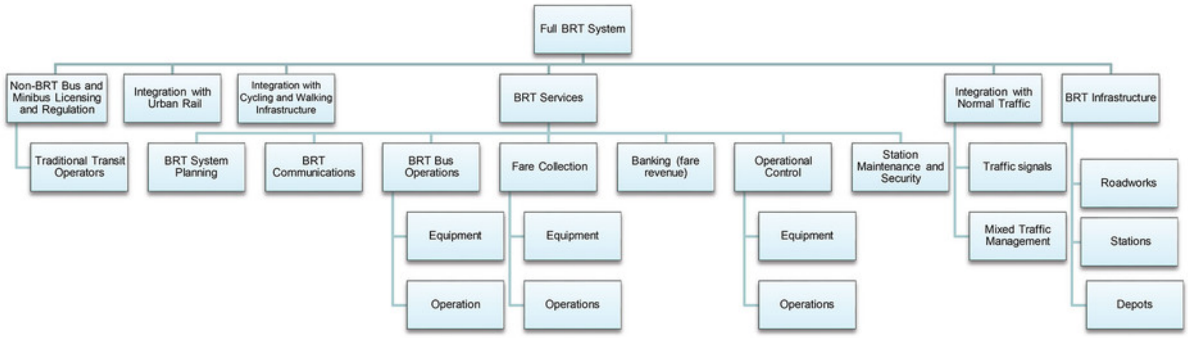

Figure 12.1. Basic functions of a full BRT system. *Walter Hook, BRT Planning International, LLC.*

BRT Services

- BRT system planning:
  At the inception of any new BRT system, there is a team assigned to plann and implement the new BRT. Once the first phase of the system is built, the BRT planning function is still needed for later stages of the system. At the inception of a BRT project, it is often the case that there is not a lot of local knowledge about how to design and implement a BRT system. As such, many of these initial planning functions are generally done by outside consulting experts. However, it is strategic for the implementing agency to learn these tasks so that future phases can be managed in-house with less dependence on outside consultants;
- BRT system operations: Every BRT system has to operate BRT vehicles. Someone needs to first set the technical specification for the vehicles, then someone needs to buy the vehicles, and then someone needs to operate and maintain the vehicles;
  In addition, every BRT system needs to collect fare revenues from its customers. First someone needs to establish the fare, then someone needs to select an appropriate fare system technology and procure it, then someone needs to operate the fare system;
  From time to time, every BRT system needs to update schedules and bus routings to better match demand;
  Most BRT systems have special BRT stations that need to be cleaned, maintained, and made secure. Most BRT systems deposit the fare revenue into a separate bank account that is managed by a fund manager. Most BRT systems have an operational control center that is used to keep vehicles running on time and monitor the behavior of the vehicle operators;
- BRT system communications:
  Communications is important to a BRT system. In the early stages of BRT planning and throughout the life of the system, information about the BRT system needs to be strategically released to key stakeholders and the general public, and these relationships need to be carefully managed. The system needs to develop a clear brand. Finally, customers and the general public need to be kept informed about services on an ongoing basis.

BRT Infrastructure

A BRT system has special infrastructure designed to ensure an optimal bus service. This infrastructure nearly always includes redesigning the road right-of-way to create an exclusive bus lane, or in some special cases, includes the construction of a fully grade-separated busway. BRT infrastructure provision also includes designing and building special BRT stations. If the services that have been designed are "trunk-and-feeder" services (see Chapter 6: Service Planning), then construction plans will also need to include transfer facilities. Most BRT systems also build special depots for BRT vehicles. BRT infrastructure must be compatible with the type of BRT vehicle being procured for vehicle operations, and it must provide the appropriate power and telecommunications technology required by the fare collection system, and the operational control system. As such, the design and construction of the infrastructure needs to be carefully coordinated with BRT operating companies;

BRT Integration

- Integration with normal traffic:
  As BRT systems generally operate on normal city streets, they have a big impact on traffic patterns in the BRT corridors. Normally, BRT systems require making changes to traffic signals, and often changing the location of turning bays and in the turning movements that are allowed. The systems also require the designation of one or more lanes of traffic for exclusive use by the BRT. Each of these changes will have some effect on normal traffic operations and as such will need to be managed;
- Integration with other road-based public transport:
  Most BRT services are modelled on bus and minibus services that operated on the same corridors prior to the implementation of the BRT system. Usually, these services are modified and then incorporated into the BRT services in some form, and the old services are modified or cancelled. What happens to these former bus and minibus services has a big impact on the profitability of the BRT system, on the amount of congestion in the mixed traffic lanes, and on the social impact of the project. Within a BRT institutional structure, someone first has to plan any changes to existing bus and minibus operations, and then to supervise the necessary licensing and regulatory changes to make these changes possible;
- Integration with urban rail:
  Some cities that are designing and building BRT systems also have urban rail public transport systems. It is generally in the interest of both the BRT system and the urban rail system to have smooth, fast, and comfortable integration between urban rail systems and the BRT systems. For this to happen, someone needs to take responsibility for ensuring this seamless integration. Integration can happen through physical connections and/or through the fare system. Integration is also likely to involve longer term planning to ensure that the two systems are complementary, rather than competitive, with one another;
- Integration with cycling and walking infrastructure:
  By designing connections to cycling and walking infrastructure from the BRT stations and along the corridor, cities can maximize the effectiveness and efficiency of their multimodal networks while increasing accessibility and equity for those without other options of reaching the BRT. Planning for non-motorized transportation can also leverage dense and mixed-use development that further increase the ridership of the BRT system. Physical integration can be achieved between the BRT system and biking and walking infrastructure through the provision of bicycle parking, crosswalks with refuge islands to shorten walking distances across traffic for pedestrians, and adequate space for protected bike lanes and sidewalks alike. Meanwhile, informational integration also plays an important role, such as the incorporation of clear and consistent way-finding signage to help customers navigate the connections between the BRT system and the area. More details are provided in Chapter 28: Multimodal Integration.

12.2 Initial BRT Project Office

"I believe a lot of our lives are spent asleep, and what I've been trying to do is hold on to those moments when a little spark cuts through the fog and nudges you."

— Rufus Wainwright, singer-songwriter and composer, 1973–

All BRT systems were started by a handful of inspired individuals with an idea. This project initiator might have been the mayor, the head of the planning office, a city councillor, a transport commissioner, or even a president. Wherever the project starts, work only begins once a talented group of individuals takes the initiative to begin putting in place the basic elements of the BRT system.

It often takes a project initiator with the will to get a BRT implemented to kick-start the project, even before a more final institutional structure is in place. Thus, most BRT projects begin with a temporary project office. In some of the best BRTs, the initial project office grew into a more formal, independent BRT authority. There are a few cases where no temporary office was created and the BRT was operated under its long-term institutional structure. This is generally more successful when the existing institutions and their staff are already strong enough to take on a new function.

In many cases, the initial BRT project office is housed in the office of the political leadership or institution responsible for initiating the project, such as a mayor's office, before eventually becoming an independent agency. Other BRT projects were initiated by the institutions that later implemented and operated them, such as a transit authority. Figure 12.2 shows the institutional locations of the project management office of a variety of successful BRT projects.

	Special project office directly under Mayor or Municipal Commissioner	Municipal Transport Dept Planning Staff	Pre-existing Transit Authority	Municipal Planning Office or Body	State or Provincial Transport Dept	Planning office of Regional Authority	Special project office under the National government	Development Bank Project Office	Special Project Office under Municipal Construction/Public Works
TransMilenio, Bogota	X								
GBRT, Guangzhou									X
BRT, Curitiba				X					
Guadalajara, Mexico					X				
Pereira, Colombia						X			
Jan Marg, Ahmedabad	X								
Rea Vaya, Johannesburg		X							
Leon, Mexico		X							
Guayaquil, Ecuador		X							
Quito, Ecuador				X					
Metrobus, Mexico City	X								
HealthLine, Cleveland			X						
Lanzhou, BRT								X	
Transantiago							X		
TransJakarta, Jakarta		X							
LA Metro Orange Line			X						
Cape Town MyCiTi		X							
Pittsburgh MLK busway			X						
San Francisco (no BRT yet)						X			
Dar es Salaam DART (2016)	X								
Lagos busway								X	

Gold Standard BRT
Silver Standard BRT
Bronze Standard BRT
Basic BRT or Below

Figure 12.2. Institutional home of initial BRT project office. *Walter Hook, BRT Planning International, LLC.*

TransMilenio, for instance, started out of a special project office directly in the mayor's office. Later, most of the key personnel became the staff of TransMilenio SA, an independent BRT authority. Curitiba's BRT was initiated by Instituto de Pesquisa Planejamento Urbano de Curitiba (IPUCC), a planning agency that was created to implement Jaime Lerner's vision of an urban form anchored by BRT corridors. IPUCC later became a regional planning body for Curitiba. Quito's BRT was initiated out of the Department of City Planning. The BRT in Guangzhou, China, was initiated by a project office under the Construction Commission. BRT projects in León, Mexico; Guayaquil, Ecuador; Johannesburg and Cape Town in South Africa; Jakarta, Indonesia; and a number of other cities began as project offices in the municipal departments of transportation. In the United States, most BRT projects were initiated by the regional transit authority, sometimes with the support of the city department of transportation. A few projects, such as Transantiago in Santiago, Chile, began under a special interdepartmental task force of the national government, in large measure because the City of Santiago is run as an amalgamation of many separate municipalities. Pereira's BRT project started under the auspices of a regional government body. Figure 12.2 (and many of the graphics showing BRT systems to follow) shades each BRT according to its highest score on *The BRT Standard*—gold, silver, bronze, or basic/not BRT—as a very preliminary way to determine whether there are correlations between certain administrative structures and *The BRT Standard* ranking of a system. In the case of this particular question—where initial BRT project offices are hosted—there seems to be no relationship between the success of a BRT project and the initial host of the BRT project office.

Regardless of where the initial BRT project office is housed, it is critical that the project head has access to key decision makers so that he or she can get key decisions made in a timely manner. Having the best quality staff and hiring consultants are also critical. Some projects, like Bogotá's TransMilenio, were initially managed by talented young professionals with little background in managing a rapid transit system but with very strong general management skills. The average age of the initial TransMilenio staff team was under thirty years, with over 95 percent of the staff having never worked for an urban public transport authority or a private transit operator. By bringing together an entirely new team with a fresh perspective, the team was not ingrained in established practices that TransMilenio was trying to transcend. Experience was provided to TransMilenio not from locally entrenched bureaucrats but from top-notch management consultants (provided by McKinsey) and BRT system planners (provided by the independent consultancy Steer Davies Gleave and its subcontractor Logit from São Paulo).

Other project teams were led by professionals of long standing, such as the Quito BRT project, which was formed in the office of the Municipal Planning Department by Cesar Arias. Johannesburg's Rea Vaya was always led by the transportation department head under the auspices of the Member of the Mayoral Committee (MMC) responsible for transportation. Guangzhou's BRT project office was led by an NGO (ITDP) in partnership with the Guangzhou Municipal Engineering and Design Research Institute (GMEDRI) under the authority of the Construction Commission.

Critical to success was generally learning from the experiences of others and hiring skilled consultants. The best consultants for a BRT project are those who have already worked on a gold or silver–rated BRT project. Each city that develops a new successful BRT creates a cadre of competent professionals, and many of these professionals eventually become available as consultants.

In general, the initial project team should have a maximum of eight staff. They are:

1. A general manager—a business-oriented management expert who deals with the political leadership and the nontechnical, business-oriented side of the project (contract preparation, tendering documents, etc.);
2. A finance and administration manager;
3. An engineer who oversees the contractors responsible for designing the infrastructure and supervises the work done by the relevant department of public works;
4. A planning director who oversees the consultants responsible for the initial service planning and plans next phases;
5. An operations director who helps draft the operating contracts, establishes operational protocols, supervises the operating tenders, and then supervises compliance with the operating contracts, and finally manages the contract for the operational control system;

6. A communications and customer relations manager who deals with external communications and coordination with the public and with affected bus franchises;
7. A lawyer (who could be under contract rather than on staff);
8. If necessary, a probity adviser or internal control person. This person is necessary if there is a significant concern about possible corruption undermining the project.

At first it is likely that each person will be responsible for more than one of these tasks, and later as the project office becomes more institutionalized, roles can be divided among more people. In Table 12.1 the staff positions and their functions are listed for two BRT systems: TransMilenio in Bogotá and Rea Vaya in Johannesburg. For TransMilenio, these positions were initially in a project office under the mayor, and for Rea Vaya they were in a project office in the City of Johannesburg's Department of Transportation.

Table 12.1. Staffing for Initial BRT Project Offices in Bogotá and Johannesburg

Title	Responsibility	Bogotá - TransMilenio	Johannesburg – Rea Vaya
General Manager	Political interface with decision makers	2	1
Communications	Preparing, sharing, and controlling information to key stakeholders	1	0
Transport Planner	System design and planning	1	1
Engineer	Physical design supervision	0	2
Operations	Scheduling, operational contract supervision, establishment of operational protocols, operational control	0	2
Legal Affairs	Contracts and legal matters	0	1
Finance	Accounting and budgeting	1	1
Administration	Administration and human resources	1	1
Probidy	Transparency, anticorruption	0	2
Total		6	11

12.3 Long-Term Institutional Structure for BRT Management

"We must use time as a tool, not a couch."

— John F. Kennedy, former U.S. President, 1917–1963

Immediately after the establishment of an initial BRT project office, the government should already be thinking about a strategy for administering the BRT system in the long term. The initial BRT project office can help plan and design the initial BRT corridor, but operating it requires a new set of skills and brings up additional issues, both financial and legal. Some institutions will need to sign contracts with construction companies and operating companies, and the institutions that sign these contracts will de facto control the system.

Designing and operating a BRT system is more complicated than operating a bus system or building a road. It requires that specially designed infrastructure be completed and traffic signals and traffic patterns changed. This should all occur at roughly the same time as when new vehicles are purchased and operating companies are hired and become operational. Few of these skills are generally available locally at the beginning, so the skills have to be developed as the project proceeds. The institutions to manage these functions need to either be heavily adapted from existing institutions, or a new agency needs to be created to serve these functions. There are advantages and disadvantages to each method.

The primary challenges in developing an institutional structure that can achieve a high-quality and efficient BRT are assigning responsibilities to institutions that have:

1. The capacity to competently implement the required tasks;
2. The administrative power to compel coordinated action across a number of government institutions;
3. The independence that ensures there is no conflict of interest with implementing a successful BRT system.

The introduction of a BRT system is sometimes used as an opportunity to make changes in the institutional structures responsible for managing the public transport system in a metropolitan area. This is far more frequently the case in lower-income economies than in higher-income economies.

In the United States, Australia, and Canada, BRT systems have largely been the efforts of existing large and powerful transport authorities, which are typically also directly responsible for vehicle operations, since the operations and financing of the BRT system are no different than that of the rest of the bus system operated by the same authority. In Europe, including England, there is a growing trend toward contracting out entire public transport systems or parts of systems to private companies or to companies with mixed public and private ownership. Both large public transport authorities and private transit service companies have years of experience purchasing, testing, operating, and maintaining large fleets of modern buses using integrated fleet management. In either administrative form that is typical in higher-income economies, buses tend to roughly follow schedules, stop at predetermined bus stops, and behave reasonably safely in traffic. The age of the vehicles is generally set by administrative rules or contractual requirements at under ten years. While these services are sometimes costly to taxpayers and are rarely perfect by every measure, they are quite acceptable by international standards. These institutions emerged after decades of institution building, administrative reform, and public investment. The BRT systems developed by these institutions also represented a reasonably small share of total public transport trips. In this context, BRT has not been closely tied to institutional reform.

In lower-income economies, by contrast, the situation is different. BRT systems are frequently on the highest demand corridors, carrying hundreds of thousands of customers daily, and they are being introduced into a very different administrative setting. In lower-income economies, BRT systems have frequently been used to leverage significant administrative reforms in the public transport sector. Public transport authorities almost never exist, or if they exist, then they seldom function as imagined. There are rarely large public or private vehicle operators able to purchase, operate, and maintain large fleets of modern vehicles using integrated fleet management. Most commonly, a municipal department of transportation issues route licenses to small, informal individual owners of a handful of buses or minibuses.

Bus and minibus fleets are generally old, polluting, and poorly maintained. The profits of these small informal operators are not very stable. If a driver becomes ill, or the vehicle breaks down, the profit drops. The services provided by such route licensing arrangements generally suffer from a number of problems. The services infrequently follow a schedule, they rarely stop at specific stops, the buses are seldom well maintained, vehicle fleets are generally old, emissions are usually high, insurance coverage is uncertain in the case of an accident, and drivers are sometimes poorly qualified and not even licensed. Rarely are these sophisticated businesses that grow and thrive. Individual bus owners competing for customers at the curbside frequently engage in dangerous combative driving, killing pedestrians and waiting customers.

The departments of transportation that manage these systems are frequently involved in corruption and/or the distribution of political patronage, and they are often not well loved by the public or the private operators. As the administrators of individual licenses, they seldom have the skills needed to manage or regulate a modern vehicle operation. Often salaries and skills are low, and these government departments lack financial or administrative autonomy. Their budget is generally decided as part of the typical municipal budgeting process, so funding is uncertain from year to year. The staff are bound by civil service hiring and firing practices, and hence difficult to replace or remove if unqualified. As traffic congestion worsens, the profits for the small informal operators tend to fall, adversely affecting their profitability and their ability to modernize their vehicle fleets and the quality of their services. Sometimes their profitability is further hampered by fares that are set at levels too low to support commercially viable operations, yet there are no mechanisms in place to subsidize the operations.

The BRT institutional structures that emerged in lower-income economies were largely responses to these failings. Some lower-income economies have done better than others in resolving these problems. The most successful systems have set up independent BRT authorities modelled loosely on the administrative structures of metro companies, but with some innovations that were only possible with vehicle operations.

12.3.1 Starting a New Agency or Adapting an Existing Agency

One of the first decisions that needs to be made when designing the institutional set-up of a BRT system is whether or not there is an existing institution that can adequately manage the new BRT system, or whether good quality management requires creating a new entity unencumbered by the administrative responsibilities of existing institutions.

In higher-income economies, BRT systems have rarely been of sufficient scale to warrant a new administrative structure to manage them. Further, the administrative structures in place are generally up to the task of managing a BRT service. Higher-income economy transit authorities or transit service providers are sometimes criticized for inefficiency, and in a few limited instances BRT projects have been part of efforts to contract out vehicle operations to private companies, but for the most part a BRT project does not introduce any significant administrative change.

BRT was not the initial motive for the contracting out of these services, and the BRT services are generally incorporated into the responsibilities of these private or public-private companies. The introduction of a BRT rarely requires significant administrative reforms or new institutions to be successful.

In the institutional context that is more typically found in lower-income economies, however, trying to implement a BRT system with a high quality of service is frequently extremely difficult to accomplish through an existing government entity. Entrenched mindsets can stifle the creativity required to develop a bold new approach such as BRT. A person whose main job has been to ensure road maintenance or regulate informal minibuses may be ill-equipped to manage an international competitive bid for vehicle operations and fare collection systems, or he or she may have no idea how to oversee the creation of BRT infrastructure and so forth. Further, given the legal and political difficulties in reshaping existing agencies and replacing civil service staff, changing the existing agency staff, structure, and mindset may not be realistic within the confines of a relatively short project timeline.

Existing government entities may also have vested interests. Any agency that awards public contracts or licenses is susceptible to corruption in the form of kickbacks, but some are more problematic from a BRT governance perspective than others. It is common, for instance, that the agency responsible for awarding public transport route licenses receives certain kickbacks, and they also sometimes play a political role of managing a network of patronage. Such an agency is likely to be reluctant to give up the benefits to the old ways of doing business. It would be ill-advised to put such an agency in charge of a BRT project, as it is just as likely to obstruct the project as it is to implement it.

Also, existing officials are likely to be associated with inefficiency and blamed by the general public for the chaotic state and poor quality of public transport services that have led to the introduction of the BRT system. A history of mistrust is likely to exist between officials and political leaders that is difficult to set aside. Finally, existing authorities are likely to be consumed with addressing daily transportation problems and are unlikely to have the incentive or time to dedicate to the development of a BRT.

For these reasons, many cities have opted to create an entirely novel institutional structure with new staffing specifically to develop and operate BRT. For many of the most successful BRT systems in lower-income economies, new institutions were created to manage them. However, creating a new agency is sometimes time consuming and politically challenging, if not impossible. In some countries, new autonomous agencies have been created, only to be mismanaged, giving such entities a bad reputation. It may also require a vote of the legislative body, and budget allocations, which are not always politically feasible.

If creating a new agency is not possible, a unit will need to be created within an existing institution or department. If a new agency cannot be created, then the BRT administrative office should be given as much authority and independence as possible. If running a BRT system under an existing government department is the only viable alternative, the problems with this should be mitigated to the extent possible by doing the following:

- Give the BRT project office its own physical offices identified as such, properly equipped with the supplies and technology necessary for staff to do their jobs;
- Dedicate full-time staff to the office without other administrative responsibilities;
- Allow for a fully dedicated budget, under the control of the BRT project head, sufficient to the tasks expected of it. This budget should be sufficient to hire long-term consultants who can fill in the skill gaps that cannot easily be filled through traditional civil service hiring procedures.

If these objectives are fulfilled, many of the problems of running a BRT out of an existing government department can be partially mitigated.

12.3.2 Institutional Independence and Financial Ring Fencing

In higher-income economies, public transport authorities and public transport service providers have found a reasonable balance over time between political accountability to the voters and independence from day-to-day political interference in their affairs. While this autonomy can be achieved in multiple ways, first and foremost, the government agency is likely to be able to retain its independence only if it is financially independent. The financial autonomy of any public authority or transit service company is generally achieved by ensuring that operating expenses (including personnel costs) are covered, to the degree possible, by revenue from user fees. For a transit authority or a transit service provider, this starts with dedicating the fare system revenue to the transit service.

Financial independence starts by designing the system from inception to be self-financing. This means that regulatory authorities need to be prepared to adjust fares if necessary to ensure that fare revenues can cover operating costs, or, if there is to be a political decision to subsidize the fares, that a stable source of government subsidy is readily and reliably available to make up the operating deficits. This is normally done by earmarking tax revenues to a specific public purpose such as the public transport system. Without this, BRT services will enter the same downward spiral of disinvestment and service quality decline that has frequently afflicted normal bus services.

Secondly, financial autonomy is generally achieved by having the transit agency incorporated in such a way that it is impossible for politicians to reallocate any operating surpluses to other public purposes. Also, it should be incorporated in such a way that the authority responsible for a BRT system is not responsible for other public debts. Any surpluses should be pumped back into the system in the form of improved services or new capital investments, and it should be unencumbered by other public debt not related to its own activities. When these objectives are achieved, a transit agency is said to be financially "ring-fenced." Because not all public transport systems are alike, it is likely that one mode of public transport will have greater debts or greater needs for operating subsidies than another. In general, rail properties are more expensive to build and operate than BRT systems, and less likely to recover their operating costs from users than BRT systems.

BRT systems in lower-income economies are often huge operations with hundreds of thousands, if not millions, of daily customers, and generally there are fare structures and ways of structuring the business that create the conditions for full recovery of operating costs from fare revenue. Most BRT operators were created out of fully private bus or minibus operations that also earned a profit and operated under a hard budget constraint, and once the services were removed from traffic congestion and bus stop delay, the system became highly profitable and still able to provide a much higher quality of service over the previous system. BRT service planners who have worked in lower-income economies typically design the new BRT system to operate with full cost recovery. As such, the possibility exists in most lower-income cities for a BRT to operate without subsidies and hence to be fully financially ring-fenced without earmarked tax revenues.

Rail properties in lower-income economies, by contrast, rarely if ever recover their operating costs, particularly if the maintenance of the infrastructure and rolling stock is included as an operating expense. Because full cost recovery generally applies only to BRT, an administrative setup that involves financial ring fencing based solely on user fees is possible only if the BRT system and the rail systems are kept institutionally separate. By integrating the administration of BRT with rail, any operating surpluses from the BRT system risk being diverted to the rail properties, rather than being reinvested into the BRT.

To give an example, the Mexico City Metro recovers only 39 percent of its operating costs from the fare box revenues (Cervero, 1998), while the Metrobús BRT system operates with full cost recovery, and covers most of the cost of the rolling stock out of the fare box. Raising the fares on the Mexico City subway has been politically difficult and Mexico City lacks the sort of earmarked tax base that can make up for the losses. As such, the Metro system has faced a gradual decline of service and disinvestment that has alienated many customers. The BRT system, being a new system, was politically easier to initiate at a higher fare level, and it has proved relatively unproblematic politically to raise the fares. As such, in this context, financially ring fencing the BRT agency independently from the Mexico City subway, and hence keeping the two institutional bodies administratively separate, was critical to allowing the Mexico City Metrobús BRT system to flourish unencumbered by the growing debts of the subway system.

In higher-income economies, as most BRT systems are not operated independently from other bus services, the accounting systems are frequently not in place to assess the profitability of the BRT system separately from the rest of the bus system, and as a whole the bus systems tend to operate at a loss. For instance, in the US Federal Transit Administration's National Transit Database, of the five older BRT systems in the United States (Los Angeles, Cleveland, Las Vegas, Eugene, Oregon, and Pittsburgh), only Cleveland lists separate fare box recovery ratios for its BRT system.

Table 12.2. Greater Cleveland Rapid Transit Authority Operating Expenses and Revenue (in US$)

Mode	Operating Expense	Operating Revenue	Cost Recovery Ratio
BRT	$6,514,207	$4,813,838	74%
LRT	$12,339,684	$2,970,307	24%
Heavy Rail	$29,362,013	$6,489,400	22%
Bus	$142,998,626	$35,208,409	25%

Source: National Transit Database, 2015

The cost recovery ratio of the BRT system was 74 percent, much higher than any other public transport mode in the Greater Cleveland Metro area, with normal buses performing the next best at 25 percent. Though it operates at much less of a loss than other modes, it still operates at a loss. The fleet of the BRT, only sixteen vehicles, is also too small to manage as a separate concern. Financially ring-fencing a public transport system in higher-income economies thus generally requires tying together BRT, standard bus, and rail properties and finding stable sources of long-term operating subsidies from earmarked tax revenues to complement fare revenue for all of the modes. Because rail and bus management—and by extension, BRT—is generally already integrated into the same institutional structure in higher-income economies (since all modes need subsidies), and because the scale of the BRT system is generally pretty small, the case for financial ring-fencing only the BRT system in higher-income economies is weaker than in lower-income economies. That said, were the BRT systems in Pittsburgh and Los Angeles analyzed for their cost recovery ratio, and were BRT implemented in the cities with higher bus demand like New York, Chicago, or Seattle, it could be possible that the BRT lines would be financially self-sufficient, opening up the possibility of new institutional and contractual forms to be considered in the future.

12.3.3 Clear Authority and Lines of Responsibility

A new BRT system requires significant coordination across a number of existing departments and agencies, many of which may not have much experience working together. Unlike a metro project, which might be able to tunnel under or bridge over many of the daily traffic management issues confronted on surface streets, a BRT system generally uses surface streets, and therefore the management of a BRT project has to coordinate with or control all the bodies that govern what happens on those streets.

In higher-income economies, most of the key functions needed to operate a successful BRT are under the control of a transit or transport authority, the municipal department of transportation, or the companies contracted to manage these functions for city government. Transit authorities or transit service provider companies both have experience managing large vehicle operating contracts and can readily assume responsibility for the core BRT operational tasks. Meanwhile, departments of public works or transport have experience with road projects and can assume responsibility for these tasks, and coordination is primarily needed between these two entities—usually the lines of administrative authority are reasonably clear.

In lower-income economies, the situation is often quite different. There may be multiple government administrative bodies with overlapping legal mandates and limited capacity to fulfill these mandates. The core operating functions of a BRT system can be entirely new to the city, and there is no existing institution in place with experience in public transport service planning, contracting out of vehicle operations, hiring of companies responsible for fare systems. This administrative skill generally has to be built from scratch using consultants. Other functions, such as road construction, route licensing, and traffic management generally already have institutions managing them, but sometimes there is more than one agency responsible for the same tasks, and perhaps none of the tasks are being performed particularly well.

Because of the need for this broad coordination across multiple areas, it can initially seem appealing to deal with all of these issues by creating one large, new transportation authority with broad powers over all elements of urban transport that is capable of coordinating all critical project elements in-house. In theory, it might be an appealing prospect to take the opportunity of a BRT project to put all these functions under a single institution to ensure the greatest degree of coordination.

While Transport for London seems like an almost mythical touchstone for a single agency able to responsibly manage all elements of urban transport, it was not created from scratch; Transport for London was created by consolidating pre-existing functional institutions under a single leadership structure over a period of decades. Unfortunately, in lower-income economies, the reality is that the basic building blocks out of which Transport for London was created are not yet in place. It is extremely difficult to create a new government institution. Creating an institution on paper with nominal authority over every aspect of urban public transport is a different matter from creating a functional institution actually capable of managing even one element of the urban transport system, let alone all of them.

Thus, in order to get a BRT implemented in a relatively short time frame, it is critical that if the municipality decides to create a new public agency to manage the BRT system, that the administrative responsibilities of this agency be as narrowly defined as possible down to those critical elements of BRT system management that cannot be managed by another existing government body or agency. A fledgling agency trying to learn about BRT cannot also be tasked with solving other problems, such as traffic management, public transport route license regulation, unsafe intersections, or the number of potholes citywide. The new staff will be unable to resolve all of the city's transport problems, and in the end runs the risk of being able to solve none of them.

How, then, can a new government agency with a very narrow focus also be able to make sure that road designs, traffic lights, and large engineering projects not under their full administrative control be implemented in a manner consistent with the needs of the BRT system? BRT system planners will need to muddle through with some combination of the existing suboptimal government bodies and perhaps one new institution with much more limited powers and abilities. If such an institution with broad powers cannot be created as a prerequisite of implementing a BRT system, how then can all of these distinct elements of a successful BRT system come together and function?

The answer lies in having the chief executive in charge (usually the mayor or transportation secretary) empower the head of the BRT project—generally still housed in an interim BRT project office—with decision-making authority. This should be backed by the direct involvement of the mayor or his or her designated representative, on all critical matters related to the BRT system implementation. Sometimes this is backed up by interagency agreements that clearly stipulate that the BRT project team leader, and eventually the head of the BRT agency, if one is created, has final say over infrastructure designs, traffic signals, affected competing public transport licensing, and other matters related to the BRT in order for the project to be successful. In other words, the trick is usually to extend the powers of a modestly sized agency by extending its authority related to BRT matters over other administrative units, either through interagency agreements or through intervention of the chief executive in charge, or both.

In the case of Bogotá, for instance, the BRT project office (at that point, already TransMilenio SA, a municipally owned company) had to make critical decisions affecting the public works department (Institute for Urban Development), which supervised the construction. Much of the design work was done by consulting engineers under contract to the BRT authority and the construction work was then tendered out by the Institute for Urban Development following these design specifications. There was a good match between the designs and actual construction, although in other cases there have been some problems.

Mexico City, which has several silver standard BRT corridors, followed Bogotá's example and created a new BRT authority (Metrobús) that designed the BRT system and supervised the overall project, though negotiations with affected public transport operators were managed by the Department of Transportation, and civil works were managed by a public works department. This structure worked well because the mayor made sure that his line agencies coordinated with Metrobús on what they needed.

Unclear lines of authority and control can undermine a BRT authority even if one is created. In the case of TransJakarta, a BRT agency (TransJakarta) was created, but it did not have final say over the design of the infrastructure, which was supervised by the Department of Transportation. There were numerous design flaws that significantly adversely affected operations. In other cases, such as Lanzhou, China, the engineering was done by a Guangzhou-based engineering firm, Guangzhou Metropolitan Engineering Design Research Institute (GMEDRI), but construction was done by the Municipal Construction Commission and GMEDRI did not have a contract to supervise the construction. As a result some small but important changes were made to the design in the construction phase that had some adverse impact on operations.

In the case of the Brasília BRT, the transit authority Transporte Urbano do Distrito Federal (DFTrans), which was responsible for the BRT operations, did not have sufficient control over the development of the infrastructure or fare collection system. The delivery of stations as well as fare and customer information systems were the responsibility of the Roadway Infrastructure Department (DER-DF). This department previously had only been responsible for civil works, and had no experience with station architecture or intelligent transportation systems. The design and delivery of stations and terminals were poor, with only some terminals operational more than a year after the initiation of operations, with many nonfunctioning turnstiles and nonfunctioning customer information systems. Contracts will eventually be shifted to DFTrans.

In Dar es Salaam, both the BRT agency Dar Rapid Transit (DART) and the transportation licensing authority Surface and Marine Transport Regulatory Authority (SUMATRA) had a legal mandate to license public transport operations in Dar es Salaam. Since DART was under the Ministry of Regional Administration and Local Government and SUMATRA was under the Ministry of Transport, resolving any differences of opinion required escalating the issue to the prime minister for resolution.

The traffic signals, lane markings, right-of-way enforcement, operational control system, and fare collection system also need to be overseen by the agency responsible for the BRT system. In the case of the Rea Vaya system in Johannesburg, the fare collection system, the operational control system, the lane demarcation, and the traffic signals were all under the Johannesburg Roads Agency (JRA), an independent municipal entity that did not initially report to the Department of Transportation that was in charge of the BRT project. As a result, the operational control system procured was mostly aimed at normal traffic management and was not primarily a BRT operational control system. Additionally, the fare collection system was delayed, and lane markings, road signage, and turning movements were implemented well after operations had started, leading to a lot of traffic confusion in the first months after the system opened. As these tasks were not under the administrative authority of the head of the BRT project, all these problems had to be elevated to the mayoral committee level for a decision. Since then, to address these problems, the JRA was put under the administrative oversight of the Department of Transportation.

In many parts of Africa, administrative authority over licensing of public transport operations and management of specific urban roads remains unclear, leading to considerable uncertainty for potential investors in these systems and generally poor quality public transport services.

Therefore, success of a BRT system requires that the government establish clear lines of control and reporting on all key functions necessary to the smooth running of a BRT system. This might be done through a single government body being placed in charge of all aspects of a BRT system, but more commonly this is done through more informal arrangements where a key decision maker remains sufficiently involved so that the decisions critical to the functioning of a BRT system are made in a timely manner and government agencies responsible for implementing these decisions all abide by a common decision and are held accountable for their actions.

12.3.4 Functions to Be Performed by a BRT Institution

This section lays out the functions of a BRT system that need to be managed well for the BRT to be successful. Before the BRT system becomes operational, the BRT project office (Section 12.2: Initial BRT Project Office above) should already be in place with a fully functioning team learning how to manage a BRT system. Although consultant teams can be recruited to undertake a variety of specialized functions, a strong nucleus of skilled experts will be required to assume long-term operation of the system. To ensure continuity and coherence in decision-making, the staff managing the BRT project office should be incorporated into the management structure of whatever government body is entrusted with the long-term management of the BRT system, as they are the staff with the most experience with BRT in that city.

The period during which technical studies are being developed by the consultants is the time when the local government team must be trained and the institutional structure established. Waiting for the culmination of an external consultancy to study and present the system information before initiating the preparation of the implementation phase of the project will significantly undermine the ability of using the consulting studies to train the local team, as competent, experienced consultants are generally the best teachers. Ideally, training the local team should be included in the terms of reference (TOR) of any BRT consultant brought in to help design the system.

Some of the core functions will ultimately be contracted out, and others will be done in-house by the agency responsible for the BRT system. Chapter 13: Business Structure and Contracting considers which functions to contract out and how to do so. For now it is enough to know that all of these functions will need to be the responsibility of someone.

The functions are as follows:

1. **BRT Service Planning**

(a) **Design of the BRT services**

This is usually done by consultants initially but the work should be supervised by a team that eventually can learn how to design and optimize BRT services for future phases without the need for outside consultants. Normally, conceptual design of the BRT services (the basics) is managed by the planning department and the detailed service plan (scheduling, precise routing, etc.) is managed by an operations department. This service design becomes the basis of the contracts for BRT services.

(b) **Prepare and manage operating contracts**

This is usually done by public transport operations experts and lawyers together, as well as by institutions with experience managing public transport operating contracts if such exist. This is usually managed by the operations department of the BRT agency or the planning department. Such contracts may include, but not be limited to:

- BRT vehicle operations (trunk, feeder, complementary);
- Fare collection provider;
- Operational control center;
- Station management and maintenance;
- Financial service provider (picks up fare revenue, deposits it, holds it, pays contractor);
- Business plan consultant;
- Transaction adviser.

2. **BRT Infrastructure**

(a) **Design of BRT infrastructure**

This task is usually initiated (conceptual design level) by the planning department as basic infrastructure designs are needed for cost estimates and they need to be carefully harmonized with the needs of the BRT services;

(b) **Detailed engineering design and procurement plan for BRT civil works**

Usually based on an agreed-upon schedule of infrastructure and maintenance contracts. Functions include:

- Procure works and other contracts;
- Supervise the construction works for compliance with the plans;
- Supervise the enforcement of the contracts and monitor the performance of every contractor;
- Ensure that all procurement is undertaken in accordance with appropriate regulations.

It is important that civil works and the installation of IT systems be harmonized with the needs of operations, and that the timing of the completion of the civil works and IT systems be harmonized with the timing of the vehicle operation commencement. This is normally done by individuals and institutions with experience in tendering and supervising large public works contracts. The actual work is usually done by construction companies. Tendering should be designed to ensure that high-quality construction companies are encouraged to bid.

3. **BRT System Planning Functions**

(a) **Design of the project timetable**

This is normally done by the planning department of the agency responsible for the BRT, and is the tool used to ensure the harmonization of project deliverables across time.

   (b) **Defining future BRT corridors, and conceptual design of the infrastructure**
   Sometimes future phases of the BRT system affect the design of the first phase, and the more information known about future phases the better, though it is not always practicable. This is normally a function of the planning department of the BRT agency.

4. **Land Acquisition**
   (a) **Supervise land acquisition and any required resettlement**
   While most BRT systems do not require much land acquisition, most require some, usually at bottleneck stations and in planned depot locations. Land acquisition and resettlement can be time consuming and difficult, but are important to get right to avoid needlessly driving up project costs or compromising the system's services or having adverse social impact. This could be handled by the public works department (as it is probably used to this issue), the agency responsible for BRT operations, or a competent contractor to one of these agencies.
5. **BRT Operations**
   (a) **Coordinate schedules of all BRT operating companies**
   As most BRT operators are paid by the bus kilometer, the allocation of service kilometers between the operating companies is an important quality control mechanism. This is usually done by either the operations department or the planning department of the agency responsible for the BRT system, or its outside contractor.
   (b) **Define and update operational aspects of BRT services**
   This generally entails updating the number of bus kilometers, routes, frequencies, and so forth, based on changing demand. This is usually done by the operations department of the BRT authority or its contractor.
   (c) **Oversee quality of service contracts and maintain operator penalty fund**
   This is normally a responsibility of the BRT operations team. Usually their personnel sit at the depot of the operators and clock the arrival and departure of the vehicles, as well as the status of the vehicles and their operators at time of depot exit. It can also be done remotely from the operational control center via electronic surveillance.
6. **Industry Transition**
   In lower-income economies, where existing services are managed by private informal operators, developing and implementing a policy for how existing non-BRT public transport operations affected by BRT operations will relate to new BRT operating contracts is critical to project success. This involves using the service plan to determine which existing public transport services are affected or not affected, then walking key decision makers through their options with respect to how best to involve the affected operators. This is normally best done by people with experience both in business development, labor negotiations, and managing community participation processes. It is normally a function of the team responsible for BRT operations.
   In higher-income economies, it is important to understand all outstand-

ing contracts with private service providers that will affect the implementation of a BRT project. If there is already a firm contracted to manage bus services in the city, for instance, it will need to be involved in the development of the BRT system. If there is a firm contracted to manage all the bus shelters in the city, or all the parking spaces in the city, then there needs to be a review of how these firms and their existing contracts will be affected by the new system, and any significant issues should be reviewed and addressed.

7. **Financial Administration**
   (a) **Prepare and approve a fare policy**
   Normally, for a BRT system to remain financially self-sufficient, the fare needs to be increased gradually to keep pace with inflation. The best BRT systems have a formula agreed upon by the BRT system operators and the body responsible for regulating the fare, which forms the basis of automatic fare increases. As this is normally pegged to outside economic indicators such as published costs of fuel, consumer price indexes, and so on, it is typically done by a staff economist at the team responsible for the BRT system operations.
   (b) **BRT business plan and financial model**
   Ideally, the overall BRT system's costs and revenues have been modelled in advance of operations so that the profitability of the system overall can be roughly known in advance and adjustments can be made if necessary. The more the planning team knows about the profitability of the system overall, the better it can present the financial needs of the system to any executive or legislative bodies needed for financial support. It also helps when going into negotiations with informal operators to know in advance what the services should cost. These functions are usually performed by the planning department of the BRT agency together with the finance department. How this is done is covered in Chapter 14: Financial Modelling.
   (c) **Oversee quality and security of fare collection system**
   Since the system's main source of income is fare revenue, making sure that the fare revenue is being properly collected, deposited, and accounted for is a critical function, normally of the team responsible for BRT system operations.
8. **Communications**
   (a) **Define and promote BRT brand**
   Most great BRT systems have a recognizable brand that helps set apart its superior services from normal bus services. This brand only gets created once and is usually done by a consultant or can sometimes be done through a public contest.
   (b) **Communicating to the public about the BRT system's benefits**
   A successful communications strategy will have a big impact on how well the system is received. A skilled communications team can win broad sympathy for the BRT project by highlighting the problems with the existing system, and the benefits of the new system. This can significantly strengthen the government's hand during public hearings and negotiations with various stakeholders. Getting such public hearings right is critical to BRT system success, particularly in places like the United States where public participation procedures are mandatory

and often result in watering down critical BRT elements.

(c) **Manage system user information**
A high-quality BRT system should be equipped with attractive, easy-to-use system maps, functioning real-time information, an up-to-date website, integration with relevant social media, and readily available information about schedule changes.

(d) **Manage public awareness of temporary changes in roads**
Regularly publicizing major road works is part of the standard operations of a public agency with experience with major public works. However, if it is done poorly, it can adversely affect public perception of the BRT project. It is therefore important that BRT project staff ensure that this is handled professionally.

(e) **Manage public awareness of the project overall**
Normally, the public will want to know what is coming. Managed release of project information (the vehicle, station design, etc.) can keep the media focused on positive change and divert attention from any problems. This is a key role of the agency responsible for the BRT project or its contractors.

(f) **Promote ridership**
Once the system is operational, the BRT system can be promoted and advertised like any other business.

(g) **Administer any system advertising contracts**

9. **General Management**

(a) **Manage general finances and human resources**
These are the normal administrative functions of any public authority, agency, or department.

In most cities, there are likely to already be personnel skilled at doing some of these tasks operating inside some institutions, while it may be that there is no one inside any existing government institution with experience in other tasks. For these tasks, new institutions may be desirable, and staff expertise will need to be developed over time.

Starting day for the BRT team occurs well before the first day of operation. It commences as operational contracts are developed. Technical teams of the BRT agency should be involved with legal experts in the development of all operational contracts, to ensure that contracts are desirable, practicable, and enforceable. One of the largest institutional and management challenges to any BRT system is to develop the necessary staff inside the government authorities responsible for managing the various aspects of the BRT system, to ensure that reporting structures and responsibilities are clear, and that the team is sufficiently trained and motivated. The use of traditional management consultants in institution building is often a worthwhile investment to make sure the BRT authority functions as well as possible in the service of its customers.

Hiring the right staff to fill each of these tasks, and properly training them, is as critical, if not more critical, than perfecting the institutional structure. Recruiting high-quality staff requires competitive salaries and the potential for career advancement within the BRT agency built on a system of merits, knowledge, and preparation. Advancement and recruitment processes need to be independent and transparent. Ideally, the hiring process should be done through an open invitation at the start of the implementation process to ensure continuity and coherent decision- making. An appropriate time to commence hiring would be as the consultants are developing technical studies. This allows the government team to be trained and the institutional structure to be established prior to operation. Waiting for the culmination of an external consultancy to hire staff will significantly affect the ability of this unit to perform its duties, since they will not be adequately trained and will be poorly equipped. This leads to a situation of constant "firefighting" rather than effective operational management. That being said, institutional structures do matter, and it is to these issues that we now turn.

12.4 Alternative Institutional Structures for BRT System Management

> *"To punish me for my contempt for authority, fate made me an authority myself."*
>
> — Albert Einstein, physicist, 1879–1955

While urban transportation systems are managed in a variety of ways in different cities, successful BRT systems tend to exhibit certain characteristics and organizational forms. Figure 12.3 provides a reasonable sample of the better BRT systems and their associated institutional forms.

Institutions Managing BRT Systems, Select Cities

	Bus Authority	BRT Authority	Transport Department Contracted BRT	Public Bus Company	Metro Company	Authority (excluding Metro rail)	Transport Authority (All transport)	Transit Authority	Contracted Transit Service Provider	Transport Department In House
Lower-Income Countries										
TransMilenio, Bogota		X								
Medellin, Colombia					X					
GBRT, Guangzhou		X								
Guadalajara, Mexico		X								
Lima (Protransporte)		X								
Rio de Janeiro (Transoeste)			X							
Curitiba (URBS)	X									
Belo Horizonte (BHTrans)						X				
Pereira, Colombia (Megabus)		X								
Guayaquil, Ecuador (Metrovia)		X								
Cali, Colombia (Mio)		X								
Sao Paulo, Brazil (SP Trans)	X									
Ahmedabad (Jan Marg SPV)		X								
Johannesburg (Rea Vaya)			X							
Monterrey, MX			X							
Mexico City (Metrobus)		X								
Estado de Mexico (Mexibus)		X								
Jakarta, ID (TransJakarta)		X								
Leon, MX (rating pending)		X								
Caracas, VZ					X					
Lanzhou, BRT				X						
Beijing, China				X						
Jinan, China				X						
Puebla, MX		X								
Cape Town BRT			X							
Lagos busway (Not BRT)							X			
Delhi HCBS (basic BRT)				X						
Dar es Salaam (2016)		X								
Higher-Income Countries										
Rouen, France (TransDev)									X	
Paris Mobilien, Ile de France (RATP)									X	
Brisbane, Australia (TransitLink)								X		
Amsterdam R-Net (rating pending)									X	
Nagoya busway (rating pending)										X
HealthLine, Cleveland (RTC)								X		
Cambridgeshire, England									X	
Nantes, France (Semitans)									X	
LA Metro (Orange Line)								X		
Las Vegas (RTCSV)								X	X	
Ottawa, Canada (OC Transpo)										X
Pittsburgh MLK (Port Authority)								X		
London (busways only)							X			
San Francisco (no BRT yet)							X			

Gold Standard BRT
Silver Standard BRT
Bronze Standard BRT
Basic BRT, not yet rated BRT, not BRT, not yet implemented, as specified

Figure 12.3. Administrative authorities responsible for BRT systems in select cities. *Walter Hook, BRT Planning International, LLC.*

The types of institutions responsible for managing BRT systems vary greatly between higher- and lower-income economies. In lower-income economies, the majority of BRT systems are managed by public authorities with responsibilities solely focused on the BRT system. A few are managed by public authorities with responsibilities for managing both BRT routes and normal bus routes. A couple are managed by public metro companies. A few are managed by public bus monopolies. The South African systems are managed by multiple divisions inside municipal departments of transportation, but they are contracted out in a manner similar to how a Latin American BRT authority would contract out operations.

In higher-income economies, the trend is for public transport authorities to operate BRT systems in addition to standard bus and rail operations, or to contract out all public transport services (not only BRT) to a public transport service provider that is likely to have mixed public and private ownership. A few systems are directly operated by a government department.

12.4.1 BRT System Administration in Lower-Income Economies

12.4.1.1 BRT Authorities

The majority of the best BRT systems in lower-income economies are managed by public authorities or companies with a mandate focused solely on managing the BRT system. These authorities are often similar in structure and purpose to metro companies. Decision makers looked at how successful metro projects were managed, and they noticed that most of them were run by specialized corporatized agencies or government companies specifically focused on building and operating the metro system. They wanted BRT systems to enjoy the same management benefits as metro companies. However, they were also able to explore other contracting forms, such as having multiple, separate vehicle operators operating on the same trunk infrastructure, which have proved more difficult to implement in rail systems.

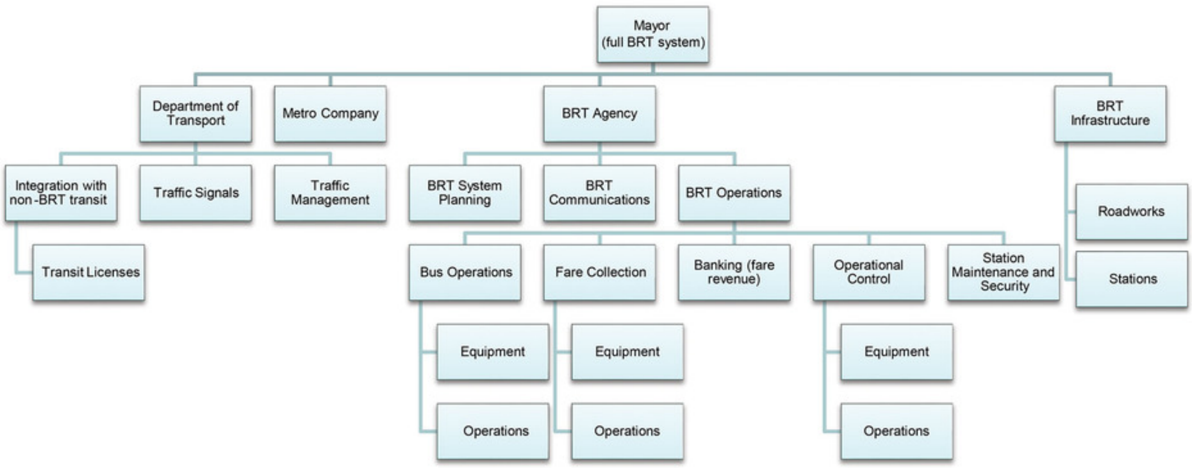

Figure 12.4. Typical administrative structure under a BRT authority. *Walter Hook, BRT Planning International, LLC.*

Figure 12.4 depicts a fairly typical administrative structure for a BRT system managed primarily by a BRT authority. The BRT authority manages the vehicle operations (usually through subcontractors), the fare collection system, the operational control systems, the system communications, and the customer information. The BRT authority is also given oversight of the design and construction of all BRT infrastructure. They are not generally responsible for directly contracting out the necessary civil works, however. Contracting out large civil works is a specialized skill that is generally better managed by an entity that already has experience managing civil works contracts worth tens, if not hundreds, of millions of dollars. Though this is generally managed by a department of public works or its equivalent, the designs need to be approved by the BRT authority before they can be tendered. This approval role is best written into the BRT agency's bylaws and confirmed by interagency agreements. If this is impossible, the mayor or another key decision maker will need to support the decisions of the BRT authority leadership in frequent interagency meetings, where final approval over the design by the BRT authority is not fully formalized.

Similarly, responsibility for traffic markings, designation of the dedicated lanes, traffic signals, and the licensing and regulation of non-BRT public transport operations on the BRT corridor, generally remains with the city or national department of transportation. Again, if the BRT authority needs traffic signals changed, or non-BRT public transport licenses changed, the key decision makers will need to back up the BRT authority or else the quality of the system will be compromised. Police or traffic departments that refuse to follow proposed turning restrictions or signal phasing proposed by the BRT authority can cause operational problems for the BRT system and worse mixed-traffic congestion.

Metro companies are typically separate management entities. Coordination of the physical design and fare systems of the BRT with the metro depends on the BRT authority designing the system with good physical integration and fare system compatibility with an existing metro system. If the metro system is new and the BRT already exists, it is incumbent on the metro authority to design its new system with integration with the BRT. The mayor or senior decision makers need to require this.

Normally, BRT authorities are public entities governed by a board of directors, and in this way they differ from normal government departments. The board of directors generally gives the management of the BRT authority an arms-length relationship to the heads of government. The board is likely to be appointed by the mayor, or in the case of an agency funded by both state and local government, by the state and local government. An appropriate composition might include a high-level city representative, a representative from both the local and state governments, and two further representatives from academic institutions or technical experts in the field. Though it sometimes occurs, it is generally not advisable to include private transporters (e.g., vehicle operators) or unions directly on the board as this is likely to lead to conflicts of interest, since public transport operators and unions are likely to end up on the other side of the negotiating table from the BRT authority's management. Ideally, board positions would be rotated with overlapping tenures to ensure continuity and minimize the impact of political changes. The general manager of the BRT agency should be chosen by the board for fixed periods of at least three years, subject to extension.

TransMilenio SA was formed as a BRT authority that reports to the city's mayor through a board of directors. Other more traditional government departments also play a significant role in Bogotá's BRT system, but the new BRT authority has taken the lead in terms of ensuring efficiency and an entrepreneurial approach. TransMilenio's board consists of ten directors who are derived from a cross-sectional representation of interested parties. The city's mayor or a representative of the mayor acts as the board's chairperson. Included in the board are NGOs and citizens' groups who are better able to provide a customer perspective. Many of the related agencies, such as the transport regulator and the public works agency, are also represented on the board in order to assure coordination between all government organizations. In summary, the groups and individuals included in the TransMilenio board of directors are:

- Mayor of Bogotá;
- Secretariat of Transit and Transport (transport regulator);
- Institute for Urban Development (IDU);
- Civil society representative (from academia or elsewhere);
- Civil society representative (from transport or environmental NGO);
- Municipal Department of Planning;
- National Department of Planning;
- Municipal Secretariat of Finance.

In the early years of TransMilenio, the board did not include the Department of Transportation. It was only added later, after TransMilenio was well established.

Board meetings are also attended by the general manager and assistant general manager of TransMilenio SA. The staff does not have a vote but is there to answer questions that may arise. The board of directors is also served by financial and accounting specialists who can handle audits of the system.

BRT authorities are generally established as independent public authorities or government companies for the same reasons that metro companies are set up this way. First, independent agencies and companies can be (though they are not always) established in a way that frees them from cumbersome civil service personnel policies. Such policies tend to make the hiring and firing of staff difficult; compromise the ability to pay competitive salaries for specialized skills; make the hiring of new staff a protracted affair; and politicize decision-making and hiring and firing procedures, leading to ineffective institutions, lack of customer responsiveness, and bloated payrolls.

The other reason specialized BRT authorities are established is that BRT systems are complicated to set up and operate, so they need a fully dedicated team managing them. If the team managing the project has other administrative tasks, or is constantly being diverted from the task of implementing the BRT project with other political objectives, then it is likely that the project will be delayed or badly implemented. Too frequently, the persons responsible for a BRT project have so many other administrative responsibilities that they are never able to focus on creating the new system. Over time, as the BRT project team learns their jobs, develops protocols for running the system, and the number of trained staff expands, it may become possible to expand the responsibilities of the BRT authority to the management of the remainder of the bus system.

Additionally, BRT system administration is generally easier to financially ring-fence when it is a stand-alone entity than when it is administratively under the same management as a rail system. This is because a BRT system in a lower-income economy is more likely to be able to fully recover the cost of the operations, including the cost of procuring the vehicle fleet, financing the vehicle fleet, and managing the system, than is a rail company. TransMilenio in Bogotá, for instance, funds the entirety of its operating contracts, the cost of its management staff (TransMilenio SA), the vehicle procurement, and the financing of the vehicle procurement from fare box revenue. This creates the possibility of insulating all of these functions from political interference in management, which becomes possible as soon as the management entity relies on the legislature for its budget allocation. A rail system, by contrast, is far less likely to be able to cover its operating costs, its rolling stock procurement and financing costs, and its own management costs out of fare revenues. By linking the two entities, it is likely that the BRT system will be financially encumbered by the losses of the rail division and lose the independence possible only from financial self-sufficiency.

The BRT authority *initially* is not generally in charge of managing the licensing and regulation of the remaining non-BRT public transport services. There are several reasons for this:

1. Transportation departments of municipal governments tend to regulate informal bus and minibus operators in a way that earns both licit and illicit revenue for the department. As such, these departments' revenue streams are threatened by the BRT projects, and hence they are sometimes bad advocates for BRT. Initially at least, it is sometimes safer to keep the BRT project team at arm's length from these departments of transportation.
2. It is a big job to regulate the non-BRT public transport operators in a city, and requiring a BRT authority to also be responsible for this task is likely to take talented administrators away from other more mission-critical tasks involved with implementing and operating the BRT system itself.

If the non-BRT routes are regulated not by the BRT authority but by an existing department of transportation, it is important that the BRT authority be given the authority to cancel or reroute any preexisting route licenses or service contracts where these services will be superseded by the new BRT service plan. If the BRT authority does not have the power to regulate the non-BRT public transport routes, it is possible that these routes will continue to operate in parallel with the BRT, contributing to mixed-traffic congestion in the corridor and draining the BRT system of customers. Forcing department of transportation heads to comply with this mandate has frequently proved difficult. For TransMilenio, Mayor Peñalosa had to fire several department of transportation heads in order to get the department to comply with TransMilenio's order to reroute or suspend certain route licenses that were made redundant by TransMilenio. In Jakarta, coordination on non-BRT route licensing between TransJakarta and the Department of Transportation was a continuing source of tension. In Johannesburg, Cape Town, and many other BRT systems, it has proved very difficult to coordinate the BRT and non-BRT services.

Experiences with the quality of these independent BRT agencies varies greatly with circumstances and other considerations. TransMilenio's relative independence and administrative skill was exceptional in the early years of its operation. Over time, however, it became clear that the institutional structure alone was insufficient to protect the system from mayors who were less politically vested in the system. After Mayors Peñalosa and Mockus were no longer in power, subsequent mayors were less interested in maintaining and improving the quality of service at TransMilenio. Operational problems went unresolved, overcrowding that could have been solved by operational adjustments and targeted investments was left unaddressed, and the once stellar reputation of TransMilenio, while still positive, was tarnished. Most of the other BRT systems in Colombia are modelled on TransMilenio and have performed reasonably well.

Metrobús in Mexico City, which was an independent BRT authority modelled after TransMilenio, did a reasonable job of emulating the management success of TransMilenio and has maintained a reasonably good level of service as new corridors have been added. Guayaquil's BRT is run by a dedicated BRT authority. Guayaquil placed the BRT system under the control of a nonprofit quasi-governmental body, the Fundación Municipal de Transporte Massivo Urbano de Guayaquil, which has representation of a wider group of stakeholders on its board of directors and thus has slightly greater political independence. This works well in Ecuador to insulate certain critical institutions from political interference in a country where polarized politics tends to hamstring the management of other forms of public enterprise.

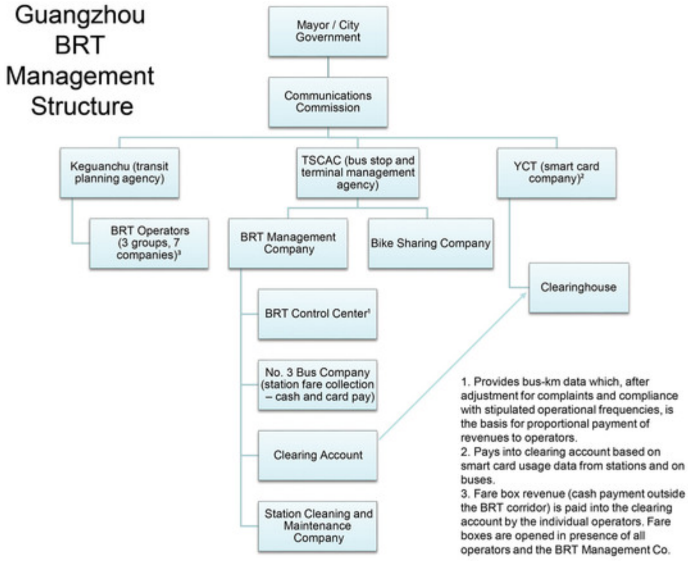

Figure 12.5. Guangzhou BRT management structure. *Walter Hook, BRT Planning International, LLC.*

Guangzhou also created a public administrative body to manage the BRT known as the BRT Management Company. It is under the Bus Stop and Terminal Management Agency of the Communications Commission (Department of Transportation). It is not a public authority with an independent board of directors. It controls the fare collection system at the stations (via a subcontract with one of the BRT vehicle operators), the operational control center, and a station cleaning and maintenance company. The contracts with the three BRT vehicle operating companies, however, are not signed by them but by the Transit Management Bureau (Keguan Chu) that manages all the vehicle operating contracts in Guangzhou. The smart card fare collection contract is managed directly by the Communications Commission. The quality of service in Guangzhou's BRT is generally considered to be better than in most of the rest of China, where BRT operations have generally been turned over to monopolistic municipal public bus companies. Guangzhou was an innovator in the contracting out of bus services to quasi-private companies (only a few of them were fully private, the others were companies owned by different branches of government) even before the BRT system was implemented, and these reforms were extended with the use of some basic quality of service contracting for the Guangzhou BRT, something that has made little headway in other Chinese cities.

In Mexico, in Puebla, and in the State of México, where part of the infrastructure is nominally going to be paid by the fare revenue, special purpose BRT authorities have issued contracts for both the infrastructure and the fare collection system in one contract and the vehicle operators in a separate contract.

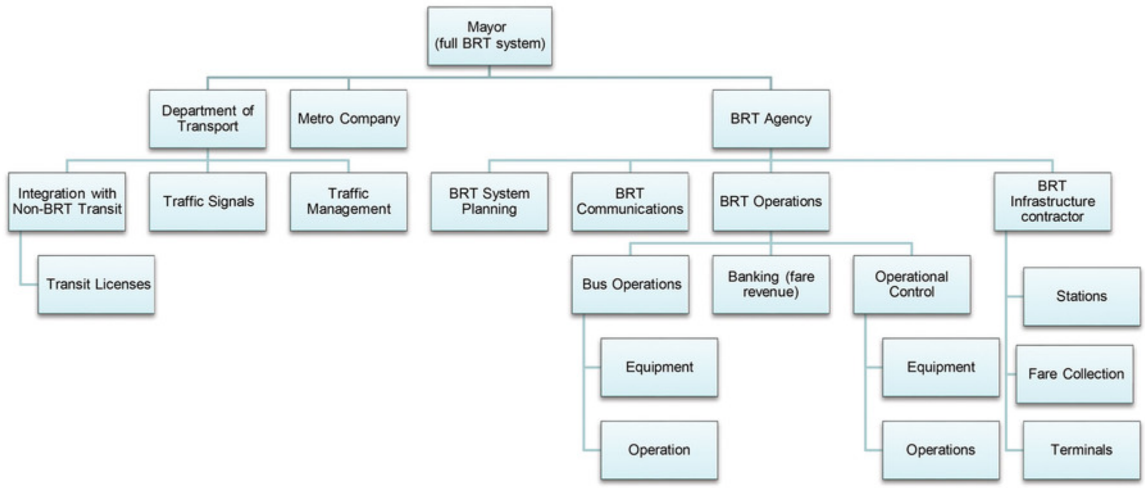

Figure 12.6. Administrative structure of public-private partnership (PPP) BRT projects in Mexico. *Walter Hook, BRT Planning International, LLC.*

In India, the creation of a special purpose vehicle (SPV) for administering a BRT project became a requirement for the receipt of national government public transport investment funds through the Jawaharlal Nehru National Urban Renewal Mission (JN-NURM) program. These SPVs are for the most part not as independent from municipal government as a public authority or a government-owned company typically is. They are mainly offices inside the office of the municipal commissioner and chaired by the municipal commissioner or deputy municipal commissioner. As such, BRTs in India have been funded by JNNURM while metro companies in India have been funded through "viability gap funding" administered by the ministry of finance for public–private partnership corporations. Though many of these SPVs were a far cry from the administrative competence of the Delhi Metro Rail Corporation, the Ahmedabad Jan Marg SPV (BRT Authority), however, was better than most. Though essentially an office of the municipal commissioner, it did successfully contract out the vehicle operations to private companies using quality of service contracts. Having an agency with an exclusive focus on managing the BRT system has thus generally been a reasonably successful strategy for managing a high-quality BRT system in a lower-income economy context.

However, it is insufficient to guarantee successful management. Other authorities with an exclusive focus on BRT have done less well. Normally, this has been because the BRT authority was never given the authority over all the key elements of a successful BRT system listed above. Governor Sutiyoso of Jakarta created TransJakarta, a BRT authority, when the BRT system first opened. Nominally modelled on TransMilenio, TransJakarta had few of the powers that TransMilenio had. TransJakarta did not sign contracts with the vehicle operators or collect the fare revenue: these functions were controlled by the Department of Transportation. Nor did it have control—or approval power—over the physical design. This was also controlled by the Department of Transportation. There were frequent disputes between TransJakarta staff and the Department of Transportation, all of which were won by the Department of Transportation because it controlled the budget, the contracts, and the fare revenue. How many of the design flaws and operational problems with TransJakarta were the result of the Department of Transportation's control over key system elements in the early phases of implementation will never be known. Additionally, their concern about losing licensing revenues preempting their interest in designing a great BRT system will never be precisely known, but there is no question it was a significant factor. Over time, the powers of TransJakarta relative to the Department of Transportation have increased, but it is still too early to gauge the results of these transitions.

Though Delhi tried to create a BRT authority (SPV) to manage the high capacity bus system (HCBS) corridor, in the end it was never given the powers to properly regulate vehicle operations in the HCBS corridor, and it was also tasked with developing other potential public transport investments. Poor service, frequent vehicle breakdowns, flaws in the initial design, and an inability to take control of the traffic signals all contributed to a negative public image of the system.

In summary, while the best BRT systems have tended to be managed by BRT authorities, it is critical that these authorities actually have the administrative powers, control over fare revenue, and staff capacity to fulfill their mandate to manage the BRT system.

12.4.1.2 Bus Transit Authorities

Bus transit authorities are similar in structure to BRT authorities, except that their mandate and area of responsibility extends beyond the BRT system to the regulation and licensing of all non-BRT bus and minibus public transport in the city. This form of BRT system management is typical of the Brazilian BRT systems, and Colombian systems may evolve into this administrative form.

Such bus transit authorities have been fairly successful in Brazil, mainly because Brazilian cities went through a process of bus industry consolidation and corporatization earlier than most lower-income economies. In most Brazilian cities, large private companies divide up bus operation management responsibilities across individual zones of the city. Small, informal bus operators were already transformed into companies by the 1960s and 1970s.

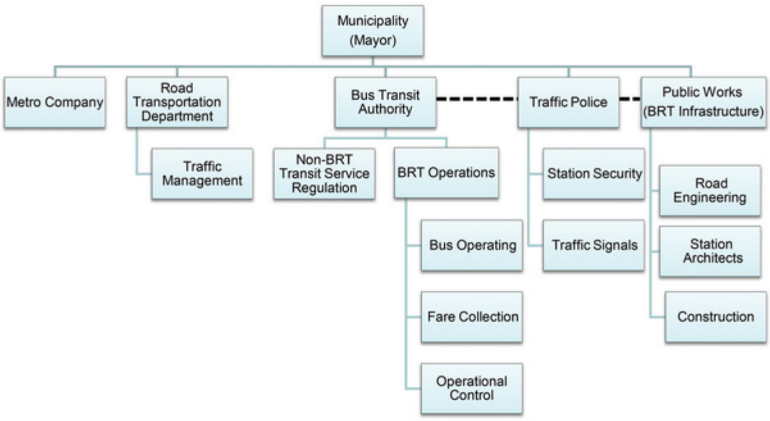

Figure 12.7. Typical administrative structure of a BRT under a bus transit authority. *Walter Hook, BRT Planning International, LLC.*

In Curitiba, for example, the company URBS began in order to manage a simple fare-sharing mechanism between the bus operators. BRT required off-board fare collection. The public transport market in Curitiba was divided into zones, and initially each corridor was controlled by the bus company in charge of that zone. When off-board fare collection was introduced, and some bus routes began to pass between one zone of the city and another, a third party was required to collect the customer revenue and then divide it between the bus operators in a manner that was acceptable to both companies. URBS, now the bus transit authority of Curitiba, was initially set up only to serve this function. Over time, it grew to become a full BRT authority; as it built its administrative competence, it added non-BRT routes and different roles in urban planning and operations like deciding the location of kiosks and cafés in public spaces, operating paid public WCs, and occupying needed underground or aerial space for infrastructure installation.

In São Paulo, the municipal BRT corridor and the bus corridors that allow taxis are all controlled by the same bus operator, São Paulo Transporte (SPTrans), which controls the entire zone of the city. The fare revenue on both BRT and non-BRT corridors is collected by SPTrans, a municipal public bus authority. BRT corridors that connect São Paulo cities within the metropolitan region are controlled by a bus agency of the state government (EMTU), part of the State Secretary of Metropolitan Transportation, under which there are similar agencies that control São Paulo metro (Metro-SP) and commuter rail lines of São Paulo Metropolitan Train Company (CPTM).

TransMilenio is also evolving into an agency that not only regulates the BRT system but also a growing number of strategic public transport corridors. In other words, it is trying to use the same type of quality of service contracts it implemented on the BRT trunk corridors for non-BRT corridors.

In both the Brazilian and Colombian cases, the expansion of the BRT authority's remit evolved over time. It is largely unheard of for a newly created agency to take over the administration of both a new BRT system and an existing bus system, mainly because it is administratively difficult to manage both tasks at once.

12.4.1.3 Municipal Department of Transportation-Contracted BRT

In a few municipalities, most notably in South Africa and in the Cambridgeshire Guided Busway in the United Kingdom, municipal or county departments of transportation are contracted out BRT operations to private operators in a manner similar to the contract structures typical of the Latin American BRT systems. However, the contracts with the BRT operators were instead signed directly with the municipality rather than with a new BRT authority.

In South Africa, the contractual form of an independent public authority under the municipality does exist (a "Municipal Entity"), but the track record of these institutions has been somewhat negative as they have proved to be difficult to hold to account and not particularly well managed. As such, when the BRT systems opened in both Cape Town and Johannesburg, both cities decided not to create new municipal entities to manage the BRT systems. Some elements of the BRT project were put under three different municipal entities in Johannesburg, and none in Cape Town. Both cities tried, in different ways, to mimic some of the elements of the contractual structures typical of the Latin American BRT systems.

In the case of Cape Town, a recent restructuring has set up a quasi-transportation authority, called Transport for Cape Town (TCT) but inside a government department. The histogram below shows the structure of TCT.

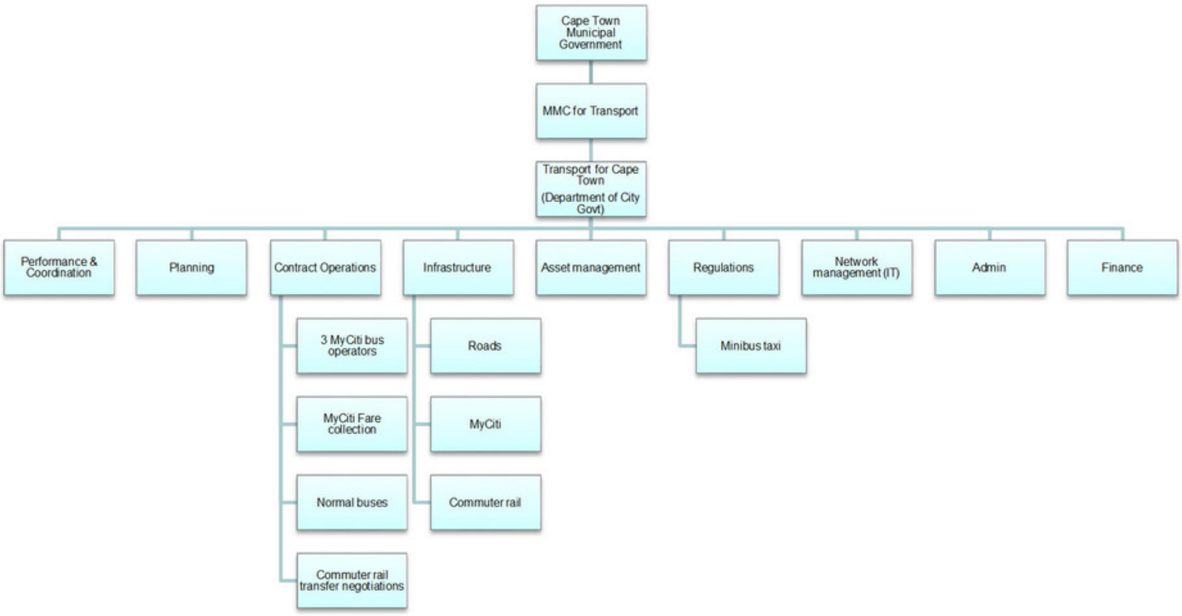

Figure 12.8. Administrative structure of Cape Town MyCiTi BRT system. *Walter Hook, BRT Planning International, LLC.*

TCT is a single large department of the city government that mainly reorganized the functions of the former transportation department. When the MyCiTi BRT system was first designed and became operational, there was a public transport unit inside the municipal department of transport. That unit's only job was to design and implement the MyCiTi BRT system, because at that time other vehicle operations in the Western Cape Province were under the provincial government, though these services were in the process of being devolved down to municipal government control. The municipality had also not assumed control over commuter rail, which was still managed by PRASA (Passenger Rail Agency of South Africa), a national government agency. The public transport division had two divisions: infrastructure and operations. Most of the critical tasks related to the BRT system were managed by this office. After the restructuring, staff previously responsible for focusing exclusively on the BRT system are, as a result of this process of devolution, responsible for some additional tasks. The contracts department also manages contracts related to the takeover of the rail operations, the takeover of the vehicle operations, and other contracts. Though the name is modelled on Transport for London (TfL), TfL's administrative structure is quite different. Rather than being a city department, TfL, and its main subsidiary, Transport Trading Limited (TTL), is a holding company for a number of largely independent subsidiary government companies such as London Bus Services Ltd. (which regulates and manages the buses), and London Underground Ltd. (which regulates and manages the metro system).

In the case of Johannesburg, the general structure of a BRT authority was also partially replicated inside a municipal government department. The BRT project office, Rea Vaya, had a dedicated staff and much of the attention of the executive director for transportation. Similarly to Cape Town, Johannesburg had not fully assumed responsibility for managing private vehicle operations or minibus taxi regulation or the local commuter rail lines. Johannesburg, unlike Cape Town, also operated a municipal bus company, Metrobus. As devolution proceeded, the executive director for transport had to take on other responsibilities as well. The histogram below shows how Rea Vaya was restructured. Rea Vaya no longer has any independent identity as an administrative unit. Earlier problems with the JRA and its contractors not being responsive to the needs of the Rea Vaya system were partially mitigated by putting it under the supervision of a special unit in the Transportation Department.

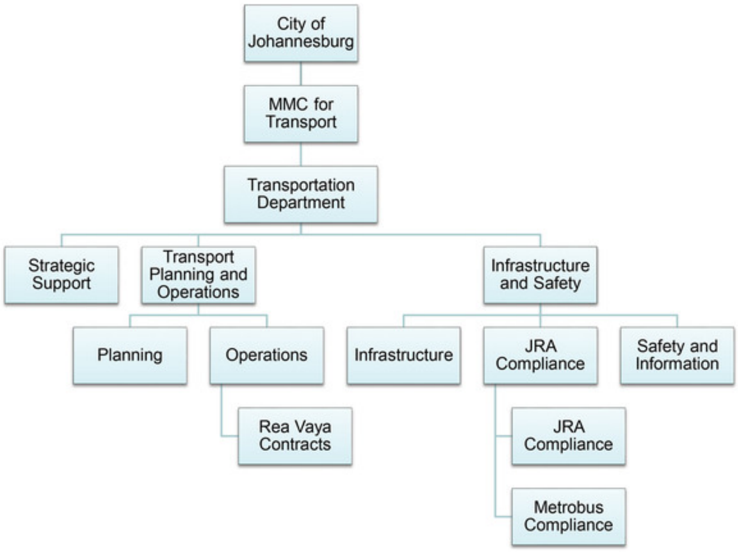

Figure 12.9. Johannesburg Rea Vaya's administrative structure as one of many municipal department of transportation responsibilities. *Walter Hook, BRT Planning International, LLC.*

In both Cape Town and Johannesburg, the fare revenues are not strictly pledged to the BRT system. Both systems are currently operating at a loss. In both cities, staff have not been able to dedicate their full attention to the needs of the BRT system, and some operational problems have taken longer to resolve as a result. There have been issues with attracting and retaining talented staff, and of removing problematic staff, due to relatively modest municipal pay scales and civil service hiring and firing rules. To some degree this has been mitigated by bringing in long-term consultants to support the administrative staff.

12.4.1.4 Public Bus Companies

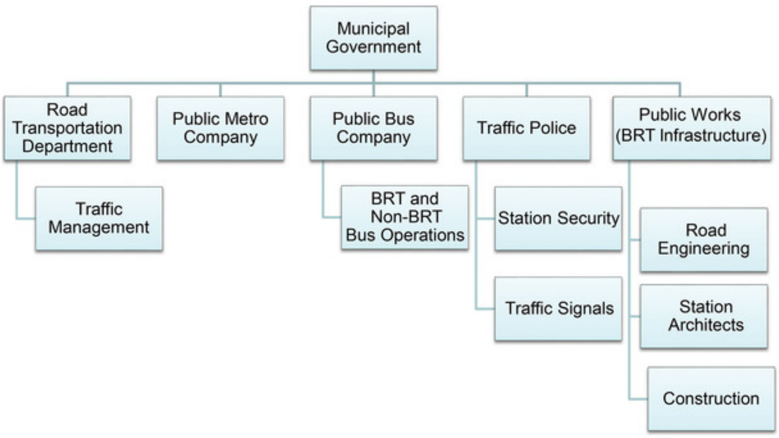

Figure 12.10. Administrative structure for BRTs operated by public bus companies. *Walter Hook, BRT Planning International, LLC.*

In some cities, BRT services are managed by government-owned "public bus companies." These government-owned companies differ from public authorities in that they only operate bus services, and they are generally structured like a company—but one that is owned by a government, usually a municipality. This administrative form was typical in many lower-income economies from the 1960s until the 1980s and most of them collapsed due to mismanagement. This administrative form survived, however, in a few countries, most notably China, India, and in a few places in Latin America. The legal vestiges of these companies still sometimes exist in other lower-income economies with rights that can cause problems for future BRT efforts.

In China, with the exception of Guangzhou, public bus companies are the norm. In the Chinese context, they offer an adequate quality of service, but are often resistant to change, and in general their performance as BRT operators is not strong. The BRT systems in Beijing, Jinan, and Lanzhou all have vehicle operations controlled by the public bus company. The vehicles and the quality of their service is of a similar standard of service to normal bus services. In India, many municipalities also continue to have public bus companies, though the Indian public bus companies do not generally manage BRT systems. The bus services managed by public bus companies in India vary in quality across the country, ranging from those with a reasonably good reputation (Bangalore, Mumbai), to those systems that nearly collapsed due to mismanagement (Ahmedabad's AMTS, the public bus company that predated the BRT and continues to operate on some corridors in Ahmedabad). Most of the BRT systems in India are instead operated by special purpose vehicles (SPVs), as is the case in Ahmedabad and Indore. Delhi is the exception in which some of the HCBS buses are operated by the public bus company, but the sole responsibility for the poor quality of service does not rest on the public bus company as, in fact, there is no single entity responsible for managing the HCBS system. It has buses operated by both a public bus company (Delhi Transport Corporation, under the government of the National Capital Territory) and private individual operators with route licenses. Buses operated by the public bus company are generally considered to offer a better quality of service than private individual operators with route licenses. On Delhi's HCBS BRT services, the DTC buses are more likely to have new buses and are somewhat better managed than the STA registered private buses but in other ways are operationally indistinguishable from other municipal bus services.

Metro-Company-Administered BRT Systems

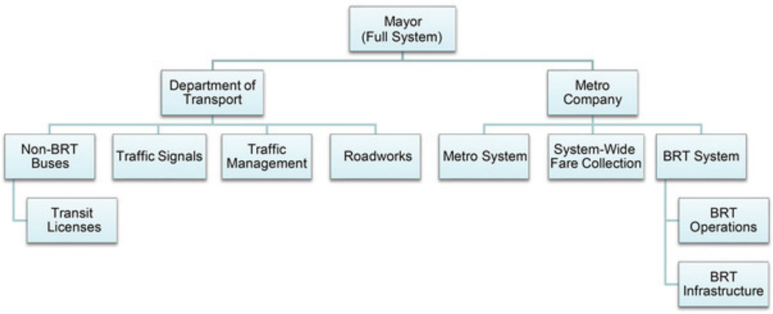

Figure 12.11. Typical administrative structure of BRT systems managed by metro companies. *Walter Hook, BRT Planning International, LLC.*

In two cities surveyed, the operations of the BRT systems were managed by a publicly owned metro company: Monterrey, Mexico; and Caracas, Venezuela. The advantage of this structure is that it improves the chances of reasonable integration between the BRT services and the metro system services, both in terms of fare collection and physical infrastructure. The other advantage is that some metro companies, because of their relatively high cost, are able to afford reasonably qualified staff who can also be used to manage the BRT system.

The main downside of metro system administration is that any debts that might encumber the metro system will also end up encumbering the BRT system, so the possibilities of financially ring-fencing the system are less.

12.4.1.5 Other Forms of BRT System Administration Observed in Emerging Economies

In Belo Horizonte, a public agency, BHTrans, is responsible for the management of the BRT corridors and other transportation services (conventional buses, taxis, etc.) within the city, including road transport and planning of non-motorized transportation. Regional bus services and the metro are under separate government authorities within the state government. This administrative structure has worked reasonably well to date.

In the case of Rio de Janeiro, the Municipal Department of Transportation (SMTR) supervises the service provided by a private BRT operator (Consórcio Operacional BRT Rio). This private enterprise is the result of an arrangement between the four consortiums that won the city conventional bus lines bid. SMTR is responsible for the BRT operational design and BRT Rio operates the system, provides vehicles, and maintains the stations' infrastructure. This administrative structure is more typical in higher-income economies and will be discussed in greater depth there. In the specific case of Rio, it has limited the ability of SMTR to fully regulate the operating consortium, and the main problem has been significant overcrowding on the system that resulted from an insufficient fleet and the inability of SMTR to require additional fleet.

The Lagos busway, which did not meet the basic criteria to qualify as BRT, is supervised by a transportation authority with a very wide mandate but which in practice has yet to fulfill some areas of this mandate. It is further discussed in the next section on forms more typical of higher-income economies.

Conclusion: How and Why Lower-Income Economies Best Administer BRT Systems

In lower-income economies there is an emerging professional consensus that government institutions need to be built with the capacity to regulate and contract out BRT operations to qualified private operating companies. In most lower-income economies with either gold- or silver-rated BRT systems they are managed by special BRT-specific authorities. In countries with relatively weak municipal institutions it has proved easier and more effective to set up an authority focused specifically on managing the BRT system and only gradually widen the scope of this institution's responsibilities. In countries like Brazil with a longer history of functional public authorities, these authorities often have a wider remit, but this emerged only gradually as the institutions developed the necessary administrative competence. In a few cases, even very good BRT systems have been operated by municipalities that have directly contracted private BRT operators without involving a public authority. What has not worked well in most cases is to have a BRT operated by a public bus company. Where these remain in lower-income economies, most notably in China and India, these institutions have not provided the best quality BRT services. Also relatively unheard of are large public authorities with responsibilities for all aspects of urban transport, ranging from BRT to metro rail to road traffic. Whatever the theoretical benefits of this institutional form, the institutional capacity to manage all of these functions in an integrated manner rarely exists in lower-income economies.

12.4.2 Typical Administrative Forms in Higher-Income Economies

12.4.2.1 Transit Authorities

Transit authorities are a form of public benefit corporation that is typically found in the United States and British Commonwealth countries (Canada, Australia). They are generally publicly owned and controlled bodies intended to act like private companies but for the purpose of fulfilling a public service. These entities generally collect and control user fees as part of the mechanism through which their operations are funded.

In these countries, it is most common for BRT systems to be managed by a transit authority. A transit authority will generally have a remit over all vehicle operations and rail transit operations in a metropolitan area, but it does not have authority over traffic management.

These transit authorities were not created to run a BRT system but were pre-existing institutions already managing bus and rail services when a BRT system began operation. In the United States, these transit authorities are generally the direct operators of public transport services, though about 40 percent of them contract out at least some services to private operators, and a few—mostly suburban bus systems—contract out all of their services to private operators (Institute, 2015). Hence, there is nothing inherent in the public authority administrative structure that precludes the contracting out of BRT services to private operators.

These transit authorities developed over decades as a result of historical circumstances specific to the suburbanizing cities of the former British colonies as described below. And as such the forms should not be applied to cities in lower-income economies without careful and critical consideration to understand why this administrative form emerged. These conditions are:

- Public transport services that were originally private, but private provision led to a deterioration of service due to disinvestment in the face of declining ridership;
- Public transport services that have ended up serving urbanized areas well beyond the original municipal administrative boundaries;
- Public transport services where the fiscal strength of the municipality is much weaker than that of the surrounding state or county government.

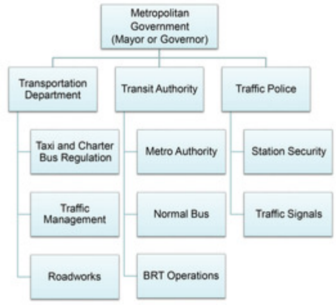

Figure 12.12. Typical administrative structure of a BRT under a metropolitan government. *Walter Hook, BRT Planning International, LLC.*

Over time, transit authorities have become relatively successful at operating BRT bus services at a reasonably high quality of service. However, this came only after decades of institution building and massive capital and operating subsidies from state and national governments, sustained over decades. When they were first created, many of them were taking over for failed private operators, and their public transport properties—both rail and bus fleets—were badly deteriorated. As publicly funded enterprises, the quality of their services tends to rise and fall with the strength and weakness of state and local government finances and the degree of political commitment to public transport.

They have been reasonably successful at introducing single integrated fare systems that are usable throughout the public transport network. As the same entity controls the buses and the rail properties, it is relatively easy for this authority to develop or contract out a fare system that is usable in both bus and rail systems.

Typically, these public transit authorities are governed by a board of directors. The board members are often appointed by the chief executives of local governments served by the system and/or by the governor. In Australia, the Brisbane BRT (silver standard) is managed by TransitLink, a public authority controlled largely by the governor of Queensland Province with some board members appointed by local governments in the service area (Transport Operations [TransLink Transit Authority] Act 2008). In the United States, of those cities that have BRT systems that rank bronze or silver (using *The BRT Standard* as of 2014), all of them were managed by transit authorities. Greater Cleveland's Rapid Transit Authority (RTA) has a presidency always controlled by the City of Cleveland, but the board includes three representatives appointed by the mayor of Cleveland but approved by the City Council; three representatives appointed by the Cuyahoga County chief executive and approved by the Cuyahoga County Council; and three representatives elected by the heads of surrounding municipalities.

Pittsburgh's Martin Luther King Jr. East Busway is operated by the Port Authority of Allegheny County. The board of the Port Authority of Allegheny County is appointed by the chief executive of Allegheny County (which encompasses the City of Pittsburgh), leaders of both political parties in the Pennsylvania House of Representatives and Senate, and also by the governor. The Los Angeles Metro Board of

Directors, which operates the bronze-standard Orange Line, represents the chief executives or their appointees (usually city councillors) from each of the municipalities that are served by LA Metro, supervisors from Los Angeles County, and one nonvoting member appointed by the governor. All of them are typical transit authorities responsible for managing bus and rail operations in the greater metropolitan areas. The Eugene Emerald Express (EmX) BRT is managed by Lane Transit District (LTD), a transit authority controlled by appointees of the governor of Oregon, and it is responsible for all bus services in the Eugene region. It also serves as the regional Metropolitan Planning Authority (MPO) for the region.

All but one of these transit authorities operates their BRT and bus services in-house. The only transit authority that contracts out its BRT operations to private operators is the Las Vegas BRT system. Like the other systems, BRT and standard bus and rail operations in Las Vegas are all ultimately controlled by the Regional Transportation Commission of Southern Nevada (RTC). It is controlled by appointees of the various county and municipal governments served by the system. RTC also serves as the regional MPO. However, RTC contracts out its bus services to multiple private operators. The only routes that qualify as BRT under *The BRT Standard*, the SDX routes (Strip-Downtown Express), are operated by Keolis, which is 70 percent owned by the French National Railway Corporation (SNCF) and 30 percent by a Canadian group of investors. Keolis also operates most of the other bus routes in the southern part of Las Vegas. As such, it is possible for a transit authority to contract out some of its routes.

Internationally, transit authorities are unique for the limited role played by the municipal government, due to the historical reasons described above. State government also controls national level funding in the United States, so whether explicit or implicit, most transit authorities are most heavily influenced by the state governor or provincial governor.

As transit authorities do not control the city streets or national highways, cooperation between municipal departments of transportation and transit authorities has been important to success. If the BRT is on a state highway, then cooperation with state departments of highways or transportation has also been important. Often this relationship is managed informally through ad hoc working groups. Some state transportation departments are more pro-transit than others. The Massachusetts Department of Transportation, which also oversees the Boston-area transit authority, MBTA, is leading BRT efforts and is generally quite progressive. However, there have been conflicts between the California Department of Transportation (Caltrans) and San Francisco city and county transport officials over the designs of planned BRT systems.

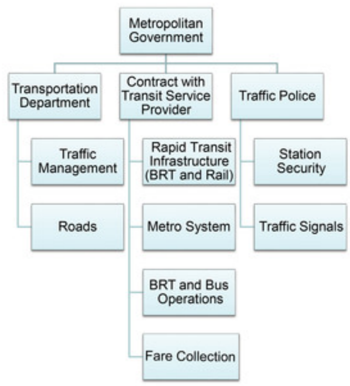

Figure 12.13. All public transport operations and infrastructure contracted to a single public transport service provider. *Walter Hook, BRT Planning International, LLC.*

12.4.2.2 Integrated Transit Service Providers under Contract to a Municipal, Regional, or State Government

In Europe, and in a few smaller US cities, it is becoming typical for metropolitan areas with BRT systems to contract out the entirety of public transport operations to a private company without the mediation of a transit authority or BRT authority. In these contracts, it is typical that a single firm manages all of the system's functions, from fare revenue collection to operational controls and planning to bus and rail operations. These firms are sometimes private firms, sometimes firms with both public and private ownership, and sometimes government-owned firms. Policies such as fare levels tend to remain under elected bodies. Public transport infrastructure construction and maintenance is sometimes left to municipal departments, and sometimes it is included in the service contract.

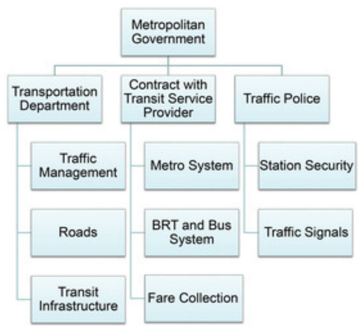

Figure 12.14. All public transport services contracted out to a public transport service provider (but not infrastructure). *Walter Hook, BRT Planning International, LLC.*

This administrative form achieves many of the system integration and coordination objectives that an integrated transportation agency aims to achieve (see Section 12.4.7 below), but under a slightly different organizational form.

In France, for instance, public transport is generally the responsibility of the regional level of government. This level of government frequently contracts out public transport services to a single large integrated public transport service provider. This company is in some cases a government-owned company, in other cases a joint venture between a regional government and a private company, or purely a private company. In this way, integration of different public transport services becomes the responsibility of a single public transport service contractor. In essence, the transit authority model is re-created inside a transit service corporation, whether it be public, private, or a combination of public and private ownership. In most of the French systems, the services of the BRT system are not contracted out under a separate contract but are just one of many services provided under a single contract.

The Paris Mobilien BRT (bronze standard) is operated by Régie Autonome des Transports Parisiens (RATP), the Paris regional public transport service provider that is responsible for all bus and rail services throughout the Paris metropolitan region, and is under contract to the Isle de Paris, the regional government of the Paris Metropolitan Region. RATP functions by all intents and purposes as a private company licensed to perform a public function, but it is a company with the majority of its shares owned by the government. RATP in turn contracts out many of its bus routes, including the Mobilien routes, to TransDev, a private company. Fare collection as well as operations are all under the same subcontract to TransDev. The Rouen BRT is also operated by the same private company (TransDev) that manages all public transport operations, though in this case directly under contract with the regional government (Communauté de l'Agglomération de Rouen Elbeuf Austreberthe) and as part of the contract was also required to construct and operate an LRT system. The Nantes BRT is operated by Semitan, the same public-private consortium that operates the entire public transport system in Nantes. Semitan is a joint venture formed out of the former public vehicle operator, and is more than 60 percent owned by the City of Nantes and about 15 percent owned by TransDev.

The BRT in Amsterdam that serves Schiphol Airport, now called R-Net (previously known as Zuidtangent) is operated under contract to the Amsterdam regional government by Connexxion, a public-private company that is 66 percent owned by TransDev, the same private company involved in many of the French public transport systems. Connexxion does not operate the entirety of the Amsterdam-area public transport system, but it does operate a selection of services, including the BRT.

The Cambridgeshire guided busway (bronze rated) was built by private firms under contract to the Cambridgeshire County Council Department of Economy, Transport and Environment's Strategy and Development Department. Vehicles along the busway and elsewhere are operated by two private vehicle operators, Stagecoach and Whippet, as part of more general vehicle operating contracts for the Cambridgeshire County Council.

In summary, if a municipal or county government has a well-functioning department of transportation, this municipal or county government may elect to manage multiple contracts to private vehicle operators, fare system operators, and other contractors without necessarily creating a new legal entity to supervise these roles. More research is needed to determine if this administrative structure results in management weaknesses for the BRT operations.

12.4.2.3 Transportation Authorities

Most transportation authorities grew out of the consolidation of preexisting transportation agencies and institutions. Transport for London (TfL), created in 2000, is the most famous example of combining these functions. It took over the functions of the previous London Regional Transport Authority, which was created in 1984 out of the Transit Department of the Greater London Council, which had run public transport services in London since 1964 and had also managed the street network. The LRT also controlled the London Underground, a wholly owned subsidiary of LRT called the London Underground Ltd. established in 1985. It also took control of the airport authority, the port authority, and other government companies. Thus, TfL is not a multifaceted integrated agency that was created from nothing. It is largely the planning and board governance functions of a multiplicity of largely independent subsidiary companies with large staffs that have clear responsibilities over the successful management and regulation of a single mode. TfL does not currently operate a BRT system, though it manages some bus lanes such as the Oxford Street bus corridor.

San Francisco's Municipal Transportation Authority (MTA) is another example of where these functions are combined into one agency. It was also created, in 1999, by consolidating the Department of Parking and Traffic of the City of San Francisco and the Public Transport Commission, which managed the Muni (bus, LRT, cable car, streetcar). There is also no BRT system yet operating in San Francisco. There are plans for BRT on both Van Ness and Geary Avenues, both of which were not initiated by the MTA but by the San Francisco County Transportation Authority, and then transferred over to the MTA for implementation.

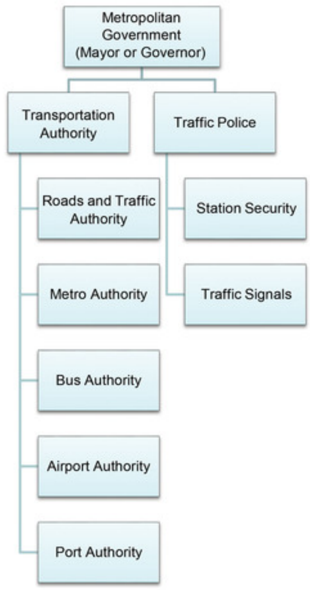

Figure 12.15. BRT operations under a transportation authority. *Walter Hook, BRT Planning International, LLC.*

Most similar examples of traffic and public transport system management integration under a single administrative unit are in higher-income economies, and all have been amalgamated from functional, preexisting institutions. There is limited experience with such administrative forms in lower-income economies. Transportation authorities were set up in Dakar, Senegal, with Conseil Executif des Transports Urbains de Dakar (CETUD), and Lagos, Nigeria, with Lagos Metropolitan Area Transport Authority (LAMATA), both to manage World Bank–funded projects. The initial proposal for the creation of LAMATA was introduced in 1994. It took until 2002 to pass a law creating LAMATA, and a further revision of the law in 2004 for the institution to function. It was financed out of the World Bank Lagos Urban Transport Project and a product of that project, which was the main promoter of the effort. As of the last report, the Lagos transportation authority (LAMATA) focused mainly on the implementation of the Lagos light-rail system and a bus system improvement, which has some elements of a BRT corridor. Other areas of its mandate, such as traffic management and improvements on some 800 kilometers of roads in the greater metropolitan area of Lagos, and the regulation of the remaining public transport services remain largely unfulfilled, and it plays more of a coordination role in these areas (Banjo and Mobereola, 2012). ETUD in Dakar, Senegal, was also set up to administer loans by the World Bank, with a very broad mandate.

The theoretical advantage of combining these often interrelated functions under a single management structure is better coordination between related projects, possibilities for financial integration of services, cross subsidization of less profitable services, and possible integration of fare technologies. If staff working on one area are unwilling to coordinate with staff working in another area, the issue can theoretically be elevated to a single manager with decision-making authority without having to be further elevated to the political level. The lower the level of government that minor coordination problems need to be elevated to, usually the better the outcome. With a transportation agency structure, issues need only be elevated to the transit agency head. Thus, it is worth considering whether metropolitan areas in the early stages of developing their urban governance institutions should set up authorities such as TfL.

However, these theoretical benefits need to be weighed against the risk of over-encumbering a fledgling institution with more tasks and responsibilities than it can handle. Most large agencies emerged over time, consolidating functions already mastered by their staff, with their administrative authority and competence no longer disputed. In lower-income economies, it is quite common for several departments to claim administrative authority over the same functions, with none of them having the capacity to properly perform this function. Creating a new administrative body in this context, with responsibility over a large number of functions currently controlled by another department of government, without clearly defining these roles and responsibilities in the law, can lead to a compounding of administrative confusion, with several government departments claiming control over key functions.

12.4.2.4 Transit Systems Directly Operated by a Municipal or Regional Government Department

There are a few municipal and regional governments in higher-income economies that directly operate public transport systems as government departments. In Japan, the Nagoya guided busway's infrastructure, meaning the busway's construction, ongoing maintenance, and management, is managed by a "third sector" public-private partnership called Nagoya Guided Busway, which is under contract to the city government. Buses operating on the guided busway are operated directly by the transportation agency of the City of Nagoya that also operates the city bus system and part of its rail system. In Canada, the Ottawa BRT system is operated by OC Transpo, a department of the City of Ottawa, which was recently created from an amalgamation of smaller municipalities in the Ottawa-Carleton region (hence, "OC Transpo") (City of Ottawa 2015).

12.5 Conclusion

> *"I have always believed, and I still believe, that whatever good or bad fortune may come our way we can always give it meaning and transform it into something of value."*
>
> — Hermann Hesse, poet and novelist, 1877-1962

There are significant differences in the way in which the most successful BRT systems have been administered in the developed as opposed to lower-income economies. In higher-income economies, the most successful BRT systems have been operated by financially ring-fenced transit authorities or corporate transit service providers with a clear mandate to manage BRT systems as part of overall public transport system operations. There is certainly room for institutional innovation. The high cost recovery ratios possible in BRT systems makes it more likely that BRT services could be contracted out to private operators, which could in theory make a profit and avoid the need for operating subsidies, although to date the relatively small scale of BRT operations as stand-alone services would probably make them unattractive to most private transit service providers. There is also plenty of room for using BRT to better reduce the overall operating losses of a metropolitan public transport system under the existing institutional structures. In either case, institutional reform is certainly not a prerequisite for a successful BRT system in higher-income economies.

In lower-income economies, things are different. The most successful BRT systems in lower-income economies required significant institutional innovation. The best BRTs created new BRT authorities or management companies to fill an administrative vacuum. It was rare that institutions already existed that successfully contracted out and regulated efficient, high-quality, and modern vehicle operations with integrated fleet management, so they had to be created. These new institutions were responsible for initiating a number of significant administrative reforms all at once, and they often stimulated the creation of the first large vehicle operating companies. Additionally, they were often the first to use quality of service contracting and the first vehicle fleets to use integrated fleet management. These new institutions shepherded in solutions to far more serious public transport problems. They were key to resolving problems such as buses being old, poorly maintained, refusing to follow a schedule or stop at designated stops, and the dangerous competition for customers at the curb-side that too frequently resulted in pedestrian fatalities. However, these stand-alone BRT authorities did not work out well in all cases. Eventually, they ended up being nearly as sensitive to good political leadership as other administrative forms, and the other administrative forms also proved able to provide a good quality of service. Therefore, it is highly possible that with growing sophistication in the governance of public transport systems in lower-income economies that the next generation of BRT systems will introduce new administrative forms not currently used in these areas. It is also likely that new institutional forms will emerge in lower-income economies, such as the direct contracting of private integrated transit service providers by municipal and state governments, but in new contractual forms. These new contractual forms might build on the institutional achievements of TransMilenio and other successful BRT systems in lower-income economies, while avoiding some of the pitfalls that they ultimately faced.

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13. Business Structure

"Perfection is achieved, not when there is nothing more to add, but when there is nothing left to take away."

— Antoine de Saint-Exupéry, writer and aviator, 1900–1944

Once a project team has been assembled to manage a BRT project, and the basic administrative structure for the project has been decided, a BRT project is likely to go in one of two directions. The BRT operations are either going to become part of an existing public transport system and will need to adopt the standard operating procedures of this system, or the BRT system will be operated as a separate "system," that is, as a stand-alone system, making it a stand-alone *business proposition*. This chapter is designed primarily for those BRT systems that are being designed as stand-alone business propositions.

If the BRT project is to become part of an existing public transport system, administered by an existing transit authority or transit service provider, and operated in-house as part of that transit authority's ongoing operations, then the project will need to follow the typical rules and procedures governing new projects within that system. The necessary capital investments will need to be included in the capital budget of whichever government body administers the transit system's capital program. Also, the operating expense ramifications of the new BRT system should be analyzed and included in projected operating budgets. In the United States, inclusion in the capital budget has historically meant completing the requirements for federal New Starts/Small Starts funding. Much of this is set by the National Environmental Policy Act of 1969 (NEPA). The operating cost impacts of BRT systems in the United States have for the most part been nearly budget-neutral, as operational cost savings that result from the BRT investments have tended to be poured back into increased services, rather than into operational cost savings. If the BRT project's operations are modest (fewer than forty vehicles, for instance), it is unlikely to make economic sense to tender the BRT system's operations separately from other municipal vehicle operations.

Most BRT systems in higher-income economies to date have been too small to be economically viable to tender as stand-alone business propositions. While there may be exceptions to this, and while this may change in the future, there is relatively limited BRT-specific business planning experience in higher-income economies as a result. There is also growing interest from state and local governments to find ways to leverage private investment in BRT projects, bond against operational cost savings resulting from BRT projects, and circumvent or streamline the often cumbersome NEPA process by leveraging private sector investment. However, most of these efforts remain tentative in the United States, and there is too little BRT-specific experience in this area to draw significant conclusions for this edition.

If, on the other hand, the BRT system is of sufficient scale to be economically viable as a stand-alone system, and some or all elements of a BRT project are going to be tendered to private operators, then planning the BRT system *as a business* becomes an essential part of a BRT project. While, to date, business planning as a key part of BRT system planning has primarily been a lower-income economy phenomenon, it is likely to emerge in higher-income economies in the future as BRT systems grow in scale and opportunities for contracting out BRT services emerge.

The BRT business plan defines precisely what separate BRT-related businesses will be tendered, and which will be done in-house by a government authority. It makes this determination in part based on how much revenue the system is likely to earn, as well as how much of the system's operations can be covered from this revenue, the majority of which is fare revenue. It then determines what element of the system can be financially ring-fenced and tendered to private operators. This chapter is primarily intended for cities that have decided to involve private companies in the operation of their BRT system.

This business plan must be carefully grounded in the service plan (see Chapter 6: Service Planning). The service plan, if it has been done properly, will define all of the public transport services that are to be considered part of the BRT system and allowed access to the BRT system's infrastructure. It should provide a clear estimate of the number of vehicles needed, the types of vehicles needed, and the basic approach to fare collection. Ideally, all of these services should be contracted to the same administrative authority and branded as part of the BRT system. It should also define how many depots will either be constructed or leased as an essential part of the BRT system's operations. Starting from this baseline information, these services can then be parcelled out into separate tenders.

Ideally, the business structure of a BRT system should (roughly in order of priority):

1. Maximize the quality of the service over the long term;
2. Minimize the cost of the service over the long term;
3. Maximize the level of private sector investment over the long term;
4. Maximize the public benefit from the public investment.

In examples around the world, the clever application of well-placed incentives has persuaded operators to concentrate more on customer service and less on battles between competing vehicles. From the BRT projects undertaken to date, there is a growing consensus over the core principles that lead to an effective business model.

The principal components of this consensus are each discussed in turn in this chapter:

1. Privately contracted operations;
2. Competitive tendering of operations;
3. Private sector procurement of the vehicles;
4. Multiple vehicle operators on each BRT corridor;
5. Quality of service contracting.

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13.1 Private BRT Operations

> *"There are two types of stories: public and private."*
>
> — Antonio Muñoz Molina, novelist, 1956–

All BRT systems have basic functions that need to be handled by either private companies under contract to a government authority or by a department or branch of the government itself. The critical functions include:

- Vehicle operations;
- Fare collection;
- Station management;
- Trust fund management;
- Control center management;
- Scheduling.

Figure 13.1 shows whether different well-known BRT systems around the world contract out the operations of the two most critical functions, vehicle operations and fare collection systems. Although there are examples of BRT systems with well-managed public operations, particularly in higher-income economies, the emerging consensus is that private operation of the fleet of vehicles and the fare collection system tend to lead to better quality of services, if the contracts are written and supervised properly.

Institutions Managing BRT Systems, Select Cities		
BRT System	Bus Operations	Fare Collection
Lower-Income Countries		
Rio de Janeiro (Transoeste)	Private	Private
TransMilenio, Bogotá	Private	Private
GBRT, Guangzhou	Private*	Private*
Lima (Protransporte)	Private	Private
Belo Horizonte (BHTrans)	Private	Private
Curitiba (URBS)	Private	Public
Guatemala City	Public	Public
Medellin, Colombia	Public	Public
Pereira, Colombia (Megabus)	Private	Private
Ahmedabad (Jan Marg SPV)	Private	Private
Cali, Colombia (Mio)	Private	Private
Monterrey, MX	Private	Private
León, MX (rating pending)	Private	Private
Johannesburg (Rea Vaya)	Private	Private
Mexico City (Metrobús)	Private	Private
State of Mexico (Mexibús)	Private	Public
São Paulo, Brazil (SPTrans)	Private	Public
Quito EcoVia	Private	Public
Caracas VZ	Public	Public
Medellin, Colombia	Public	Public
Quito Trolebus	Public	Public
Lanzhou BRT	Public	Public
TranSantiago	Private	Private
Puebla	Private	Private
Cape Town BRT	Private	Private
TransJakarta, Jakarta	Private	Public
Beijing, China	Public	Public
Jinan, China	Public	Public
Higher-Income Countries		
Rouen, France (TransDev)	Private	Private
Paris Mobilien, Ile de France (RATP	Private	Private
Brisbane, Australia (TransitLink)	Public	Public
Amsterdam R-Net (rating pending	Private	Private
HealthLine, Cleveland (RTC)	Public	Public
Cambridgeshire , England	Private	Private
Nantes, France (Semitans)	Public*	Public*
LA Metro (Orange Line)	Public	Public
Las Vegas (RTCSV)	Private	Private
Ottawa, Canada (OC Transpo)	Public	Public
Pittsburgh MLK (Port Authority)	Public	Public
Nagoya busway (rating pending)	Public	Public

(gold)	Gold Standard BRT
(silver)	Silver Standard BRT
(bronze)	Bronze Standard BRT
(white)	Basic BRT, not yet rated BRT, not BRT, not yet implemented, as specified

Figure 13.1. Private contracting of bus and fare collection operations for top BRT systems. *Walter Hook, BRT Planning International, LLC.*

13.1.1 Private Contracting of BRT Operations in Lower-Income Economies

In lower-income economies, the degree and nature of private sector contracting of BRT services is quite different from that in a higher-income economy. The administrative form of a transit authority or transportation authority is largely unknown. The vast majority of BRT systems in lower-income economies are operated by private companies. The exceptions are those systems operated by a public bus monopoly (Chinese BRT systems outside of Guangzhou), by a former public bus monopoly that remains in control of part of the market (Mexico City's RTP and Delhi's DTC), the systems operated by public metro companies (Medellín and Caracas), the electric Trolebús BRT in Quito (subsequently privatized), and the Guatemala City BRT. All of these systems are operated by publicly owned companies, not transit authorities. BRT vehicle operations in all the other cities of lower-income economies are operated by private companies.

The same holds true for most of the fare collection systems, with the exception of some of the better BRT systems in Brazil (Curitiba, São Paulo), TransJakarta, and some of the Mexican systems where problems with the private operator require the government to step in. In Curitiba and São Paulo, fare collection is managed directly by the transit authority (SPTrans in São Paulo and URBS in Curitiba). In some cities in Brazil, private transit operators ceded control over fare collection over time to public authorities (though never in Rio or Belo Horizonte). This has been relatively unproblematic.

In the case of Puebla, Mexico, the fare collection service provider was so poor it had to be replaced by the BRT authority. In the case of the State of México, the infrastructure service provider originally also collected the fare as part of a PPP deal, but the system could not cover the cost of the infrastructure, so the state had to take control of the infrastructure and step in to control fare collection. In the case of TransJakarta, the fare collection system was initially primarily a paper fare system (the original smart card rarely functioned), and was managed in-house by TransJakarta, a weak public authority. The fare collection system had numerous operational problems and the system's revenues were notoriously non-transparent. Eventually the fare collection system was taken over by a consortium of six national banks. Transparency of the system improved as paper ticketing was stopped and all transactions were recorded as smart card transactions, but a weak contract with the consortium led to the loss to the public authority of most of its control over fare policy.

The decision about whether the public sector can directly manage the fare collection system of a BRT system is somewhat based on whether the government is strong enough and has the administrative capacity to take control of the fare collection process from private operators. It also depends on the degree to which the vehicle operators and their bankers trust the government to honestly report fare revenue and pay them. In many BRT systems, the private vehicle operators turn to private banks to borrow money to buy the vehicles. The only guarantee that these private operators have that they will be able to repay the loan is their operating contract with the government, which promises to pay them. If the government is trusted by the bankers to pay them, then there is no fundamental problem with having the government directly collect the fare revenue; however, there is such rapid progress in fare collection system technology that it may not be easy for a government body to keep pace with innovation.

In lower-income economies, private contracting of BRT vehicle operations generally means that the procurement of the vehicles is done by the private operating company. This has a few distinct advantages in the lower-income economy context. First, public vehicle procurement in lower-income economies often invites corruption. Too often public officials, given the power to make a multi-million dollar procurement decision, will base this decision more on the basis of illicit payments than on the technical merits of the bus. Second, public officials rarely know as well as a private vehicle operator what sort of vehicle will be the most efficient or appropriate for a given service. Third, public procurement of the vehicles sometimes leads to litigation. If a private operator is forced to operate a vehicle that was procured by the government, and the vehicles face significant problems, it is unclear whether the responsibility for the breakdown of the vehicles is the fault of the private operator or the government that made the procurement. Fourth, a private company is more likely to diligently protect the vehicles and properly maintain them if it owns the vehicles than if it operates them on behalf of the government.

In all but a few cases, where a BRT vehicle operator is private, the private operator bought the vehicles. The only exceptions to this are in Cape Town, Jakarta, part of the fleet in Mexico City (the part operated by RTP, the public operator), and part of the fleet in Guangzhou. In some cases, it is easier to financially ring-fence the BRT system. These include situations in which a BRT system is unable to cover its operating costs, and where it violates public procurement rules to have a government buy the vehicles then turn the ownership over to a private operator (as is the case in South Africa). In these situations it helps to have the government close an operating budget gap by buying the vehicles and turning them over to the operator over time in a lease-to-buy arrangement, rather than having the private operator buy the vehicles and then be paid on a gross cost basis.

Many BRT systems have been experimenting with contracting out more and more of the functions of the BRT system as a way of avoiding the bureaucratization of these functions. TranSantiago contracted out the operational control system and operational planning as well. TranSantiago noticed the growing numbers of staff in the operations division of TransMilenio, despite a lack of improved services, and wondered if it would not do better contracting out operational controls and operational planning. These functions both require highly technically skilled staff, who are difficult to retain. There is also a lot of innovation in this area. Contracting out these functions intelligently to firms with expertise in public transport system optimization is likely to prove to be a win-win proposition.

In lower-income economies, there is a long history of privately owned, poor quality public transport services in which municipal governments use public companies to try to improve the services. This leads to these public services encountering a number of problems, with most of them ultimately failing. These are then replaced with either private, zone-based bus concessions or private, largely informal route concessions. Informal bus and minibus route licensed services survive largely without subsidy but there is generally public dissatisfaction with the quality of service. The competition for customers at curbside frequently leads to unruly behavior and fatalities. Services rarely adhere to a predictable schedule or set of predictable stops. Additionally, the vehicle fleets tend to be old and highly polluting, weakly insured or uninsured, and not particularly roadworthy. Services tend to be divided up into territories that force needless transfers on customers.

In Latin America, BRT was frequently used as leverage to bring about public transport sector regulatory reform, moving from either weakly regulated, informal operators or a dysfunctional public vehicle operating monopoly to a form of well-run, well-regulated private operating companies.

BRT systems first emerged in Latin America, where in many cities they played a central role in this regulatory transformation. As in higher-income economies, private trolley and tram concessions and later bus concessions dominated the Latin American cities from the turn of the nineteenth and twentieth centuries into the 1940s.

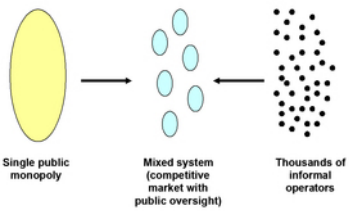

Figure 13.2. BRT systems have sometimes been used to leverage a transition to a competitive market with public oversight. *Walter Hook, BRT Planning International, LLC.*

In Brazil, BRT and regulatory transformation mostly occurred separately. In São Paulo the tram network was built by a Canadian investor with a franchise. The municipality cancelled the franchise in the early 1940s and turned the assets over to a newly created municipally owned company, CMTC (Companhia Municipal de Transportes Coletivos). CMTC introduced trolleybuses to São Paulo as well as normal buses, and it was the main bus and trolleybus operator in São Paulo until it was broken up and privatized in the early 1990s in the aftermath of the Latin American debt crisis. What emerged in the aftermath of the privatization was similar in form to what had existed in Curitiba and other Brazilian cities since the 1960s: zone-based concessions. In

Curitiba, Rio, and other cities that implemented BRTs, these operated without municipal subsidies, but fares were high. In São Paulo, they operated with subsidies and fares were lower. As they controlled entire zones of the city, reasonably large vehicle operating companies entered the market. When Curitiba, Rio, Belo Horizonte, and São Paulo opened their BRT corridors, all of them turned over the operation of the BRT corridors to the same private vehicle operators that already controlled vehicle operations in that part of the city.

In other parts of Latin America, however, the BRT projects were instrumental in modernizing the contractual structures of the private bus industry. Mexico City had private route concessions until 1980. In 1980 the head of the Federal District analyzed the status of all the route concessions and created a much bigger municipal vehicle operator to take over the poorer quality routes. It was called Ruta 100, and it survived until 1995, when it went bankrupt. It was broken up, partially privatized, and part remained under a new public vehicle operator, RTP. With the collapse of Ruta 100, a few routes survived under public control of RTP, but most of them went back to operating as route franchises with small owner operators, with the majority of them only owning one or two vehicles. When Metrobús started in Mexico City, operations were divided between RTP and a new firm formed of the collective that controlled the route licenses on the BRT corridor. The creation of each new BRT corridor has been used to create a new company, and some of these companies have formed ties with intercity vehicle operators to become regionally competitive firms.

In the rest of Latin America there were also attempts to introduce municipally controlled vehicle operating companies out of dissatisfaction with declining privately provided services. Most of these public efforts had failed by the mid-1990s. In the vast majority of other Latin American cities, route licenses predominated. Small, informal, and independent owners and operators with individual route licenses rose up or took the place of the former municipal operators. In most of Colombia, the route licenses were dominated by a small number of bus “enterprises” that did not own vehicles. Their primary economic asset was a cozy relationship with municipal departments of transportation that controlled route licenses, and the ability to enforce their route monopolies. When BRT was introduced into most Colombian cities (except Medellín), the BRT was used to force these private operators to form new, modern, competitive private companies. Most of them were constituted primarily from the bus enterprises that owned the licenses, and the former affected bus owners, but many joined with larger firms to create regionally competitive companies. Some of these firms are now active in other parts of Latin America.

BRT in Johannesburg and Cape Town has played a similar role, though the process is far from complete. Under the apartheid government, provincial governments contracted out heavily publicly subsidized public transport services to white-dominated private contractors who offered a fairly low level of service. These were long-term cost-plus contracts heavily subsidized by the provincial government. In Johannesburg the Gauteng was contracted out to Public Utility Transport Corporation (PUTCO), and the Western Cape Province contracted out to Golden Arrow. As these services were poor and did not fully serve the ever-sprawling townships, and as black South Africans were not allowed to operate legal businesses, many invested in small minibus taxis. These minibuses were reasonably well regulated in Cape Town, with route licenses; in Johannesburg they were weakly regulated. Though there was a similar nominal route licensing scheme in place, most of the minibus taxis operated without a route license. In Johannesburg, in frustration with the poor quality of PUTCO services, the municipality started its own vehicle operating company, Metrobus. When BRT was established in South Africa, operations were contracted out to new companies composed of the former affected minibus taxis and/or the former private vehicle operators if their routes were affected. It is too early to determine whether these firms will thrive and provide a good quality of service: they have been hampered by labor unrest.

In the rest of Africa, prior to liberation, many major African cities had monopoly bus services privately provided by a major bus manufacturer from the colonial power that ruled the country. Renault, for instance, tended to provide bus services in much of Francophone Africa. After liberation, most of these bus properties were nationalized, but lacking experience in managing vehicle operations, short on money, and with weak governance structures, most of these public vehicle operations collapsed. There are sporadic attempts to resurrect these companies. The cities of Africa also came to be dominated by small individual owner-operated minibuses, and as the countries have gotten richer, these minibuses are sometimes traded up for larger vehicles. Sometimes they operate with route licenses, and sometimes there is no government regulation at all, and informal forms of regulation dominated by unions or quasi-mafias manage public transport operations. These bus and minibus operating companies rarely own more than a few vehicles, and integrated fleet management is largely unknown. As BRT is being introduced into Africa, it is still unclear how the operating companies will be formed. In Lagos, which has a system that is not a full BRT, the former cooperative that controlled the private minibus routes took control of operations, and the operations have been of relatively poor quality. In Dar es Salaam, DART had not begun operations as of this writing, but it is likely that a consortium of the formerly public but now privatized municipal vehicle operating company Usafiri Dar es Salaam (UDA), and two private minibus (Daladala) associations together with a foreign investor who can bring management expertise, will become the operator.

In Jakarta, throughout the Suharto years, private bus and minibus concessions were made. There were bus companies, but they primarily owned fleets of buses and bought licenses from the DKI Jakarta government and then leased the vehicles to individuals to operate and collect the fare revenue. There was a poorly run but very low-cost national government owned vehicle operator in Jakarta, Perusahaan Pengangkutan Djakarta (PPD) that remained in operation. When TransJakarta opened, Governor Sutiyoso forced the creation of a new company from the former private bus owner associations, PPD, and a municipal taxi company. Later corridors had operators formed from existing vehicle operating companies (most are leasing companies), or intercity vehicle operators.

In India, the Delhi High Capacity Bus System has two types of operators: those operated by the Delhi Transport Corporation (DTC) and private individual informal operators licensed to operate on the routes with BRT trunk infrastructure. Most of India has large, subsidized monopoly public vehicle operating companies, but most of the BRT systems in India are operated by special purpose vehicles (SPVs). Ahmedabad's BRT is operated by a private company that won an open tender; it was not a former vehicle operator but ran a trucking business.

The Quito Trolebús was for many years operated by a government company. The government initially intended to privatize it, but due to the escalation of electricity prices after the privatization of the electric company the government found it difficult to privatize. Eventually it was able to offer it to a private concession. The Ecovía lines in Quito were intended to be privately operated, but operations were so poor the government had to retake control of the operation, only to return it to private control a few years later.

Thus, in most lower-income economies, BRT has been central to efforts to modernize the contractual relationships through which public transport services are offered to the public. The construction of infrastructure that creates a highly efficient and highly profitable operating environment gave these cities new leverage to renegotiate their relationship with largely private operators, and to get a better deal for their citizens.

13.1.2 Private Contracting of BRT Operations in Higher-Income Economies

In higher-income economies, half of the BRT vehicle operations and fare collection systems are operated by the public sector, and half are operated by private contractors. Public sector operations dominate in the United States, Canadian, and Australian BRT systems, while private contracted operators predominate in Europe. Where the vehicles are operated by the public sector, the fare collection system is also always then operated by the public sector, as are most key elements of the BRT system. If the vehicles are operated by the private sector, most frequently the fare collection system is also operated by the private sector. Usually, but not always, fare collection is handled in higher-income economies by the same company that operates the vehicles.

In higher-income economies, it is more common for the vehicles to be procured by the public sector and then maintained and operated by the private contractor, than it is in lower-income economies. This is somewhat less problematic in higher-income economies as there are frequently fewer vehicle procurement options, there is less corruption in the public procurement process, and since vehicle procurement in higher-income economies is almost always subsidized by the government it is sometimes easier contractually to have the public sector buy the vehicles.

The introduction of a BRT in higher-income economies has rarely if ever led to significant innovation in terms of the degree or form of private contracting, though the idea has been discussed. Generally, privatization of services occurred independently of the emergence of BRT systems.

In the United States (Cleveland, Los Angeles, Pittsburgh, Eugene) and Australia (Brisbane), a public transit authority directly operates the vehicles that operate on their BRT systems. In Canada the vehicles on the Ottawa BRT are operated by a municipal department (Ottawa). In Europe, Cambridgeshire, Rouen, Amsterdam, Nantes, and Paris all contract out their BRT operations (as well as other public transport services at the same time), though Nantes is operated by a company that is majority public sector owned and used to be the public sector transit operating company of the city. In the United States, only Las Vegas contracted out its vehicle operations, including the BRT routes, first to one and most recently to two private firms.

While there is a clear trend toward privatization in Europe, there is a less pronounced trend toward private operation in the United States, Canada, and Australia. Curiously, Brisbane and Los Angeles contract out some of their vehicle operations to private companies, but not the routes that serve the BRT systems in these cities.

This gradual shift to private operation of vehicles in higher-income economies is in some ways a return to the past, but under different contractual forms. In the United States, bus transport was almost exclusively provided by private, for-profit monopoly franchises. This began to change in some cities in the 1950s but many continued in private hands into the 1970s. These monopolistic bus companies, many of them owned by General Motors, were franchises licensed by the municipality, and none of them were subsidized. Initially, they successfully competed with older streetcar systems, and many of them purchased and then dismantled competing streetcar lines. In the 1940s, most of the major United States municipalities took over their remaining streetcar and rail systems that had collapsed financially, and bus systems remained viable for-profit concerns in private hands. After World War II, however, mass suburbanization killed public transport ridership, and annual public transport trips dropped from thirty-five billion to twelve billion from 1945 to 1958 (J. Teaford, 1990). As such, private vehicle operators soon followed the same decline as the tram systems, and by the 1970s virtually all cities had taken over direct operation of their bus systems (Frick, Taylor, and Wachs, 2008). In the United States, some level of privatization began again in the 1980s, and by 2001, over one-third of all agencies in the

National Transport Database reported contracting for some services (H. Iseki, 2004). These are not the subsidy-free franchises of old; virtually all of these contracts are public service contracts where the services are determined by the government, the assets are owned by the government, and the service is heavily subsidized by the government.

Public vehicle operation in Europe is older, and the shift to private operation also began earlier. In Germany, public transport firms have been publicly owned and operated since the 1920s (Buehler and Pucher, 2012). A wave of privatization began in the UK in the mid-1980s, and in Scandinavian countries in the late 1980s, becoming more widespread beginning in the 1990s. European Union directives on public procurement from 2007 and 2009 further reinforced this trend toward privatization and made it more transparent by requiring the tendering of all public services above US$161,000 (€125,000). Thus, even where public operators are still functioning, they must compete against private firms for the contract. This has led to a client relationship between public operators and public authorities, or contracts with private operators.

In Europe, as in the United States, the contracts specifically for BRT services (or Bus with High Level of Service—BHLS) are very similar to conventional bus contracts, albeit with somewhat stricter performance parameters. The level of subsidy as well as the cost recovery ratio has little bearing on the degree of privatization in the BRT systems in higher-income economies. Fare-recovery ratios in both the United States and Europe range from as low as 20 percent in some cities in Greece, Italy, the Netherlands, and Eastern Europe, between 30 and 40 percent in France and much of Central Europe, to as high as 60 to 70 percent for German cities and on the New York City subway system.

13.2 BRT Operating Contract Types

> *"Simple, genuine goodness is the best capital to found the business of this life upon. It lasts when fame and money fail, and is the only riches we can take out of this world with us."*
>
> — Louisa May Alcott, novelist and poet, 1832–1888

The number of different types of vehicle operating contracts used in BRT systems continues to grow, but these types can generally be grouped into the typology of vehicle operating contracts listed in Table 13.1.

Table 13.1. Contract Forms Typical of BRT Systems and Their Pros and Cons

Contract Type	Description	Pros
Profit sharing	Operator is paid a predetermined share of total system revenues, based on a pre-agreed-upon formula (usually linked to bus kilometers, customers served, or a combination).	• Gives operators strong incentive to reduce costs and attract customers; • Causes large companies to form; • Removes destructive competition for customers; • Reduces risk of needed subsidies.
Service contract (gross cost)	An operator is paid to operate a minimum number of kilometers of public transport services over the life of a contract anywhere directed by the municipality. Revenues are owned by the municipality, though may be collected by the operator.	• Ensures good service coverage; • Makes for compatibility with off-board fare collection and free transfers; • Ends dangerous competition at the curb; • Makes for compatibility with interzone routes and modifying services. • Makes it easier to have multiple companies in the same zone, so the operator is
Area contract (gross cost)	An operator is paid to operate a set of services within a zone, anywhere instructed by the municipality, usually by the bus kilometer or the bus hour. Fare revenue is owned by the municipality.	• Ensures good service coverage; • Makes for compatibility with off-board fare collection and free transfers; • Ends dangerous competition at the curb.
Area contract (net cost)	A private operator provides a set of services determined by the municipal authority within a specified zone, and owns all fare revenue in that zone.	• Reduces risk of open-ended subsidies; • Makes it easy for large companies to form; • Allows for good coordination and possible cross subsidy within zone; • Mitigates destructive competition within zone.
Design-build-operate forms	Concessionaire is given a long-term contract to design, build, and operate a public transport system. Contractor owns fare revenue.	• Raises capital for infrastructure, can provide good project management for new • Can provide quality, coordinated services.

Route contract (gross cost)	Operator has a license with a city authority to provide bus services specified by the municipality on a route or a particular route, but revenue is owned by the municipal authority.	• Gives the municipality greater control over the services; • Avoids dangerous competition for customers at curbside; • Makes for compatibility with off-board fare collection and free transfers.
Route contract (net cost)	Operator has a license with a city authority to provide bus services specified by the municipality on a route or a particular route and all fare revenue is owned by the operator.	• Minimizes risk of ongoing open-ended subsidies, exposes operator to demand ri • Gives the operator an incentive to collect revenue and operate the route efficien • Gives municipality some control over services.
Unregulated entry with quality control	A private operator can get a license to operate anywhere, any time, so long as the vehicle is the right type, and it is properly maintained.	• Lowers barriers to entry for positive short-term employment impacts; • Requires minimal administrative capacity or legal mandate; • Works without need for subsidies; • Leads to better quality vehicles than for unregulated entry without quality contr
Unregulated entry without quality control	A private operator can get a license to operate anywhere, any time, with any quality of vehicle so long as the vehicle is the appropriate type.	• Lowers barriers to entry for positive short-term employment impacts; • Requires minimal administrative capacity or legal mandate; • Does not require subsidies.

+ The term *municipality* in this context refers to whatever public authority is responsible for the administration of the municipal public transport system

Source: Modified from PPIAF Urban Bus Toolkit at: https://ppiaf.org/sites/ppiaf.org/files/documents/toolkits/UrbanBusToolkit/assets/3/3.4/34(i).html

While there is more than one way of grouping contract types, the typology in Table 13.1 groups them based on the following characteristics:

- **Geographic share of the market**: A contract may cover only one route (route contract), an area of the city (area contract), or have no specific geographic range (service contract);
- **Ownership of the fare revenue**: A contract may assign ownership of the fare revenue to the private operator (net cost) or to the public authority responsible for public transport in the city (gross cost). A city might allow a private operator to collect the fare revenue on behalf of the public authority, but if the revenue belongs to the public authority it is still considered in this typology a "gross cost" contract;
- **Payment method**: Any form of payment of the vehicle operator based on an operating characteristic, such as payment per bus kilometer, or per passenger kilometer, or per bus hour, or any operating characteristic other than the direct receipt of fare revenues, is considered in this typology as a "gross cost" contract;
- **Degree of financial ring-fencing**: A new category, "profit sharing," was created to describe those contracts where a BRT system is financially ring-fenced, and all system profits are shared by a formula. Net cost contracts are also generally financially ring-fenced, whether subsidized or not, while gross cost contracts are not financially ring-fenced;
- **Degree of infrastructure construction and maintenance in the contract**: Any contract that includes some element of infrastructure construction and maintenance together with an operating contract has been grouped together as a "build-operate-transfer form" of contract. Even if the payment to the operator is based on an operational characteristic, if infrastructure is involved the terms of the contract tend to be much longer, and the nature of the contract quite different, so they have been classified separately.

The distinction between whether there is *competition "within"* a defined public transport market or *competition "for"* a particular public transport market is taken up separately in two later sections. The sections deal specifically with whether or not there are multiple operators serving the same BRT system, and whether or not the contracts were competitively tendered or negotiated. The presence or absence of *quality of service contracting* is also treated separately, as its inclusion created too complicated a matrix of types.

Most of the contractual forms being used in BRT systems were first developed for normal bus services, or for metro systems, with the exception of the "*profit sharing*" type of contracts, which are an innovation that was introduced by the TransMilenio BRT system and subsequently replicated in some other BRT systems.

Figure 13.3 lists many of the better BRT systems by the type of contracts that govern their vehicle operation. It also lists those systems that are subsidized or not, and those systems for which fare collection is separated from the vehicle operator. In Figure 13.3, there is a correlation between the better quality systems and those that do not require subsidies. Systems not requiring subsidies are coded green and systems requiring some subsidies are coded yellow. Generally BRT systems are built on the corridors with high levels of demand where preexisting bus services tend to be more profitable. This is likely to be where user benefits are also maximized. It also appears to be true that the systems that are designed for full cost recovery also tend to be the better designed systems overall.

BRT Operating Contract Types

BRT System	Contract Type	Subsidies	Separate Fare Collection
Lower-Income Countries			
TransMilenio, Bogotá	Profit sharing	No subsidies*	Separate fare collection
GBRT, Guangzhou	Profit sharing	No subsidies	Separate fare collection
Lima (Protransporte)	Profit sharing	No subsidies*	Separate fare collection
Curitiba (URBS)	Area contract (gross cost)	No subsidies*	Separate fare collection
Belo Horizonte (BHTrans)	Area contract (net cost)	No subsidies	Bus operator collection
Rio de Janeiro (Transoeste)	Area contract (net cost)	No subsidies*	Bus operator collection
Pereira, Colombia (Megabus)	Profit sharing	No subsidies	Separate fare collection
Ahmedabad (Jan Marg SPV)	Service contract (gross cost)	Subsidies	Separate fare collection
Cali, Colombia (Mio)	Profit sharing	No subsidies	Separate fare collection
Johannesburg (Rea Vaya)	Service contract (gross cost)	Subsidies	Separate fare collection
Mexico City (Metrobús)	Route contract (gross cost)	No subsidies*	Separate fare collection
State of Mexico (Mexibús)	Design-Build-Operate forms	Subsidies	Separate fare collection
León, MX (rating pending)	Area contract (net cost)	No subsidies	Bus operator collection
Monterrey, MX	Design-Build-Operate forms	No subsidies*	Separate fare collection
Guayaquil, Ecuador	Profit sharing	No subsidies	Separate fare collection
São Paulo, Brazil (SPTrans)	Area contract (gross cost)	Subsidies	Separate fare collection
Quito EcoVia	Route contract (net cost)	Subsidies*	Bus operator collection
Puebla	Design-Build-Operate forms	Subsidies	Separate fare collection
TranSantiago	Service contract (gross cost)	Subsidies	Separate fare collection
Cape Town BRT	Service contract (gross cost)	Subsidies	Separate fare collection
TransJakarta, Jakarta	Route contract (gross cost)	Subsidies	Separate fare collection
Delhi HCBS	Unregulated entry without quality control	No subsidies	Bus operator collection
Higher-Income Countries			
Rouen, France (TransDev)	Design-Build-Operate forms	Subsidies	Bus operator collection
Paris Mobilien, Ile de France (RATP)	Service contract (gross cost)	Subsidies	Bus operator collection
Cambridgeshire , England	Route contract (net cost)	No subsidies*	Bus operator collection
Nantes, France (Semitans)	Service contract (gross cost)	Subsidies	Bus operator collection
Las Vegas (RTCSV)	Route contract (gross cost)	Subsidies	Bus operator collection
Amsterdam R-Net (not yet rated)	Route contract (net cost)	Subsidies	Bus operator collection

*With qualifications described in text

Figure 13.3. Privately operated BRT systems, types of contracts, separation of fare collection, and their relation to subsidies. *Walter Hook, BRT Planning International, LLC.*

There also tends to be a correlation between the better BRT systems and those with separate companies managing the fare collection system. Separating fare collection from the vehicle operators tends to give the municipality more control over the private operators. Systems with separated fare collection are coded green and those where fare collection is managed by the vehicle operators themselves are coded yellow.

As can be observed from Figure 13.3, there is a clear relationship between "net cost" contracts in lower-income economies and direct collection of fare revenue by the vehicle operator. In lower-income economies, gross cost contracts always involve a separate fare collector, whether it be the government or a separate private contractor.

In higher-income economies, by contrast, gross-cost contracts are the norm, and fare revenue is generally collected by the operator, though the fare revenue is owned by the public authority in charge of the system and not the vehicle operator. This contract structure can work when fare collection systems are largely electronic, and it can work where the public authority or its third party auditors can effectively monitor the integrity of the fare collection system. In lower-income economies, where familiarity with electronic fare systems and the sophistication of public authorities is generally lower, this sort of contract form has yet to emerge.

There is a growing consensus among most experts that certain contractual forms work better than others, providing a safer and higher quality of service at the most reasonable price to consumers and taxpayers. The best contracts distribute risks and profits fairly between the public sector and the private sector, minimize the risks to the public sector of open-ended financial commitments, create incentives to operate efficiently but continue to provide a high quality of service. In Figure 13.3, the contractual forms that perform the best are coded green, those that perform the worst are coded pink, and those that have problems that can generally be addressed within the same contract structure are coded yellow. *It should be noted, however, that any contract can be written well or poorly, and that most of the problems of each type of contract can be overcome by a good contract, and most of the best forms of contracts can be undermined by a poorly written contract.*

13.2.1 BRT Operating Contract Types in Lower-Income Economies

In lower-income economies, where BRT systems have been *financially self-sufficient and ring-fenced*, it has been possible to set up contractual relationships between private BRT operators and public authorities in such a way that the system profits are shared by the public interest and the private system actors. If done correctly, this contractual form creates incentives for cost savings, minimized subsidies, safe operations, and high quality of services. This new contractual form, defined here as "*profit sharing*," is a contractual innovation that emerged out of the Bogotá TransMilenio BRT system, on the advice of McKinsey. It will be explained in detail below. It has since been copied in most of the Colombian BRT systems, in Guayaquil, in Lima, and in Guangzhou, China. As these systems have tended to have better services (though they are far from perfect), this contractual form has been coded green. There are also some very good BRT systems in lower-income economies that operate with a *service contract (gross cost)* that is not linked to any specific corridor or zone. These contracts, if properly supervised, can function well inside BRT systems, and cause relatively few problems, and as such have been coded light green. Ahmedabad, Johannesburg, Cape Town, and the latest contractual forms in Santiago, Chile use this form of contract.

There are, however, gold- and silver-rated BRT systems in lower-income economies (primarily Brazilian systems) operating with *area contracts (gross cost)*, such as Curitiba's BRT system and São Paulo's Expresso Tiradentes, which have had problems, but they are problems that can be overcome. These are coded yellow. There are also some very good *area contracts (net cost)* such as Rio's TransCarioca and TransOeste, and Belo Horizonte's Cristiano Machado and Antonio Carlos BRT corridors, that have known operational problems but that are correctible within the same general contractual framework. They have also been coded yellow. There are a few *Build-Operate-Transfer* contracts in lower-income economies, primarily in Mexico (Puebla, Monterrey, State of Mexico), where the fare revenue is owned by the private builder of the infrastructure. In these examples, this form was generally built on faulty financial assumptions and is unstable. As such, it has been coded pink. There is also one *route contract (net cost)*, the Ecovía line in Quito, which had significant contractual problems and as such was coded pink. There is also one example of a BRT with *unregulated entry without quality control*, the Delhi HCBS system, which has had significant operational problems, and as such this contractual form is coded pink.

13.2.1.1 Profit-Sharing Contracts

Many of the gold-, silver-, and bronze-rated BRT systems in lower-income economies in our survey use a contractual form identified here as "*profit sharing*." In almost all of these contracts, the vehicle operators are paid based on an operating characteristic, such as the number of bus kilometers, the number of customers served, or some combination of system characteristics. In this way, a profit sharing contract is similar to a service contract (gross cost). The important difference, however, is that ultimately *the total payment to the vehicle operators is a fixed percentage of the system's total operating revenue*. The more revenue the system makes overall, the more the operators are paid. In this important sense, it is a profit sharing contract, and not a gross cost contract. How this works is best made clear by an explanation of the TransMilenio profit sharing contracts work, as most of the other profit sharing contracts were based on TransMilenio.

In the case of the contracts within TransMilenio, there is a public BRT authority, TransMilenio SA, which is a BRT system specific public authority. It contracts out vehicle operations to vehicle operating companies. These vehicle operating companies are paid on the basis of a combination of operating characteristics, mainly per bus kilometer and per customer. The amount that the vehicle operators are paid per kilometer is agreed upon in the contract for the life of the contract, and it is only increased based on certain external price indexes; increases in the fee per kilometer are in this way not related to the operator's actual costs, but to general costs in society. The operator's contract therefore allows them to make a big profit if they can lower their operating costs. This has been achieved primarily through the optimization of maintenance regimes, returns to scale in the procurement of spare parts, and the optimal deployment of labor.

Importantly, the vehicle operators never touch the fare revenue. The *independent concession for fare collection* helps ensure the system's revenues are properly controlled and administered. If anyone with a vested interest were to be handling the revenues, then there will always be suspicion among the different stakeholders. An independent fare collection process means that none of the vehicle operators have any relationship to handling the fares. Further, through the use of real-time sharing of fare information, all parties have an open and transparent view of revenues. In TransMilenio, fare data is streamed simultaneously to all relevant parties, creating an environment of confidence in the system.

This company deposits all the fare revenue into a trust fund managed by a bank, also under contract to TransMilenio. The bank certifies that the amounts deposited by the fare collector are the same as the amounts collected at the point of sale terminals. It also distributes the payment to the vehicle operators and their creditors, as well as to the fare collectors, without the funds ever passing directly into a government bank account. In this way, the multiple vehicle operators are not worried that one operator is stealing from them, nor do they need to worry that the government is stealing from them. All of the revenue in this way is financially ring-fenced so that all money earned is paid back to the joint profit sharing companies of TransMilenio. If the fare revenue is enough to cover the operating costs of the BRT authority, they are also paid a share of the profits. And if the money is enough to cover the operational control center, or station security, all the firms engaged in these functions can become part of the profit sharing scheme.

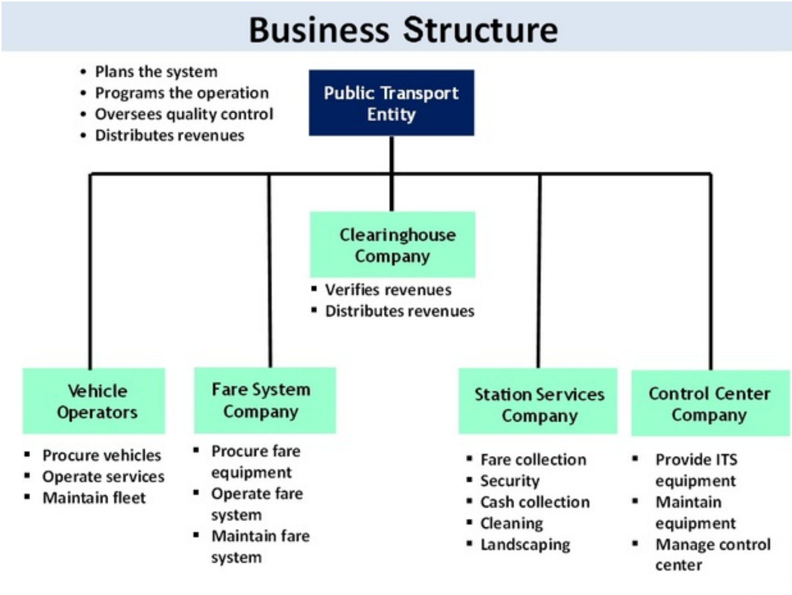

Figure 13.4. Typical business structure in a profit sharing vehicle operating contract. *ITDP*

In the case of TransMilenio, the vehicle operators were responsible for procuring their vehicles and operating them. The fare collection system operator was responsible for buying the fare collection equipment and operating it. These costs were all seized by the operators in the monthly fee per bus kilometer (in the case of the vehicle operator) and by the flat percentage of the total revenue (as was the case of the fare collector). The specific profit sharing ratios for TransMilenio are shown in Figure 13.5.

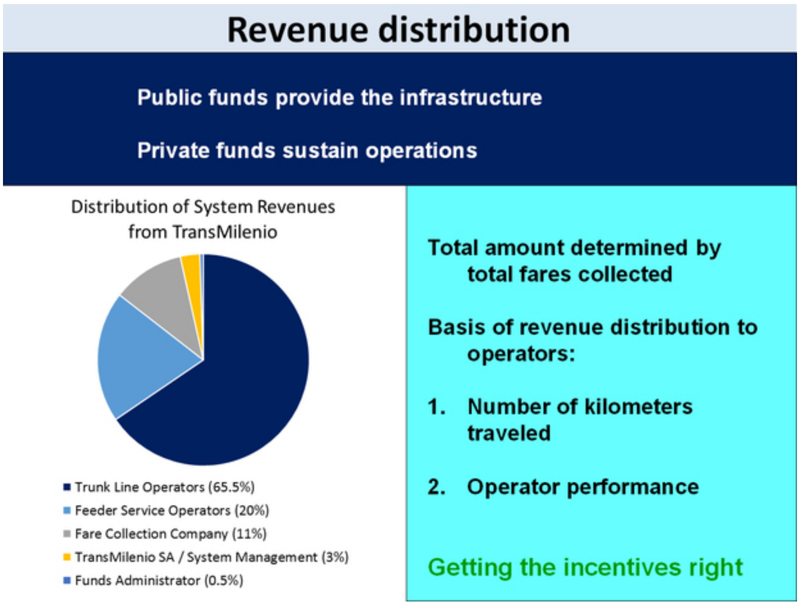

Figure 13.5. Division of profits among system actors for the TransMilenio BRT system. *ITDP*

To the customer, the services all look the same. The tight product delivery specifications ensure that the look and feel of each vehicle is quite similar, regardless of which operating company is managing the vehicle. Even though there are several operators, none have an incentive to operate in an overly competitive manner on the street. Each operator is making its revenues from the services that he or she operates and his or her share of the collective profits of the system.

TransMilenio SA controls the scheduling of trips and the routes of the operators. In theory, TransMilenio can assign any operating company to operate any route, but in practice it tends to program most route kilometers to the company with the closest depot. This allows flexibility for TransMilenio to move services from a corridor that is less than anticipated to one where it is anticipated.

The reason the contracts are not simple gross cost service contracts is that TransMilenio SA is contractually bound to increase the number of bus kilometers it assigns to the vehicle operating companies if the ridership increases beyond a certain level. Similarly, if ridership falls below a certain level, TransMilenio can cut services. In this way, unlike in a typical service contract (gross cost), the operators are partially exposed to demand risk. TransMilenio SA is contractually obligated to distribute *all* of the fare revenue based on the formula.

This contractual form has been extended to other less profitable systems by having the government pay one or more elements of the system's costs. For instance, if the total system is not as profitable as TransMilenio, the government can cover the cost of the staffing for the BRT authority and still retain the basic integrity of the profit sharing contractual structure. If it is still not profitable, the government can subsidize the cost of all or part of the vehicle procurement and still retain a profit sharing contract structure.

In this model, the infrastructure was paid for by the government and handled separately. A separate public works agency issues the tender documents to competitive bidding for the infrastructure components (busways, stations, terminals, depots, etc.). The construction work is conducted entirely by the private sector but paid for out of general tax revenues.

TransMilenio operated without subsidies for more than a decade. While a populist mayor eventually decided to freeze the fares, creating the need for subsidies, the financial soundness of TransMilenio was protected by a contractual obligation. This was an obligation on the part of the city to compensate any losses that result from the failure of the city to approve fare increases necessitated by increases in publicly published input costs, such as the price of fuel and the consumer price index.

The profit sharing agreements of TransMilenio have been criticized in a number of ways. The fare collector, receiving 11 percent of the profits, is receiving far more than could generally be justified by the cost of the equipment and the service provided. TransMilenio did not increase the services sufficiently to avoid overcrowding on the system in order to cut costs and increase the profits of the operator. The operational control system, a government position directly under TransMilenio, ended up hiring a lot more staff than necessary, and probably should have been contracted out as well. But in general, the contractual structures devised for TransMilenio overcame a lot of the problems with previous contract structures.

For this reason, similar profit sharing contracts were developed in BRT systems in Lima, Peru; Guangzhou, China; Guayaquil, Ecuador; and in most of the Colombian systems. In Lima, there were problems that the contracts were written on the assumption that another 10 kilometers of trunk infrastructure would be built to support the operations, but they were never built, throwing the contracts into confusion. In Guayaquil, municipal officials have had to deal with a nationally mandated US$0.25 fare. Nonetheless, though still in need of refinement, most experts consider profit sharing to be a best practice.

Decision makers wanting to use a profit sharing contract structure should decide from the beginning to design the BRT system to be financially self-sustaining. This decision should drive the technical design process, rather than the other way around. The administrative and organizational structure of the system will have profound implications for the system's efficiency, the quality of service, and the system's cost over the long term.

13.2.1.2 Service Contracts (Gross Cost)

In a number of lower-income cities, most of the contractual forms developed in TransMilenio were copied but without being able to achieve the same financially ring-fenced cost sharing. Ahmedabad's JanMarg, Cape Town's MyCiti BRT, Johannesburg's Rea Vaya, and Santiago's TranSantiago are all operated by vehicle operators under a general service contract that pays them based on service parameters (mostly by the bus kilometer), though in the case of TranSantiago the formula is based on many service parameters (Gómez-Lobo, 2013). These systems, however, did not specifically link the payments to the operators to the profitability of the system.

This contract structure avoids a lot of the typical problems with vehicle operating contracts in BRT systems. First, because the contracts are to operate a fixed minimum number of bus kilometers over the life of the contract, and because these can be operated anywhere within the system at any time, the public authority responsible for managing the system can easily reallocate services from one part of the system to another without needing to renegotiate the contracts. Since payment is largely based on bus kilometers, there is no destructive competition for customers at the curb, no waiting until vehicles are full, no shortage of service in off-peak periods or less popular routes. There are no problems of providing services between zones. There are no problems with multiple operators using the same infrastructures, so the operator with a service contract is less entrenched than in an area- or route-based contract. As the operators are paid a fixed amount per kilometer, set for the life of the contract, the government knows in advance what its costs will be, and the operator has an incentive to operate more efficiently to increase profits. As such, this contract structure is fully compatible with BRT operations.

Nonetheless, this sort of contract does not provide a strong incentive for the vehicle operator to ensure that the fares are collected, attract more customers to the system, or optimize their services. This is because they get paid more the more kilometers they operate, and they do not really care if the system overall is profitable. In all three cases where this contract structure was implemented in higher-income economies, there are continuing problems with fare evasion, as well as with ongoing and escalating operating subsidies.

13.2.1.3 Area Contracts (Gross Cost)

Curitiba and São Paulo, two of the cities where some of the most important innovations in BRT system development occurred, both operate their BRT systems under area-based contracts (gross cost). In these contracts, private vehicle operators have control over a large part of the city, including both BRT and non-BRT routes, but the fares are collected by a third party, in both cases the transit authority of the city. This form emerged after decades of efforts on behalf of the municipality to gain more quality control over the vehicle operators.

When BRT was introduced into Curitiba and São Paulo, most of the city's bus services had already been granted to large bus companies. These contracts were based on the "selective area principle." They gave all bus routes in a zone of the city to a single bus franchise. This contractual form had been in place since at least the 1960s. Initially, these were area-based contracts (net cost) where the operators collected the fare revenue and kept it. In both cities, these private bus companies were formal companies, but not with the same degree of transparency as would be required in the first world. The financial performance of these firms was never clear, in part to avoid paying corporate taxes.

Before the BRT was implemented, these same private bus companies had *area based (net cost)* contracts. They charged their own fares, set their own rates, and collected the fares directly. One of the main problems with area contracts (net cost) is that it is hard to introduce routes that pass from one zone to another, and it is hard to introduce a free transfer from one route to another. More than one operator would use certain BRT stations, particularly on corridors between zones and in the downtown and there was no clear way to distribute fare revenue between the operators.

In 1980, during his second term, Curitiba mayor Jaime Lerner wanted to introduce a single unified “social” fare and eliminate the paid transfers. With bus companies collecting their own fare, however, if a free transfer was implemented, the bus company carrying the customer for the second part of the trip would not get paid. To some extent this problem is mitigated by the fact that most journeys in the evening would pay the company that provided the free trip in the morning trip. Nonetheless, there were winners and losers. The problem was ultimately resolved by the creation of a “compensation fund” that was managed by a new public authority, URBS (Urbanizacao de Curitiba). Initially companies making extra profits paid into a compensation fund managed by URBS, who then paid the loss making companies. This proposal worked out well, and the separate companies began to trust the government handling this process.

In a later round of reforms, when Curitiba decided to introduce more interzone routes, after some struggle, the private vehicle operators agreed to shift to an area-based contract (gross cost) where URBS took over direct collection of all of the fare revenue and paid each operator by the bus kilometer. This emerged over time, after trust with the private operators had been established (Ardilo-Gomez, pp. 140-147, 2004).

In Curitiba the fares were allowed to rise high enough that the bus services managed under URBS, including the BRT routes and inter-corridor routes, remained as a whole profitable. Curitiba ended up with public transport fares considerably higher than in other parts of Brazil, but to date has avoided the need for public subsidies.

São Paulo has a lot of corridors that would qualify as BRT were taxis not allowed to operate in the bus lanes. It has one elevated silver-rated BRT, Expresso Tiradentes, which is a full-featured grade-separated BRT with off-board fare collection. The area-based contracts have led to weak inter-area public transport services, including through the central business district. The nature of these contracts changed over time from gross cost to net cost. After most of the bus services in São Paulo were privatized in the early 1990s, the new private operators that sprung up were under area contracts (gross cost), and vehicle operators were paid on a fee per kilometer basis. Fares were collected directly by the public authority SPTrans. This had the advantage of encouraging operators to drive more safely as they were not competing for customers. However, it gave too much latitude to private bus companies to set their own routes, which inevitably were longer than they could commercially justify. Subsidies began to escalate, and by the late 1980s one-third of public transport operations costs were subsidized by the Municipality of São Paulo. Thus, gross cost contracts in São Paulo came to be associated with government deficits and weak regulation. Facing unsustainable deficits, São Paulo shifted in 1991 to area contracts (net cost), paid by the customer. However, fare collection remained with SPTrans, mainly as a control so the city knew how much money the system was making. This shifted the demand risk back onto the vehicle operator. This helped to control subsidies for a time, but vehicle operators began cutting services to lower demand areas and during off-peak periods. Profits suffered. Competition from minibuses worsened, and the average age of the vehicle fleet began creeping up from three to seven years, and service quality began to decline. Hence, this net cost contract was associated with declining service quality (Golub and Hook, 2003, p. 14).

When the new “Passa Rapido” bus corridors were introduced in the Martya Suplicy administration (they did not qualify as BRT once they allowed taxis to use the lane), the *interligado* integrated fare system was introduced, which allowed for free transfers between routes. By the time that the Expresso Tiradentes BRT opened during the Serra administration, the contracts had already returned to an area-based (gross cost) contract based on kilometers operated. The integrated fare system significantly increased public transport mode share in São Paulo but at a significant cost to the municipality in additional subsidies to the system.

13.2.1.4 Area Contract (Net Cost)

Two of the best new BRT systems in Latin America, the new Gold Standard BRT systems in Rio de Janeiro and Belo Horizonte, are operated by area licenses on a net-cost basis. In these two cities, as in other Brazilian cities, the zones of the city were divided into separate area licenses for different vehicle operators. In these two cities, however, the vehicle operators never turned control of the fare revenue over to a public authority. As such, they continued to collect and keep the fare revenue.

When the BRT systems were opened in the two cities, they passed through the historical territory of more than one vehicle operating company with *area licenses (net costs)*. The vehicle operators maintained control of their operating territories by forming a consortium of the companies in the affected areas. They turned off-board fare collection over to a third party—the same company that already managed fare collection for their conventional vehicle operations in each city. This third party company then splits the fare among the BRT consortium partners based primarily on boarding customers. It is noteworthy that this fare collection company was created by the same historical vehicle operators. That is, in the final analysis, the fare is collected by the vehicle operators themselves.

This operating arrangement has similar benefits to the profit sharing arrangements of TransMilenio, but it is entirely in private hands. It fully privatized not only the vehicle operations but also fare collection, while insulating the city from any risk of paying operating subsidies.

There is an important difference between the structure in Belo Horizonte and Rio. In Rio, the contracts with the operators are signed directly with the Municipal Secretary of Transportation. In the case of Belo Horizonte, the operating contracts are signed with a transport authority, BHTrans. In the view of most experts, services in Belo Horizonte are better managed due to the superior oversight made possible by the existence of BHTrans. The system in Belo Horizonte has not been subjected to the same level of criticism as the services in Rio. By losing control over the fare revenue and having weak regulatory authority over the vehicle operating contracts, the municipality has ceded considerable control over the quality of operations. In TransOeste, for instance, service frequency was well below what was needed and the operators profited handsomely from crowding customers onto each bus. Performance was bad enough to reduce Rio's TransOeste service from a Gold Standard BRT to a Silver Standard BRT. The city authorities had limited contractual rights to force the operators to buy more vehicles and expand the services.

As the BRT systems are expanding, further industry consolidation is being prepared, and Rio vehicle operators are organizing to create a citywide BRT operating consortium. The division of payments between companies with control over different areas will become an issue to be settled internally by the board of a private consortium. It has yet to be implemented as of 2015 but merits monitoring.

In León, Mexico, the Optibús system is operated under a similar contractual structure. In León, the consortium operates both the trunk corridors and the feeder services. However, the distribution of revenues is handled differently for each route type. Fares are not independently collected but rather handled directly by the consortium. Even though the system has an integrated fare system and a single fare, fares collected by the feeder buses are kept by the feeder vehicle operators. The income of the feeder operators is thus based on the number of customers. The fares collected on the trunk corridors are deposited into a fund established by the consortium. Funds are reportedly distributed to trunk operators on the basis of number of kilometers travelled. However, since the payment system is not transparent, the exact nature of the revenue distribution scheme is unclear to the municipality and the public. For a while, since the feeder operators only keep the fares that they collect, they only have an incentive to serve customers during the morning commute. On the return trip in the afternoon, the trunk line operators collect the revenue. Not surprisingly, then, the feeder companies provided very little service, and thus make the trip home a relatively unpleasant and difficult experience for the customer. The city ultimately fixed the problem by creating a compensating fund.

Ultimately, some of the problems with area contracts (net cost), such as lack of compatibility with inter-area routes and off-board fare collection, can be resolved. It is likely that other problems, such as generally weak performance, could also be resolved by improvements in the contract. Ultimately, however, the public loss of control of the fare revenue significantly limits the day-to-day ability of the municipality to demand improvements in the quality of service if there are shortcomings.

13.2.1.5 Route Contract (Gross Cost)

Many BRT systems in lower-income economies continued the practice of route licenses even after a BRT was implemented. With TransJakarta in Jakarta and Metrobús in Mexico City, the BRT system only had trunk services, and services on new BRT trunk routes were turned over to the same companies or collectives that dominated the licenses on the same route. While the nature of the contract changed, and in both cities the operators were paid a flat fee per kilometer of service (gross cost), in both cases their operation was limited to one trunk corridor. As the networks expanded, and severe congestion formed at the transfer points between the two corridors, this route contract (net cost) contractual form made it difficult for the BRT authority to introduce inter-corridor routes. In both cases, however, this problem was overcome by negotiated profit sharing agreements between the two operating companies affected. Nonetheless, to avoid this problem, most BRT systems do not award route contracts (gross cost), but instead offer a fee per kilometer that can be operated anywhere in the BRT system's service area.

13.2.1.6 Route Contracts (Net Cost)

Most BRT systems in lower-income economies grew out of regulatory regimes where public transport services were dominated by *route contracts (net cost)*. With this type of contract, many small to large individual operators have a license, usually from a municipal department of transportation, to operate a public transport service on a particular route or a set of routes and to collect all of the fare revenue on those routes. This ends competition on the street within a particular route, but if there are routes that overlap, there is still competition on the street for customers. When applied to a BRT system, as it was in the Ecovía system in Quito, it led to very weak municipal control over the operator and an inability to integrate services between BRT corridors. In Quito, the municipality initially bought the BRT vehicles, and then tried to get the operators to pay for them in installments. Because the private operators that controlled the BRT routes also collected the fare revenue, however, the municipality never knew for sure how much money the system was making. Matters were made more complicated by national regulations fixing the fare at around US$0.25 per trip, very low by regional standards. It also proved very difficult to integrate services between the Ecovía routes and the Trolebus routes and other BRT routes, forcing all customers to pay twice.

13.2.1.7 Design-Build-Operate-Transfer Contracts

While popular for use in metro projects and toll roads, design-build-operate-transfer contracts are relatively little used for BRT projects in lower-income economies. In a typical metro build-operate-transfer contract, a private consortium would offer to design, build, and operate a metro system or toll road, and then it would be allowed to collect all of the fare or toll revenue for a long period of time, usually twenty or thirty years. After this, the infrastructure would nominally transfer back to the government. The government would ideally hold a competitive tender and offer the job to the firm that promised to build and operate the system for the lowest price. In the case of toll roads, this financing form sometimes works, as toll revenues are sometimes sufficient to cover the cost of building and maintaining the road. In the case of metro projects, the government would generally end up paying for all of the infrastructure and subsidizing the operations. Also, it would pay a premium for financing the system, but it would only have to pay for the system in annual installments, and it would get the infrastructure built with the least management responsibility placed on the government. This form has frequently been used to get around debt ceilings. The construction companies would usually front the money and earn it back at a premium over time in annual payments from the government. Sometimes these projects would tell the public that all the costs would be covered by the fare revenue. However, the private companies would generally require a demand guarantee on the part of the government and freedom to increase the fares or tolls. Demand levels would inevitably fall short or the government would refuse to raise tolls or fares sufficiently to cover the losses. Until recently, this contractual form was not used for BRT projects in lower-income economies.

However, there are now several BRT systems in Mexico where BRT operations are under a variation of this form of contract. The federal government there created a national government fund, called Public Transportation Federal Support Program (PROTRAM), to finance urban public transport from nationally collected revenues from national toll roads. This stimulated a lot of BRT system developments, particularly in the poorer cities and states outside of Mexico City. PROTRAM required a 35 percent private sector investment in the project in order to be eligible for the funds. As a result, several Mexican cities moved forward with BRT systems where the infrastructure was built by private companies that were also paid out of the fare revenue.

In Monterrey, there is no BRT authority. There are three contracts, one with a private vehicle operators' consortium. The vehicle operators are paid on a gross-cost basis (per kilometer) that is not part of a profit sharing arrangement. A separate private company that constructed the stations and terminals receives a portion of the fare revenue in the form of 1.1 pesos per person using the stations and terminals. The system is not financially ring-fenced. A third concessionaire, directly contracted by the state government, collects the fare revenue. It only recently began operation, so it is too soon to determine how much the system will need in subsidies.

In Puebla, the fare collection system is controlled by the company that built the infrastructure. It takes part of its costs out of the fare revenue, and then deposits the balance into a trust fund from which the vehicle operators are paid on a gross cost basis. This financial setup proved unsustainable, so the government had to step in and take control of the fare collection from the infrastructure provider. The system is subsidized.

In the State of México, there was a similar arrangement. A small public authority under the state government, Sistema de Transporte Masivo y Teleferico del Estado de México (SITRAMYTEM), contracted out infrastructure on three different lines to different construction companies, which in turn collected the fare revenue, paid themselves, and then paid the balance into a trust fund. Each had its own fare collection format, so the system was not integrated and users wishing to use multiple lines needed three different fare cards. The fleet operators were paid on a gross cost basis by the bus kilometer, out of the trust fund that is controlled by SIRAMYTEM. On Line 1, the system did not recover its costs, and the State of México had to take over the fare collection and infrastructure contract. Line 2 just began operations, but is likely to face similar problems. Demand on the corridor was lower than projected in part because the government failed to regulate competing traditional unregulated route concessions parallel to the new BRT service, which only operates with a time and cost advantage during peak hours.

As such, the track record with DBO form contracts in lower-income economies is decidedly poor. It is likely that the financial projections were invalid from inception just to ensure that the projects complied with national government PROTRAM funding requirements. It may be that these types of contracts could be improved, but only if federal guidelines are made more realistic and the systems are not designed with false assumptions about their potential profitability.

13.2.1.8 BRT Systems with Unregulated Entry

"Unregulated entry without quality control" and *"unregulated entry with quality control"* are not generally seen in BRT systems, and they are almost universally accepted as being inappropriate for BRT systems. Under these two contract types, informal operators are allowed to operate as many vehicles as they would like on as many routes as they want whenever they want, so long as they have a vehicle of the appropriate type, with or without some control as to the quality of the vehicle. These systems tend to lead to informal, often criminal forms of regulation and control of the industry, an oversupply of vehicles on trunk routes during peak periods and an undersupply on lower demand routes and during nonpeak periods. These systems tend to have high pedestrian fatalities at curbside, as vehicles compete for customers. They tend to have problems of not following any schedule, not stopping at predetermined stops, and the vehicles tend to be old, uncomfortable, and unsafe.

In the first generation of busways, starting in the 1980s, there were many busways with these contractual forms in lower-income economies, but they generally failed to reach BRT status. They had several serious problems. First and foremost, if too many vehicles are operating inside them, BRT systems saturate, and busway speeds can drop to below mixed traffic speeds. TransMilenio, in fact, was an "open" busway with unregulated entry prior to the creation of TransMilenio, and its operating speeds averaged only around 12 kilometers per hour, little more than standard mixed traffic operation due to busway saturation.

In Delhi, one of the main problems with the High Capacity Bus System (HCBS), which was rated Basic BRT, was that there were very weak barriers to entry for individual owner-operated vehicles registered with the STA to use the BRT system. These vehicles were frequently old, polluting, and subject to failures (see Figure 13.6). As a result of vehicles operating under this outmoded contractual form being allowed to use the BRT infrastructure, these vehicles frequently broke down, congesting the busway. Further, their numbers were greater than the busway could accommodate, leading to vehicle queueing at the stations and intersections that lowered operating speeds. All of this tarnished the image of the HCBS and contributed to its decidedly mixed political reception.

Figure 13.6. Non-BRT buses are shown being allowed in the Delhi HCBS bus lanes, many of which are in a deteriorated state, causing frequent stalls and breakdowns. *ITDP.*

13.2.2 BRT Operating Contract Types in Higher-Income Economies

In higher-income economies, the relative transparency of business operations, more effective governmental regulatory powers, and greater experience with sophisticated contracts and their enforcement have less trouble with some contractual forms that have caused significant difficulties in lower-income economies. That being said, the types of contracts most typical in higher-income economies all tend to leave government exposed to open-ended subsidies with relatively limited incentives for greater service efficiency. BRT systems are also smaller in higher-income economies, so the contract structures have rarely been developed specifically for a new BRT system, and operations are generally contracted out to the same vehicle operating contractors, using the same contractual forms that operate normal bus services in the municipality.

It has not yet proved possible to create a BRT system in higher-income economies that is financially self-sufficient and financially ring-fenced to the point where a profit sharing contract has been tried. It is, however, theoretically possible to build a BRT on the highest demand public transport corridors and structure the business in such a way as to achieve full financial recovery to the point where profit sharing could be discussed.

Currently, in higher-income economies, a citywide public transport *service contract (gross cost)* that encompasses the BRT routes is the most common contractual form in BRT systems (Paris and Nantes in France). There is also one system (Las Vegas, U.S.) where operators are given *route contracts (gross cost)*. These consist of one *build-operate-transfer form* of contract in which the builder of some rail infrastructure has a long-term operating concession that also covers the BRT system (Rouen, France), and two *route contracts (net cost)* in which an operator has a contract to provide services on specific routes and collects all the fare revenue for those routes (Cambridgeshire, UK; Amsterdam, Netherlands). The relative merits and problems of these contractual forms in higher-income economies are similar to those in lower-income economies but generally on a much smaller scale.

The context for contracting out public transport operations in higher-income economies is quite different from in lower-income economies. Both net cost and gross cost contracts have the problem that, unless otherwise mitigated, they create no incentive for transit operators to reduce their costs. However, in higher-income economies, the government body that regulates these contracts usually has at least some chance of knowing what the firm's costs are. Operating companies that generally have reasonably transparent corporate governance have to be audited and publish financial statements.

The deregulation of public transport services in England under the Thatcher administration, and later the encouragement within the European Union of private contracting of private operators, has over time led to the emergence of private firms able to provide these services. It is mostly these same firms that are offering their services in the United States. Initially, it was quite difficult for private firms to compete with long-established municipal transit operating companies that had trained staff, land, depots, and established supply relationships. As such, privatization began mostly on new routes, new services (such as public transport for disabled people), in newly urbanizing areas, and in smaller towns where government did not have the staff or experience to manage a public transport system. Many of the contracts are essentially management contracts, where firms are given permission to manage and operate public sector assets (depots, vehicles, etc.) on behalf of the government. Usually this involves renegotiating labor contracts, though in most cases these firms have managed to make the transition to private contracting without fundamentally disrupting labor relations (as per interviews with Veolia US).

Nevertheless, the number of firms that are likely to bid on an operating contract remains small. Entering into the market that was previously dominated only by a public sector transit operator meant that there were not existing local private vehicle operators to contend with, only public sector labor unions and their political clout. Only a very limited number of firms have emerged to enter this commercial space and are capable of bidding on municipal vehicle operating contracts, and these firms have gone through frequent changes in ownership structure.

Today, some of the largest private firms are TransDev, a French company that used to be Veolia, and before that was Connex; Stagecoach (Scottish/British), Tower Transit (Australian), and Keolis (French-Canadian), which is owned by the French national railways (SNCF) and a group of Canadian investors. These same firms have tended to buy up smaller private vehicle operations, and their names appear in virtually all of the privately operated transit systems in higher-income economies. Their main competition in Europe is from the former, partially privatized municipal transit operators, which are typically allowed to compete with these international firms. To date, most of these firms have been hesitant to move into emerging markets where they are less certain of the risks, though TransDev and a few others have moved into Latin America.

13.2.2.1 Service Contracts (Gross Cost)

The Nantes BRT is also operated as part of the gross-cost contract for all public transport services in Nantes. Nantes Métropole built and owns all of the BRT infrastructure and all of the public transport vehicles. The compensation paid to the operator is a fixed amount, agreed upon at the beginning of the contract, based on a specified number of kilometers, and integrates inflation and fare increases (personal communication with Cécile Lairet, 2013). By agreeing to a fixed amount for the life of the contract, the contract provides some protection for the metropolitan area to control costs. The operator collects and keeps all fares collected and is then paid a subsidy on top of that. In 2012, the cost of operating the public transport network was about US$185.2 million (€142.8 million per 2012 rates at USForex Foreign Exchange Services), and fares paid US$64.1 million (€49.4 million, or about 35 percent) of that cost. Nantes Métropole paid US$117.5 million (€90.6 million), and this included social fares (e.g., senior citizens who ride for free). The remaining US$3.6 million (€2.8 million) came from advertising, repayments from insurance, and ticket checks. The operator received about US$9.9 million (€7.6 million) per month from Nantes Métropole in 2012.

The level of service is specified in the contract and measured by fifteen indicators, with a specific level that the operator has to reach for each indicator. An external firm conducts the audits, and if the operator does not reach the required global level, the operator has to pay a penalty to Nantes Métropole. Close financial controls ensure that the Métropole knows exactly what the operators' expenses are before making payments.

13.2.2.2 Route Contract (Gross Cost)

In Las Vegas, compensation for the private operators is based on an hourly per-bus rate of US$53.10. The transit authority, RTC, owns all the vehicles, but the private operator is responsible for operations, maintenance, and all other costs related to public transportation provision other than infrastructure (personal communication with Angela Torres Castro, 2013). The RTC plans the routes and frequency of the vehicles, and contracts a separate company that ensures contract compliance. The contracting arrangement in Las Vegas appears to work well.

13.2.2.3 Route Contract (Net Cost)

The R-Net BRT in Amsterdam is an example of a net-cost BRT operation. The collected fare forms the basis of compensation and there is no guarantee for minimum payment for customers. For instance, if no customers are transported, the operator will not receive any payment for customers; if 80 percent of expected customers are transported, the operator will receive 80 percent of the payment, and so on. This also encourages smart pricing to raise revenue.

The Stadsregio Amsterdam, the metropolitan Amsterdam area, calls this arrangement a "supplementation contract." For example, if a firm offers a "supplementation factor" of 1.4, then for every US$10 million of fare revenue (€9.1 million), the operator receives US$14 million of subsidies (€12.7 million), so that total payment is US$24 million (€21.7 million—figures from 2016 exchange rate of Oanda.com). At tender, operators offered their "supplementation factor." According to Stadsregio Amsterdam, the result was a self-regulating contract with a focus on raising customer demand.

The Cambridgeshire BRT is also a route contract (net cost). It has two operators with routes that use the Cambridgeshire guided busway, and they both directly collect the fare revenue. As with other BRT systems, the busway was mostly paid for by funds from the central government, though some amount was paid by real estate developers who owned land close to the corridor. Two vehicle operator companies, Stagecoach and Whippet (a subsidiary of Tower Transit that operates buses in London and in turn is a subsidiary of Transit Systems, an Australian firm), both run vehicles on the busway. Both pay an annual fee to use the busway, which covers the county council's overhead costs related to the busway, including staff, maintenance, and utilities (about US$743,790 or £600,000). The operators are required to provide a minimum hourly service (three buses per hour), and have a five-year contract. Since the busway's opening, both operators have added services. They collect all fares, and receive no subsidy besides a subsidy for fuel from the central government, and compensation for reduced-fare riders (such as the elderly).

13.2.2.4 Design-Build-Operate-Transfer Contracts

The Rouen BRT is operated under a hybrid type of contract that includes elements of a build-operate-transfer contract, a net cost contract, and a gross cost contract. The schedule of services for the BRT in Rouen, known as the Transport Est-Ouest Rouennais (TEOR), is planned and managed by the local government body called Communauté de l'Agglomération de Rouen Elbeuf Austreberthe (CREA). The BRT has three corridors, is 30 kilometers long, and sometimes operates in mixed traffic. TEOR was created as an integrated part of the transport system in the city, which also includes 15 kilometers of tramway, and eight lines of conventional bus service.

The contract for operation of the BRT was part of a special contract with Veolia (now TransDev) that also included construction and operation of the tramway (CREA, not TransDev, paid for the construction of the BRT). Veolia/TransDev won a thirty-year contract in 1994, and it includes operation of the entire public transport system. This contractual form is unusual in France, where such public transport operating contracts are usually only six to seven years long. The authority pays the operator about US$65 million (or €50 million) annually for operation of the system, including tramway, BRT, and conventional buses (personal communication with Catherine Goniot, 2013). The payment to the operator is made on the basis of trips made, kilometers travelled, and customers transported, combining elements of net cost and gross cost contracts. If the operator makes more trips than foreseen, travels over the stipulated amount of kilometers, or carries more customers, CREA's payment is higher. Other parameters for payment include speed—the faster the trips, the less

CREA has to pay. This is an incentive for CREA to reduce congestion. Veolia collects fares, maintains vehicles, while CREA owns the vehicles and depots. There have been some complaints that such a long-term contract, without any quality of service provisions, has led to weaker service.

13.3 Competitive Tendering

"Goodwill is the only asset that competition cannot undersell or destroy."

— Marshall Field, entrepreneur, 1834–1906

If it is decided that operations of the BRT are to be turned over to private operators, the next key decision is whether to competitively tender the operating contracts, or to turn them over to a new or existing firm through some other administrative mechanism.

There are several reasons to make the awarding of BRT operating contracts subject to competitive bidding:

- The city is likely to pay less for the service;
- It gives the government more leverage over the remaining (non-cost) details of the contract in the negotiations;
- It is a requirement of many government procurement rules;
- It is in compliance with most development bank loans, thus opening up more financing options;
- It allows the government to stay in control of the timeline;
- It ensures that the companies that operate the system are the best companies possible;
- It can play a critical role in operating company formation.

In cities where operating contracts were negotiated, negotiations dragged on, significantly delaying the start of operations, as the city had no clear and simple way to compel a closure to the negotiations. From the perspective of company formation, the competitive tender approach allows the city to establish the minimum qualification criteria for eligible companies in the TOR for the tender. These minimum qualification requirements force the bidders to create companies that are sufficiently capitalized, that have a clear governance structure, and that have a qualified staff. Ultimately, it helps the companies become regionally competitive in the long run. It gives these cities much greater leverage over the negotiating process to ensure that companies were formed following a government-established timeline. It also ensures that the contracts were awarded to the best possible companies.

Tendering of Private Operations		
BRT System	Degree of Competition	Exclusive to BRT
Lower-Income Countries		
Rio de Janeiro (Transoeste)	Nominal tender	No
TransMilenio, Bogotá	Competitive tender	Yes
Curitiba (URBS)	Nominal tender	No
GBRT, Guangzhou	Negotiated	Yes
Lima (Protransporte)	Competitive tender	Yes
Belo Horizonte (BHTrans)	Nominal tender	No
Pereira, Colombia (Megabus)	Competitive tender	Yes
Ahmedabad (Jan Marg SPV)	Competitive tender	Yes
Cali, Colombia (Mio)	Competitive tender	No
Johannesburg (Rea Vaya)	Negotiated	Yes
Monterrey, MX	Negotiated	Yes
State of Mexico (Mexibús)	Negotiated	Yes
Mexico City (Metrobus)	Negotiated	Yes
Guayaquil, Ecuador	Stepped negotiations	Yes
São Paulo, Brazil (SPTrans)	Nominal tender	No
Quito EcoVia	Negotiated	Yes
TranSantiago	Competitive tender	Yes
Puebla, MX	Negotiated	Yes
Cape Town BRT	Negotiated	Yes
TransJakarta, Jakarta I - III	Negotiated	Yes
TransJakarta, Jakarta IV - X	Partial tender	Yes
Higher-Income Countries		
Rouen, France (TransDev)	Nominal tender	No
Paris Mobilien, Ile de France (RATP)	Nominal tender	No
Cambridgeshire , England	Competitive tender	No
Nantes, France (Semitans)	Nominal tender	No
Las Vegas (RTCSV)	Competitive tender	No
Amsterdam R-Net (not yet rated)	Competitive tender	No

Competitive tender	More than one firm bid for an operating contract no more than 12 years
Nominal tender	Competitive bid where only 1 firm bid
Partial tender	Competitive bid for part of the service
Stepped negotiation	Negotiation where a competitive bid would ensue if negotiations fail
Negotiated	Negotiated contract with pre-determined operator

Figure 13.7. Degree of competition in tendering of BRT vehicle operations. *Walter Hook, BRT Planning International, LLC.*

In general, tendering out of municipal BRT vehicle operations is rarely fully free and competitive. The degree of competitiveness, however, can have an important impact on the ultimate quality of service. Figure 13.7 ranks several leading BRT systems in terms of the degree of competition in their tendering process. Those contracts where there was a reasonably robust competitive tender with more than one bidder and some real competition are shaded green. In these cases, governments tended to negotiate for lower operating costs and more private investments, and require more quality of service guarantees. The maximum length of the contract included here is twelve years. European Union rules allow for a maximum contract life of ten years, but it is typical in some Latin American systems to extend the contracts for twelve years. Both of these types of contracts are set to mirror the expected reasonable commercial life of the vehicle so that investors can recoup their investment in the vehicle.

Those contracts that were awarded with less than full competition were shaded yellow. This included a number of possible cases. In all cases the government had some leverage over the private operators during the negotiation to require lower costs, more investments, and some quality of service guarantees. But the government had a generally weaker hand in the negotiation than in the case of full competitive tenders. This includes cases where a competitive tender was held but where only one firm ended up bidding (French and Brazilian cases), or where the period of the contract is greater than twelve years (Rouen). It includes cases where only a part of the service was competitively tendered, and the remaining part of the service was negotiated (Jakarta). Finally, it includes cases of a "stepped negotiation" where the government agrees to negotiate with a particular firm or consortium, but the government sets conditions in advance that require turning to a competitive tender if the negotiations break down (Guayaquil).

Those cases where BRT operations were awarded to a firm without a tender, usually a negotiation with a consortium of the former operators in the same corridor, are coded pink. In almost all of these cases, the leverage of the government over the private operator, to compel better services and lower costs, is considerably weaker.

13.3.1 Competitive Tendering in Lower-Income Economies

13.3.1.1 Managed Competitive Tendering of BRT Operations

Bogotá's TransMilenio initiated a significant increase in the level of competitiveness in the tendering process of Latin American BRT systems, which later spread to other cities around the world. Competitive tendering specifically of new BRT services was first done in Bogotá, and later spread to other Colombian cities, and to Lima, Santiago, and Ahmedabad. The companies that won these tenders were stronger companies as a result, and many of them have gone on to become regionally if not internationally competitive. These systems were colored green for having a reasonably competitive tendering process.

A competitive bidding process ensures that firms offering the best quality and most cost-effective services are invited to participate in the new BRT system. A bidding process can also do much to shape the long-term sustainability of the system. Competition is not just reserved for trunk line operators as other aspects of a BRT system can also benefit, including feeder services, fare collection systems, control center management, and infrastructure maintenance.

A bidding process sets expectations for the private entities interested in being part of the system and establishes the terms and conditions that will define the relationships among the different actors. The bidding process developed by Bogotá's TransMilenio stands out as one of the best examples of providing a competitive structure directed at both quality and low cost. In reality, Bogotá used its incentive structure to achieve a variety of objectives:

- Cost-effectiveness;
- Investment soundness;
- Risk allocation;
- Environmental quality;
- Opportunities for existing operators;
- Local manufacturing of vehicles;
- International experience and partnerships.

Bogotá's competitive bidding process provided the incentives to completely modernize its public transport system by encouraging modern vehicles, wider company ownership, and sector reforms. The principle mechanism in Bogotá was the use of a points system to quantify the strength of bidding firms. By carefully selecting the categories and weightings within the points system, TransMilenio shaped the nature of the ultimate product. Table 13.2 provides a summary of the bidding categories and weightings.

Table 13.2. Points System for Bidding on TransMilenio Trunk Line Operations

Factor†	Description	Eligibility	Points:Minimum*	Points:Maximum**
Legal capacity	Bidding firm holds the appropriate credentials to submit a proposal	X	-	-
Economic capacity	Bidding firm holds the minimum amount of net owner's equity to submit a proposal	X	-	-
	Passenger public transport fleet in operation		30	140
Experience in operation	Specific experience providing passenger services in Colombia		50	250
	International experience on mass public transport projects		0	50
Economic proposal	Offer price per kilometer to operate the service		0	350

	Right of exploitation of the concession			
Proposal to the city	Valuation of the share given to TransMilenio SA from the revenue of the concessionaire(1)		21	50
	Valuation of the number of buses to be scrapped by the concessionaire(2)		14	50
Composition of equity structure	Share of company's stock held by former small vehicle operators		32	200
Environmental performance	Level of air emissions and noise; disposal plan for liquid and solid wastes (1)		0	200
Fleet offered	Size of fleet; ;	X	-	-
	Manufacture origin of the fleet; ;		0	50
	Total (1350 points possible)			

† If the proposal meets all the requirements, then the proposal will be categorized as ELIGIBLE.

* If the proposal is below any given minimal value, then the proposal will be categorized as NOT ELIGIBLE.

** If the proposal does not meet the established range, then the proposal will be categorized as NOT ELIGIBLE. (1) Not present on first phase; (1) Fixed number on first phase.

The "economic capacity" category refers to the ability of the company to provide a minimum equity level as an initial investment. The minimum equity level is equal to 14 percent of the total value of the vehicles being offered to the system. The minimum owner's equity is defined in Equation 13.1:

$$\text{Minimum Owner's Equity} = \text{NMV} \times \text{US\$200,00} \times 14\%$$

Where NMV is the maximum number of vehicles offered to the system.

The value of US$200,000 was the approximate cost of an articulated vehicle in Phase I of TransMilenio, based on the specifications required by TransMilenio SA.

The points system was used in a way that rewarded inclusion of the existing operators, but the design also provided an impetus to consolidate small operators into legitimate companies.

The "environmental performance" of the bid refers to the rated air emissions and noise levels expected from the provided vehicle technologies as well as the expected handling of any solid and liquid waste products. In the case of Bogotá, the initial minimum standard for tailpipe emissions is Euro II standards. With time, this requirement will increase to Euro IV. However, firms offering Euro III technology or higher can gain additional bid points for doing so. The bidding process thus offers an in-built incentive to not only meet minimal standards, but encourages firms to go much higher. In turn, this incentive creates a dynamic environment to push vehicle manufacturers to provide improved products. Prior to TransMilenio, Euro II technology was difficult to obtain in Latin America since the manufacturers produced such vehicles predominantly for the European, North American, and Japanese markets. Now, with the incentives from TransMilenio, some manufacturers in Latin America are even producing Euro III vehicles.

The bidding process also encourages the vehicle manufacturers to develop fabrication plants in Colombia. Local fabrication of vehicles is awarded additional points. This item is not a requirement, but it does bring benefit to bidding firms that can secure local fabrication. Thus, the bidding process does not require local manufacturing in a draconian manner. Instead, the positive reinforcement of bidding points helps to instill a market-based outcome. To date, much to the credit of TransMilenio's existence, two major international bus manufacturers have established production sites in Colombia. Marcopolo, in conjunction with two local firms, has built a fabrication plant in Bogotá (Figure 13.8), while Mercedes has built a plant in the Colombian city of Pereira.

Bogotá's competitive bidding process has been successful in selecting operators who are most capable of delivering a high-quality product. Table 13.3 summarizes some of the characteristics from the successful bids for Phase II trunk lines of TransMilenio.

Figure 13.8. Due to the incentive structure in the TransMilenio bidding process, bus manufacturers have been encouraged to develop local manufacturing sites, such as this one in Bogotá. Image *Lloyd Wright.*

Table 13.3. Successful Bids for Phase II Trunk Lines of TransMilenio

Company name	Fleet size	Emissions	Price / kilometer (Colombian pesos)	Revenues* to TransMilenio (percent)	Vehicles to scrap	Participation of existing operators	
				Owners	Percent of equity	**Owners**	**Percent of equity**
TransMasivo SA	130	Euro III	3,774	3.53	7.0	452	20.22
Sí – 02 SA	105	Euro II	3,774	3.53	7.5	658	21.62
Connexion Mobil	100	Euro II	3,774	3.53	8.9	740	29.39

Source: TransMilenio SA

* The "Revenues to TransMilenio" column represents the amount of revenues that the bidding firms are willing to give to the public company (TransMilenio SA) in order to manage the system.

The successful bids in Table 13.3 indicate different strategies by each firm. Interestingly, all firms entered the same price level and the same sharing of revenues to TransMilenio. The selection of these values is not due to collusion or coincidence. Instead, these values are the median of the allowed range. The column "vehicles to scrap" indicates the number of older vehicles that each company is willing to destroy for each new articulated vehicle introduced. Thus, for example, the company "Connexion Mobil" will destroy 8.9 older vehicles for every new articulated vehicle that the firm purchases. With a total of 100 new vehicles being introduced, Connexion Mobil will thus destroy 890 older vehicles. The final columns set out the amount of participation each firm has given to existing small operators.

The second phase incorporated many additional requirements for the operators, but these additions did not discourage interest or reduce the value of the bids. The initial bidding process had many uncertainties and risks that did not hold with the second.

The duration of the concession contract has also played a pivotal role in influencing the results of Bogotá's bid process. A long concession period increases the value of the contract and thus increases the quality and quantity of the bids. However, if the concession period is too long, then the municipality's flexibility with future changes becomes limited. Further, a long concession period can have a negative effect on competition since it creates a long-term oligopoly for the successful firms. In the case of Bogotá, the duration of the concessions matches the estimated useful life of the new vehicles. Each successful firm thus receives a concession for ten years.

The ten-year concession period (based on kilometers) also applies to the feeder services. During Phase I of TransMilenio, the feeder operators only received a concession for a period of four years. The trunk operators still had a ten-year concession during Phase I. The longer concession in Phase II for the feeder companies reflects increased expectations for these firms in terms of vehicle technology and service quality. By giving a longer concession period, the operators can purchase new vehicles and amortize the vehicles over time. After Bogotá developed this form of managed competitive tendering, it was copied in a number of other cities, particularly other cities in Colombia, but also in Lima, Santiago, and Ahmedabad.

13.3.1.2 Nominal Tenders: Periodic Tendering of Area Contracts and Staged Negotiated Contracts

BRT started in Brazil. In most Brazilian cities, the history of tendering vehicle operations is similar in all cities. In almost all Brazilian cities, a set of private vehicle operators established control over an area of the city, and this control was legitimized in law with an area contract—either a gross cost or a net cost contract. In the past decades, federal law has required the retendering of route licenses after a maximum number of years. During the periods when these area licenses are re-tendered, the municipality has some leverage to demand more out of the vehicle operators. Usually this leverage is used to require them to buy new vehicles or improve other elements of their service. While inevitably the historical operators have tended to win a renewal of their contract, this period when the contract expires has given the government more leverage over the operators to demand more. For all of the Brazilian systems, the operating contracts have not been tendered upon the initiation of a BRT system, but rather they have been tendered during their periodic contract renewal phase for their area contracts (whether gross cost or net cost). As such, all of the Brazilian BRT systems have been colored yellow, to indicate that there is some nominal tendering in the awarding of contracts.

Guayaquil in Ecuador used the threat of moving to a fully competitive tender to improve its negotiations with its operators. Guayaquil's Metrovía system has been developed around a tiered approach to operator contracting. The Metrovía oversight organization set certain standards that any concession agreement must reach. Existing operators in the city were given first right to participate in the concession. If the operators did not accept this opportunity, then the second tier of opportunity would be extended to firms operating within the province. If the system was still not fully subscribed after the second tier, then the operating contracts would be opened to all national and international firms in the final tier. Given the impending presence of other firms entering their market, the existing operators agreed to terms with the city and thus filled the operating quota for the project's first phase. This gave the municipality significant leverage over the traditional operators, which still won the bid, but the Guayaquil operators have not gone on to become regionally competitive companies in the same way that the TransMilenio operators have.

In the case of TransJakarta, the DKI Jakarta government decided in Phases III and IV of the project that as they were investing roughly 60 percent of the total project cost in the form of infrastructure (as compared to 40 percent of the total cost required to buy new vehicles), that 60 percent of the market share would be put up for competitive tender and the remaining 40 percent of the market would be turned over to a consortium dominated by the traditional operators. The company that won the tender was an intercity vehicle operator that could offer a low-cost service per kilometer. Never compelled by the minimum qualification criteria of a competitive tender, the traditional operators never completed the process of transition to modern vehicle operating companies, and most continue to struggle with performance and maintenance issues and low quality of service. The services offered by the winner of the tender have tended to be better.

13.3.1.3 Negotiated Operating Contracts Around the World

In many other countries, particularly in South Africa, Mexico, and Ecuador, municipal governments never required a real competitive tender. In South Africa, the existing minibus industry in South Africa has done much to promote Black Economic Empowerment (BEE) in the country and has served a key historical role in providing transport services to marginalized communities. It was an industry composed of small individual owners consolidated into various competing taxi associations. The structure of the industry was so complex and labor relations so volatile, that the South African government decided to use provisions in its public procurement law that allowed for noncompetitive bidding in the case of black empowerment goals. In the end, South Africa decided to negotiate with the existing affected operators. Thus, the government partially achieved some of its small business development and black empowerment objectives. It did this at a very high cost, with operating costs being as much as 40 percent higher than what would have resulted from a competitive tender.

On Quito's Ecovía corridor, the existing operators formed a joint consortium (called TRANASOC) and were given exclusive rights to provide services for a ten-year period. The operators were also essentially given free financing on the new articulated vehicles since the municipality purchased the vehicles with public funds.

In Quito, the operators were to repay the municipality for the vehicles using revenues collected from the system. Unfortunately, fare collection was done directly by the operators so the municipality has little knowledge on actual customer counts and revenues. Quite worryingly, the operators' repayment of the articulated vehicles was tied to profit guarantees related to the number of customers. Clearly, the operators had a strong incentive to underestimate customer and revenue numbers to minimize any repayment of the vehicles. In the end, the city simply sold the vehicles to the operator at a greatly reduced price.

In Mexico, virtually all the BRT systems were turned over to consortiums of former operators through a process of negotiation, except in a couple of instances. In these cases, there was a powerful intercity vehicle operator that organized the affected operators, offered to manage the new system, and offered to let them join their own company as shareholders. Virtually all the other BRTS in Mexico are operated by corridor-level monopolies created by the former owner/operators.

Figure 13.9. In the case of the Quito Ecovía line system control is ceded to the operators meant sacrificing a certain quality standard. *Lloyd Wright.*

León's BRT structure is likewise skewed toward rewarding existing operators rather than overall efficiency. Like Quito, existing operators formed a monopoly consortium, in this case called the "Coordinadora de Transporte." The municipality acquiesced to the consortium's demands for full monopolistic rights of operation. The consortium's operating rights to the system do not have a termination date, implying a monopoly in perpetuity. However, on the positive side, the consortium did invest directly in new vehicles.

Figure 13.10. System control was also ceded to operators in the case of the León system at the expense of a quality standard. *Eric Ferreira.*

Besides the lack of transparency and competitiveness within the system, the market design also has negative consequences for quality of service. Given the predictable results of manipulation and inefficiency, why do municipalities choose uncompetitive structures such as those in Quito, León, and Jakarta? Principally, the reason is a lack of political will. Municipal officials are not willing to entertain the possibility that some existing operators could lose their operational rights along a particular corridor. The resulting upheaval from disgruntled operators could have political consequences. If a BRT project is faced with no other option than to proceed with a negotiated contract with an existing operator, there are still ways to optimize the results.

13.3.2 Competitive Tendering in Higher-Income Economies

In higher-income economies, if there are private operations, then some sort of competitive tendering process is generally required by public service procurement rules, including the European Union's rules on public transport procurement. In the best-case scenario, there is a robust tender with many firms bidding for the BRT services and usually other public transport services. In the worst-case scenario, a competitive tender is held to comply with EU requirements, but it is a foregone conclusion that the current operator will win, and there is only one bidder.

Some reasonably competitive tenders for BRT operators in higher-income economies include the Las Vegas SDX, the Amsterdam R-Net, and the Cambridgeshire guided busway. Some less competitive BRT vehicle operations include the Rouen, Paris, and Nantes BRT systems in France.

Public transportation in Las Vegas has for many years been operated by private companies. It is managed by the Regional Transportation Commission of Southern Nevada (RTC). Since the RTC was created in 1992, all public transportation in Las Vegas has been operated by private firms that were contracted through RFPs. Previously, public transport was operated by a single firm (Veolia), with another firm (First Transit) providing "paratransit" services. Because administrators felt the system was too large to be covered by a single contract, a new tender (or RFP) was held, and two winners, Keolis Transit America and MV Transportation, were announced in February 2013 (Velotta, 2013).

Public transportation in the Amsterdam metropolitan region is split into four zones, all of which are tendered. While the operating contract for the central region (Amsterdam proper) has been continually won by the public operator GVB, which, as per the GVB website, has operated the system for over 113 years, the area of the R-Net (previously known as Zuidtangent) is operated by Conexxion (owned mostly by TransDev), which won a competitive tender for eight years.

The Nantes BRT is operated by Semitan. It won a competitive tender for a six-year contract, but Semitan was the only bidder, and it was the former public transport operator in the city of Nantes. In Rouen, the BRT system is operated by TransDev (formerly Veolia), which won a thirty-year operating concession as part of a long-term design-build-operate contract that included building a tramway and operating the entire municipal public transport system. It won a competitive tender but the length of the contract undermines the leverage of the regional government over the private operator.

13.4 Competition within the BRT Market

"You rarely win, but sometimes you do."

— Harper Lee, novelist, 1926–2016

After the experience with transit privatization and deregulation in the UK, many experts believed that urban transit services were better off if there was competition "for" the transit market, rather than competition "in" the transit market.Competition "for the market" refers to the tendering out of a set of transit services identified as necessary by a government body. Competition occurs at the time when the services are put up for competitive bid every so many years (usually five to seven years). This had the benefit of ensuring that services were provided according to social needs, while providing periodic leverage over the private operators to improve quality and reduce operating costs. The longer the length of the contract, however, the less leverage the government has over the company once the contract is awarded. After the contract is awarded, that company has a monopoly over the provision of those services until the next tender. If the quality of service is poor, the government has little recourse but to cancel the contract, which governments are generally very reluctant to do as it involves significant disruption of services.

Competition "in the market," by contrast, traditionally meant ongoing competition for customers for the same set of services. The traditional downside of competition "for in market" was that firms would all tend to compete for the customers on the highly lucrative routes during the peak periods and underserve the times and routes with less demand. It also tended to lead to a lot of customers getting killed at curbside as buses jostled to receive customers first. On the other hand, companies have an ongoing incentive to maintain a higher quality of service as they are competing for the same customers as other companies on an ongoing basis.

When the business model for TransMilenio was developed, the service wanted to retain an element of both forms of competitive pressure. It did so by having more than one company in place to operate BRT services on the same routes, though both companies were paid by the bus kilometer. Having more than one company operating on the same routes, while paying both companies per bus kilometer, created the possibility of having the BRT authority transfer part of the market from one company to its competitor at any time that quality of service began to lag. This gave the BRT authority a lot more leverage over the private operators than in a standard contract where there is only competition "for the market" and no competition "within the market."

The mechanism for this was to have the BRT authority evaluate on a continuing basis the quality of the service for each company (see next section). If the quality of service for one firm is poorer than for another, the firm providing the poor quality of service will have part of their market taken away from them (the number of kilometers they are assigned to operate) and given to their competitor for one month.

Having multiple operators on a single corridor also significantly increases the chances that a transit authority can make good on a threat to step in in case there is a major problem with an operator. If there is only a single monopoly operator, and the government steps in, operations will stop until a new operator can be found. If there are multiple operators and the government needs to step in, it can immediately give the service and usually the vehicles as well to the competitor to operate the route with minimal disruption of service.

After TransMilenio, a growing number of cities decided to opt for multiple operators on a single BRT corridor, to provide some competition within the market as well as competition for the market.

Number of Bus Operating Companies		
BRT System	**Phase I Companies**	**Operating Conditions**
Lower-Income Countries		
TransMilenio, Bogotá	6	> 1 operating company
Curitiba (URBS)	2	zone-based or public operator
GBRT, Guangzhou	3	> 1 operating company
Rio de Janeiro (Transoeste)	1	1 company
Belo Horizonte (BHTrans)	1	1 company
Pereira, Colombia (Megabus)	7	> 1 operating company
Leon	1	1 company
Quito EcoVia	1	1 company
Monterrey, MX	1	1 company
São Paulo, Brazil (SPTrans)	2	zone-based or public operator
Guayaquil, Ecuador	1	1 company
State of Mexico (Mexibus)	1	1 company
Mexico City (Metrobús)	2	zone-based or public operator
Rea Vaya	1	1 company
Ahmedabad (Jan Marg SPV)	1	1 company
Cape Town BRT	3	> 1 operating company
TransJakarta, Jakarta	2	zone-based or public operator
Puebla, MX	1	1 company
Higher-Income Countries		
Paris Mobilien, Ile de France (RATP)	1	1 company
Rouen, France (TransDev)	1	1 company
Nantes, France (Semitans)	1	1 company
Cambridgeshire, England	2	> 1 operating company
Las Vegas (RTCSV)	2	> 1 operating company

Figure 13.11. BRT systems with competition within the market. Graphic *Walter Hook, BRT Planning International, LLC.*

In Figure 13.11, BRT systems are divided into three categories with respect to the degree of competition within the market. Those with Phase I coded green have more than one company able to operate any of the BRT routes. Those coded yellow are either zone-based contracts where there is more than one company operating on some corridors that are between zones, or they are systems where there is a public operator in place to compete with the private operators. Those coded pink are those systems where all routes are served by only one company.

The Colombian BRT systems and those in Guangzhou, Cape Town, Las Vegas, and Cambridgeshire all have private operators that have at least two operators able to operate on the BRT infrastructure. For BRT systems in Curitiba and São Paulo, there are only multiple companies on BRT corridors that pass between zones. In Mexico City's BRT system, a public operator competes with the private operator on most corridors to provide some competition for the market. For Jakarta's BRT system, in all the phases after Phase I, there was more than one operator (usually two) on each corridor: one competitively tendered and one given over to the traditional operators, or two given over to traditional operators.

In all the remaining systems, there is no competition "within" the market, with a single firm or consortium providing all the BRT services on a particular corridor.

13.5 Quality of Service Contracts

> *"The whole duty of government is to prevent crime and to preserve contracts."*
>
> — Lord Melbourne, former UK Prime Minister, 1779–1848

It is generally accepted that private vehicle operators are most likely to maintain a high quality of service if their contract includes the right incentives to provide a continuous high quality of service. A "quality of service" contract, also known as a "quality incentive" contract is an effective mechanism to encourage operators to deliver excellence in service on an ongoing basis. A quality of service contract stipulates how an operator's performance is tied to its financial compensation. If an operator fails to perform properly in certain aspects of its service, then the firm will incur penalties or deductions in its payments. Likewise, a firm that exceeds service expectations can be rewarded with a bonus payment. Normally this service quality is measured by metrics agreed upon in the contract and monitored by the government authority or a third party auditor.

Quality of service contracting is increasingly popular in higher-income economies with privately contracted transit service providers. Of the BRT systems in higher-income economies, several of them have private operators with a contract that includes some quality of service elements. The Amsterdam R-Net BRT, for instance, has a contract with its operator that includes bonuses and fines for failure to meet or exceed key performance indicators. These indicators include punctuality, information, cleanliness, and driver friendliness. An independent organization carries out a monitoring regimen with twenty indicators in the field every three months. The Nantes BRT is also operated by a company under a quality of service contract. The level of service is specified in the contract and measured by fifteen indicators, with a specific level that the operator has to reach for each indicator. An external firm conducts the audits, and if the operator does not reach the required global level, the operator has to pay a penalty to Nantes Métropole. Still, many private sector operators in higher-income economies are not operating under any sort of quality of service provisions in their contracts, and there is significant room for improvement in much of the higher-income economies.

In lower-income economies, quality of service contracting was all but unknown prior to its introduction into the TransMilenio operating contracts in Bogotá. Since then, many of the quality of service elements in Bogotá's BRT system have been emulated in other cities, such as Guangzhou, Johannesburg, Cape Town, and Ahmedabad.

In the case of Bogotá's TransMilenio system, poor performing operators can experience revenue reductions of up to 10 percent of the operator's monthly income. Further, in extreme cases, an operator can even lose the concession for consistently unacceptable services.

Since TransMilenio operators are paid based upon the number of kilometers travelled, penalties for poor performance are imposed by reducing the number of kilometers assigned to the operator. The basis for fines and penalties are explicitly set out in the initial contract. Areas covered in the quality incentive contract include maintenance practices, customer service, driver safety, administrative practices, and environmental performance. Table 13.4 summarizes the types of infractions and their associated penalties.

Table 13.4. Penalty System within TransMilenio's Quality Incentive Contracting

Area	Type of infraction	Penalty
Maintenance / vehicle deficiencies	Alteration of / damage to the vehicle interior or exterior: Unauthorized advertisements, nonfunctional signal lights, unclean bus, or damaged seating	50 kilometers
Maintenance / vehicle deficiencies	Failure to follow predetermined schedules for maintenance, repair, or inspection	50 kilometers
Maintenance / vehicle deficiencies	Nonfunctional doors or worn tires	100 kilometers
Maintenance / vehicle deficiencies	Alteration of or damage to the GPS system or the radio communication system	250 kilometers
Customer service / operations	Stopping at a different station than the assigned station or not stopping at an assigned station	25 kilometers
Customer service / operations	Stopping for a longer period than requested	25 kilometers
Customer service / operations	Blocking an intersection	25 kilometers
Customer service / operations	Use of stereos, driver's mobile devices	50 kilometers
Customer service / operations	Parking bus in an unauthorized location	60 kilometers
Customer service / operations	Changing route without authorization	60 kilometers
Customer service / operations	Delaying system operation without a valid reason	60 kilometers
Customer service / operations	Over-passing another bus with the same route without authorization	60 kilometers
Customer service / operations	Operating during unauthorized hours	175 kilometers
Customer service / operations	Permitting the boarding or alighting of customers in places other than stations	250 kilometers
Customer service / operations	Operating bus on streets different than the formal trunk lines without authorization	250 kilometers
Customer service / operations	Abandoning a bus without a valid reason	250 kilometers
Consistency of driver performance	Performance difference between best operator and other operators, < 20 percent	0 kilometers
Consistency of driver performance	Performance difference between best operator and other operators, 20 – 25 percent	30 kilometers
Consistency of driver performance	Performance difference between best operator and other operators, 25 – 30 percent	75 kilometers
Consistency of driver performance	Performance difference between best operator and other operators, > 30 percent	120 kilometers
Administrative / institutional	Failure to send reports required by TransMilenio	50 kilometers
Administrative / institutional	Impeding the work of inspectors from TransMilenio SA	50 kilometers
Administrative / institutional	Hiding information or providing incorrect information	50 kilometers
Administrative / institutional	Inappropriate administrative or accounting procedures	100 kilometers
Administrative / institutional	Abuse of power in relations with staff	100 kilometers
Environmental	Fuel / oil leaks and spillages	25 kilometers
Environmental	Noise and air pollutant levels above the levels stipulated in the bid contract	50 kilometers
Environmental	Mishandling of hazardous materials	50 kilometers
Security	Any security violations not in compliance with contractual obligations	100 kilometers for each day in violation

Source: TransMilenio SA

In some instances where public safety is compromised, TransMilenio SA will also directly impose penalties upon the drivers in addition to fining the operating company. Thus, violations such as driving at excessive speeds or disobeying traffic signals can result in driver suspensions or termination of employment (Table 13.5).

Table 13.5. Penalties for Driver Infractions

Action	Penalty to driver	Penalty to operating company
Lack of driver's license of bus registration document	Suspension (next day)	100 kilometers
Failure to provide first aid	One-day suspension	100 kilometers
Refusal to provide customer with information	One-day suspension	100 kilometers
Accident between two TransMilenio vehicles	Penalty depends upon investigation	100 kilometers
Running red light	Immediate suspension	100 kilometers
Backing up while on a trunk line	One-day suspension	50 kilometers
Possession of a firearm	Immediate suspension	100 kilometers
Disobeying police instructions	One-day suspension	200 kilometers
Driving while under the influence of alcohol or other prohibited substances	Immediate suspension	200 kilometers
Accident resulting from an irresponsible action	One-day suspension	200 kilometers
Improper approach to station platform	Three times in a single day results in a one-day suspension	50 kilometers
Excess velocity	One-day suspension	100 kilometers
Encroachment onto pedestrian crossing		100 kilometers
Mechanical problems that are not resolved in less than one hour		50 kilometers
Verbal or physical aggression to customers	Immediate suspension	100 kilometers
Conducting fare collection on board vehicle	Immediate suspension	200 kilometers
Disobeying instructions from Control Center or traffic authorities	Immediate suspension	100 kilometers

Source: TransMilenio SA

The public company, TransMilenio SA, is responsible for monitoring and evaluating compliance with contractual norms. Inspections occur both randomly and within periodic schedules. Some violations can also be detected through the GPS system. Control center staff can record average speeds and vehicle movements, and thus staff can determine when speeding or other vehicle violations occur.

TransMilenio SA collects 90 percent of the fines and penalties in the "Fines and Benefits Fund," while the remainder is retained by TransMilenio SA. The "Fines and Benefits Fund" is then periodically distributed to the highest-performing operator. Thus, the scheme provides a double incentive to avoid poor performance by first penalizing poor quality service and then rewarding excellence. In addition, since the penalized operators also forfeit a certain number of kilometers serviced, the well-performing operators also gain by receiving increased service allocations.

Penalized operators do have some recourse to contest unwarranted fines. If the operators feel that the penalties have been imposed unfairly, an appeal can be presented during the weekly meetings that take place between the operators and TransMilenio SA. If the other operators and TransMilenio SA concur that the fines were unwarranted, then the amount of the fine is returned.

Once this quality of service contract was developed in Bogotá, it was modified and usually simplified in other countries. In Guangzhou, the operating contracts with the private operators include a system of penalties linked to penalty points, as shown in the Table 13.6.

Table 13.6. Penalty Point System in the Guangzhou BRT System Operating Contracts

No	Evaluate Item	Points	Evaluate Content and Scoring Methods	Score Deduction
1	First and last bus punctuality	10 points	For each delay, deduct 0.5 points from score	0.5 points/incident
2	Number of vehicle breakdowns per thousand bus kilometer in BRT corridor	30 points	In BRT corridor, for each vehicle breakdown that happens per thousand bus kilometer, deduct 1 point from score	1 point per incident per thousand bus kilometer
3.1	The number of accidents per million bus kilometer	30 points	General accident	Both at fault: 0.5 point each incident per million bus kilometer; ; Bus driver mostly at fault: 1 point each incident per million bus kilometer; ; Bus driver at fault: 1.5 point each incident per million bus kilometer;
3.2	The number of accidents per million bus kilometer	30 points	Serious accident	Both at fault: 1 point each incident per million bus kilometer; ; Bus driver mostly at fault: 2 point each incident per million bus kilometer; ; Bus driver at fault: 3 points each incident per million bus kilometer;
4	The number of complaints per million bus kilometers	20 points	If one complaint happens per thousand trips, and the operators need to be responsible for it, one point will be deducted from the score. If one operator is complained about 30 times, all the points will be deducted from the score	1 point per incident per thousand trips
5.1	Adherence to tasks given to operators by the government	10 points	Poor completion about the tasks given by the government (such as vehicle preparation is not timely, not in place)	1 point per incident
5.2	Adherence to tasks given to operators by the government	10 points	Does not perform the tasks given by the government	2 points per incident

Cape Town developed an extensive set of penalties that not only included a long list of performance metrics but also placed the onus for monitoring conformity with the performance metrics on the operator. This included stiff penalties if the information was found to be fraudulent.

When applied fairly, a system of quality incentive contracts provides a powerful tool in motivating high-quality service from operators. By selecting the appropriate measures and following up with a rigorous inspection regimen, operators will be given the right level of incentives to remain focused on providing a quality product.

13.6 Duration of Concession Contracts

"Time is the longest distance between two places."

— Tennessee Williams, playwright, 1911–1983

The duration of the concession contract affects the potential profitability of the service for the operating company and also the financial risk exposure of the government vis-à-vis the operator. Normally, the life of the contract needs to be sufficient to allow the private investors to recapture their investment. If the vehicles being procured can only be used on the BRT corridors, and the private operators are expected to pay the full cost of the vehicles, then it is likely that the length of the contract will need to be roughly as long as the productive life of the vehicle. If the government is buying the vehicles or subsidizing the vehicles, or the vehicles can easily be reused on other corridors, the government can probably attract the needed investment with shorter contracts.

It is in the interest of the government to keep the contracts as short as possible. Most industry experts feel that very long-term contracts undermine the leverage of the municipality over the private operator, as their maximum point of leverage is during the renegotiation of the contract. Longer-term concessions can also make it difficult for the municipality to introduce changes into the system. Very long-term concessions can result in monopolistic behavior that ultimately reduces system quality. In Brazil, most of the BRT operating contracts are part of long-term vehicle operating contracts. The contract length in Rio, São Paulo, and Belo Horizonte is twenty years, and in Curitiba it is fifteen years. Most experts believe that these long terms weaken the negotiating power of the municipality with its operators.

On the other hand, the municipality wants to find competent private operators willing to invest in the vehicle fleet, so the terms cannot be made so short that investors will not realize a long-term profit. Longer concession periods increase both profitability and potential investment levels. Thus, the optimum duration for a concession contract will be such that it provides sufficient time for a profitable operation but does not impair future flexibility and competitiveness.

In Bogotá, in Phase I, the concession period was ten years or 850,000 vehicle kilometers, whichever came first. In Phase II, there was no fixed concession period. Instead, the terms were stated as 850,000 vehicle kilometers within a maximum period of fifteen years. Generally, the life of the contract is set at roughly the same length as the expected life of the new public transport vehicles.

By allowing the operators to fully amortize the vehicles over the life of the period of the concession contract, the lowest cost structure is achieved. A shorter period would place additional risk on the operators who may not have use for the underutilized vehicles if they were not successful with a future concession. A longer period would either mean that new vehicles would need to be purchased within the concession, or that pressure would be placed on the city to permit operation of older vehicles.

Since operators are paid by the vehicle kilometer, there is also going to be an issue with who regulates the total number of vehicle kilometers that the operators will serve in a given day.

Operating contracts also generally provide some sort of minimum guaranteed number of vehicle kilometers. If the BRT authority (TransMilenio) can reduce the operator's vehicle kilometers per day to zero, then the operators are fully exposed to demand risk. It is unlikely that an investor will be willing to invest if they are completely exposed to demand risk. If they are guaranteed a high number of vehicle kilometers per day that ensures they will make a profit, then they are not exposed to any demand risk. TransMilenio contracts guarantee a minimum number of vehicle kilometers over the life of the contract or else allow for the contract to be extended in time. In this way, the vehicle operators are exposed to short-term demand risk but are guaranteed that eventually they will be able recoup the cost of their investment.

In the newly contracted operations of Ahmedabad, India, by contrast, the private operators are guaranteed a daily minimum number of vehicle kilometers. This minimum number of vehicle kilometers turns out to be more than is actually needed, and the public transport authority is thus bearing most of the demand risk and losing money. In each case, it is up to the public transport authority to negotiate the best deal possible for the public while still attracting the needed private investment. The optimum concession length will vary based on the expected level of capital investment and the time it takes to recoup this investment. Acceptable vehicle ages and amortization rates will vary.

13.7 The Tendering Process

"I would have answered your letter sooner, but you didn't send one."

— Goodman Ace, humorist and writer, 1779–1848

The tender structure and its standard contents will be determined by the statutory procurement regime, the rules of the country, and the rules of the city concerned. A few examples of tender documents and draft contracts are included as annexes.

The information contained in an Invitation to Tender will typically include the following:

- A full description of all aspects of the contract envisaged;

- A description of the services that are to be delivered, such as for each route, the route description and terminal arrangements, the timetable and/or frequency of service required at different hours of the day, different days of the week and different times of the year, the fares;
- Minimum guaranteed kilometers (in the case of gross cost contracts);
- The vehicle fleet requirements, such as maximum vehicle age, emission standards, capacity, configurations of doors and seats, accessibility and other features, branding, advertising limitations, etc.;
- Minimum maintenance requirements;
- Minimum quality requirements and performance standards, and how they will be monitored;
- The penalties and bonuses that may apply;
- Contract extension rules;
- Vehicle procurement requirements in course of contract.

The tender may in fact include a copy of the draft VOC contract that has already been legally drafted, which the successful tenderer will be expected to enter into, possibly after some negotiation around the details. The tender needs to set out how the bids will be evaluated—the criteria and the points awarded for relative degrees of satisfying the criteria. The tender can also specify ranges—for example, set the minimum and/or maximum limits for aspects such as quoted fee/kilometer, existing vehicles that will be scrapped, and so on. Criteria will include price, but also factors such as previous track record, safety measures, financial stability, staffing and management, vehicle maintenance policies.

The tender will need to provide for standardized submissions by bidders so that they can be compared with each other accurately. Some tender processes allow tenderers to submit an alternative proposal, as long as the standard proposal is also submitted. The substantive aspect of the submissions needs to be the criteria against which the bid will be evaluated and scored.

The following information is likely to be required by the Invitation to Tender:

- The company's legal details, financial statements, tax clearance certificate, proof of compliance with relevant laws, etc.;
- Proof that minimum equity requirement is held by the company;
- Experience of vehicle and BRT operation, in the city, the country, and internationally
- Company size, fleet in other operations;
- Financial proposal—total costs and profit margins;
- Management and staffing proposal;
- Vehicle replacement or fleet expansion proposal and financial proposals in this regard;
- Structure and details of parties to the consortium, in case of consortium or joint venture;
- Details of participation in the consortium of existing affected operators;
- Existing vehicles to be scrapped (if this is a requirement of the tender);
- Vehicle procurement and financing proposals.

The bidding process needs to comply with the statutory provisions governing procurement in the city/country concerned. It should also be well advertised to attract as many participants as possible. There should be no perception that any one participant has any inherent advantage over another. The rules and process should be clear and specific enough that misunderstandings are minimized. Dates for submission of bidding documents should be chosen to give a fair opportunity for all.

Tender documents are typically advertised for collection at a central point in the municipality, and tenderers are required to pay a fee to purchase the documentation. Where there has been a prequalification process, the eligible firms need to be notified that tender documents are available for collection. A compulsory briefing is a common feature of tendering processes.

The tender process can be divided into two stages: prequalification and then tendering. The prequalification stage will require firms to submit documentation showing they meet specified criteria. These may include:

- Firms to hold a minimum amount of working capital;
- Firms to be legally incorporated as formal businesses, with submission of various documents including proof of compliance and all relevant laws and regulations including taxation;
- Firms to be of a certain minimum size;
- Firms to demonstrate they have the requisite experience as BRT operators.

Firms that meet the minimum eligibility criteria are then prequalified to submit a tender. Alternatively, the tender evaluation can have a first stage where bids are rejected before detailed evaluation, for noncompliance with minimum criteria. The bids that do not meet these minimum criteria can then be rejected without being subjected to further evaluation.

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14. Financial Modeling

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> *"Imagine the world of mobile based on Nokia and Motorola if Apple had not been restarted by a missionary entrepreneur named Steve Jobs who cared more for his vision than being tactical and financial."*
>
> — Vinod Khosla, engineer co-founder of Sun Microsystems, 1955–

The success of advanced transportation systems, such as BRT, does not depend solely on technical resources, such as coherent operational planning, technology selection, and transportation infrastructure, but also upon financial resources to ensure smooth operation for the entities involved. Through financial modelling, it is possible to identify specific issues of the project design, as well as quantify the monetary amounts involved. It is based on this information that decision makers may begin searching for financing alternatives and decide on operational scenarios.

Furthermore, financial modelling allows for the appraisal of:

- Different types of tariff structures;
- Vehicle fleet compositions;
- Cost/sizing parameters;
- Financing options/fees;
- Profit level/business value of system entities
- Free cash-flow and funding-gap;
- Uncertainties.

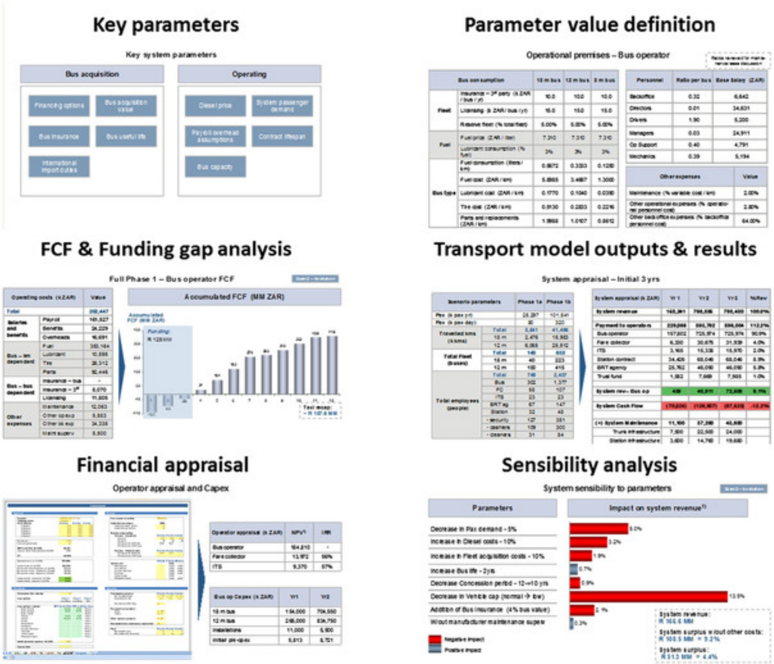

Figure 14.1. Measuring various aspects of financial modelling. *Logit.*

14.1 Importance of Financial Modelling

"When it is obvious that the goals cannot be reached, don't adjust the goals, adjust the action steps."

— Confucius, philosopher, 551 - 479 BC

Previously, transportation studies and financial appraisals were treated as separate entities, and they did not move at the same speed. The problem with this approach is that sound technical plans may have been developed, which, once finished, proved to be financially unsustainable and required significant changes. Not only would this result in unwanted project development costs for necessary alterations but also political costs, due to the postponement of the operational plan and possible tender definitions. Additionally, decision makers might have to roll back already made decisions, at an even greater political cost, or condemn the city to otherwise avoidable subsidies.

The correct approach to developing successful transportation plans is to develop the operational plan and the financial modelling simultaneously, utilizing the results of one to guide the refinement and development of the other. For each scenario, a detailed financial analysis is conducted, which then feeds back into the scenario development process.

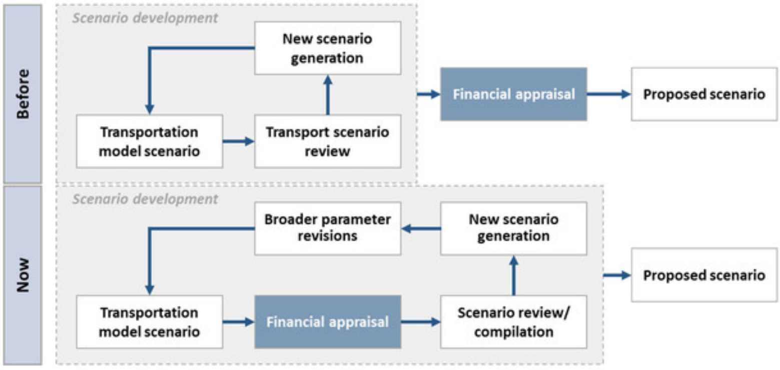

Figure 14.2. The scenario development process has evolved to become a more iterative process that develops the operational plan and financial appraisal simultaneously. *Logit.*

An added benefit of approaching scenario development in this fashion is that it is possible to generate awareness of financial implications as scenarios are being developed. This not only helps steer the scenarios toward more sustainable alternatives, but also prepares decision makers for decisions regarding the following issues:

- Subsidy analysis (if subsidies exist, the analysis includes: subsidy amount, one-off subsidy, operational subsidy, or subsidy cap limits);
- Technology choice and vehicle composition (with/without AC, Euro IV/ Euro V fleet, type of fuel);
- Number of system operators (depends on levels of minimum scale);
- Tariff schemes;
- Financing options/government guarantees.

14.2 System Entities

All the different entities in the system may be financially modelled to compose the total yearly system cost. However, the most significant entity, and the focus of this chapter, is the vehicle operating company.

14.2.1 Vehicle Operating Company

The vehicle operating company is the main player in a transportation system. Not only that, but the vehicle operating company is composed of the greatest investments made throughout the concession before the system even starts operating, and it consists of 70 to 90 percent of the total system yearly cost. By thoroughly analyzing the vehicle operating company, it is possible to shed light on the levels of profitability and sustainability of the system and to address the following:

- If the system will require subsidy and if so, the size of the possible subsidy;
- If the fleet should be purchased or partially purchased by the vehicle operating company or the government;
- The concession length, in years;
- If the BRT agency should be funded by the system itself or by the government;
- If the station/terminal security and maintenance should be incorporated or funded through the system;
- If there is to be a trust fund provision through the system surplus or if this should be topped off by the government.

14.2.2 Fare System/Technological Component

The fare or technological component of the system can be conceived in many different sizes and specifications. Depending on the size of the system and the sophistication of the design, the number of components, their specification, unit value, and quantities may vary greatly. Hence, the fare system model is trickier to standardize; however, the system must contain the following items below:

- Capital expenditures (Capex), including year zero investments, in order to set the fare system up, comprised of:
  - Equipment (station, external point-of-sale, vehicles, and depots);
  - Control center (main office, data center hardware, data center software, and smart cards);
  - Other (customer service, start-up costs);
  - Equipment and control center renovations.
- Operational expenditures (Opex), including yearly system operating costs for the following:
  - Operational personnel (collection, customer service, and administrative);
  - System upkeep and equipment replacements;
  - Administrative costs.

Depending on the system, the fare system could be run by a private operator as a profit generator, or have its expenses funded by the system itself. As a rule of thumb, the fare solution for the BRT system should consume 5 to 10 percent of system revenue, or about 15 percent of total vehicle operator company payment. Hence, for modelling purposes, it is possible to assume a percent cost for the fare system, without compromising the total system cost appraisal or conclusions.

14.2.3 BRT Agency with a Secretary of Transportation

The BRT agency with a secretary of transportation is also a simpler model to develop because it is mostly personnel driven. Issues such as the CCTV and fleet control may lie within the agency, or perhaps be bundled in a single technological component for the system. In any case, the BRT agency's cost structure is composed of the following items:

- Capital Expenditures (Capex):
  - Control center (hardware, software);
  - Bus software (fleet control, planning);
  - CCTV (stations and terminals, control center, garage depots).
- Operational Expenditures (Opex):
  - Personnel;
  - Voice/data costs for fleet control;
  - Administrative costs;
  - Maintenance and equipment replacement costs;
  - Station/terminal security and maintenance personnel (service contract outsourcing).

Unlike the fare system, the agency should not be run as a profit generator, and rather it should have its cost structure funded by the BRT system itself. Depending on the size of the system, responsibilities of the agency and, also, organogram and salary structure, the agency may vary greatly in size. However, the agency costs should lie within the range of 3 to 8 percent of total system revenue. Albeit simpler to model, if one were to adopt a percent representation for the agency, similar to the fare system simplification, the total system cost appraisal would not be compromised.

14.2.4 System Cost Consolidation

Having developed the separate models for financing and operating costs, they should all be integrated into a system appraisal, in order to determine system surplus/deficit. The system appraisal should possess the following items/and considerations:

- (+) Potential system revenue:
  - Tariff revenues;
  - Other revenues.
- (−) Discounts/gratuities;
- (=) System net income;
- (−) Payment/funding do system entities:
  - Vehicle operators;
  - Fare system;
  - Agency.
- (=) System surplus/deficit:
  - Trust fund.

The potential system revenue is obtained from the projected annual customer ridership estimates by the corresponding tariff scheme. Other revenues may be obtained from publicity or other ventures, but they usually correspond to a very small percentage of the total potential revenue. As a conservative approach, one should model the system limiting the other revenues to 3 percent, or disregard it altogether. System discounts for elderly citizens, children, or special groups may be present in the current system. In this case, it is important to properly identify which parcel of which ridership category is affected by these discounts and plan accordingly.

Once the system cash flow is appraised, it is recommended that the percent representation of every item be calculated, in order to understand the relationship between each entity and validate for possible under-/overestimations. If the system produces a surplus, then that surplus amount should be destined to the trust fund. In case the system has a deficit, it is recommended to add an additional provision to the trust fund so that the system operation/budget may be more independent from the government. As an index, one may look at the vehicle operating company's costs in relation to the system's net revenue. In case the vehicle operating cost is well over 50 percent, then the system will probably require a subsidy (continuous or onetime).

14.3 Model Structure

14.3.1 General Recommendations and Best Practices

When developing a financial model, or any model, for that matter, in MS Excel, the structure and ease of operating the model is almost as important as the accuracy of the information put into the model. As the model is developed, it becomes progressively more complex, with more information, and unless a rigid method of structure and disposition is employed, it becomes difficult to use and the propensity for errors and coding mistakes increases. A similar analogy is used by the valued 5S workplace organization method that argues that there is no reason to say that a dirty auto repair store should not repair one's car satisfactorily, but also no reason to say that cleaning it up would not aid the repair process. In other words, a cleaner, better structured model helps the development process, even more so by the fact that, differently than in the auto repair analogy, many people will use and interact with the model.

As a general recommendation, the model should be built as cleanly and be as structured as possible, with the objective of it being intended for use by third party individuals that may not share the same financial understanding or modelling experience. It is very common to see Excel coding mistakes. These best practices, although not obligatory, aim to minimize the occurrence of such mistakes.

14.3.2 Row/Column Disposition

MS Excel, by nature, is a hybrid of a database, a worksheet, and, to some, a notepad. To cater to the three purposes above, it is important to separate the worksheets by type of information and purpose.

The most important recommendation regards the horizontal/vertical disposition or segregation of the information. Since Excel has many more rows than columns, and the human eye is trained to read documents and information vertically, the proposition is to horizontally separate all information. In other words, no two different pieces of information or subjects will be horizontally adjacent. Hence, if one is to read or go through the model, one may navigate vertically and all information will be segregated. Certain premises require many rows and columns to determine a single value.

14.3.3 Grouping Hierarchical Principles

The second step is to make sure that all information is grouped hierarchically. It is important to follow a scientific/pyramid principle approach, grouping items related to the same subject together. For instance, an Opex premise should not be contained within a Capex section. Likewise, the same premise should not appear in two different sections of the document.

As an example, this type of grouping may be done utilizing the different columns to the right. For instance, each "group header" would be placed on the same column, with each subsequent group or indentation occupying progressive columns to the right as shown in Figure 14.3. This gives structure to the document and allows for a simpler understanding of the assumptions.

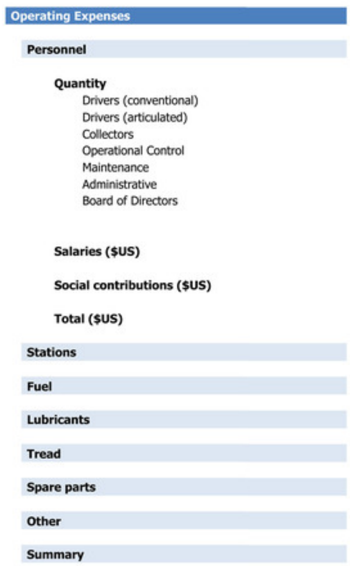

Figure 14.3. An example of the hierarchical grouping of Opex items in a table format. Image *Logit.*

14.3.4 Temporal Characteristic of Information

In addition to this, a universal and intrinsic characteristic of all information is its temporal quality. The information can be divided into time-based and non-time-based information. Time-based assumptions could be either displayed vertically or horizontally. However, given the above principle of segregating different types of information vertically, one should display the evolution of this time-based information horizontally. Once the information is displayed horizontally, it becomes easy to notice that all temporal information has as its header the "year" information. Thus, it is convenient to size all temporal columns the same. A problem with this is that non-time-based information, such as single premises and specific databases, possess different headers that require different sizes to allow for greater legibility. This brings about a width mismatch and, as such, it is recommended that time-based and non-time-based information be displayed in different worksheets.

As an additional recommendation for both non-time-based and time-based assumptions, all numeric data and information that is not a label or a textual explanation should begin upon a specific column going forward. This helps debug the model, since all parameters, specifically time-based parameters, will possess the same column reference for each year.

14.3.5 Units

As a best practice, it is recommended that the dimension of units (hundreds, thousands, millions) in the model follow the same structure. For non-time-based assumptions, the recommendation is to keep the unit in its most convenient dimension. For instance, a fuel consumption parameter makes sense to be displayed as liters per kilometer, not as liters per thousand kilometers. Likewise, the price of diesel makes sense being displayed as U.S. dollars per liter, not as thousands of U.S. dollars per liter. However, once these assumptions are multiplied and we reach total yearly values in costs, it becomes convenient to display all yearly values in thousands. Therefore, all values in time-based sheets are expressed in the same unit dimension, which is a simple and convenient best practice.

14.3.6 Color Coding and Sheet Naming

In order to facilitate the model understanding, it is recommended to color code it according to its status (as shown in Figure 14.4):

- Formula: the cell's content is derived from a formula. Since this is the most common occurrence, keep it white;
- Hard-coded inputs: parameters inserted by the model. Figure 14.4 suggests yellow for this type of text;
- Incomplete data: in case some of the data is preliminary or must be reviewed, it is important to indicate that by coloring the cell red;
- Scenario controlled: in case the cell is a formula and is controlled by a specific scenario option that may be set in a control panel. Figure 14.4 suggests green for this type of text.

Since many formulas will be referenced across different sheets in Excel, it is practical to name these sheets with the shortest name possible, so as to facilitate reading cell formula constructions (see Table 14.1). To that end, it is important to name the cells without numbers or spaces, or else Excel treats the sheet name as a "string" and references it in quotation marks. This is both cumbersome to work with, since the cell formula will now occupy more space, and may produce some complications in case one were to use the replace commands embedded in Excel.

Figure 14.4. Type of text and recommended color coding for each type. *Logit.*

Table 14.1. Information Separation Sheet Division

Sheet	Description

Info	Control of the information
CP	Control panel
sNTB	System - Assumptions not based on time
sTB	System - Assumptions based on time
sFin	System - Financial statements
bNTB	Buses - Assumptions not based on time
bTB	Buses - Assumptions based on time
bSFAF	Buses - Schedule of financing + fixed assets
bFin	Buses - Financial Statement
tNTB	Technologies - Assumptions not based on time
tTB	Technologies - Assumptions based on time
tFSFA	Technologies - Financing schedule + fixed assets
tFin	Technologies - Financial statement
agNTB	BRT Agency - Non-time-based assumptions
agTB	BRT Agency - Time-based assumptions
agFSFA	BRT Agency - Financing schedule + fixed assets
agFin	BRT Agency - Financial statement
KPIs	Key Performance Indicators

14.4 Information Organization

Having addressed best practices, another important point relates to how the information should be structured and grouped together in the model. Proper information separation sheet division aids in better model development and understanding.

14.4.1 Control Panel

The objective of the control panel is to show the relevant appraisal and profitability indexes, as well as to allow for the selection of the most important parameters per the following breakdown:

Most Important Parameters

- Use of data validation options in order to limit choices/values to predetermined or feasible ones:
  - Bus-type selection;
  - Financing-type selection;
  - Profitability “goals.”
- Sensitive consumption/operation parameters:
  - Bus acquisition value information;
  - Fuel, lubricant, tire, and other consumption rates;
  - Driver sizing parameter information.

Relevant Financial Results

- System appraisal;
- IRR for system entities;
- EBITDA margins: profitability (consists of earnings before interest, tax, depreciation, and amortization, divided by total revenue).

Goal-Seeking Functions and Automation

- Implement macros to target certain profitability values or specific revenue values;
- The goal-seeking parameter may be expressed as an index of payment per kilometer, payment per customer (technical tariff), or even a hybrid kilometer per customer payment;
- In essence, this goal-seeking approach targets a total payment amount for the system entity, which may then be broken down into whichever index is desired.

14.4.2 Time-Based and Non-Time-Based Assumptions

As mentioned above, it is convenient to separate information by its temporal characteristic. Both time-based and non-time-based sheets should cover the following topics, segregating the information accordingly:

Operational Plan

- Number of kilometers per fleet type;
- Number of vehicles per fleet type;
- Ticket revenue:
  - Number of customers/ridership;
  - Tariff scheme per ride.

It is important to recalculate these numbers in the financial model for two reasons:

- So the model contains all relevant information of the system/scenarios and is “self-sufficient”;
- As a quality check toward the values calculated in the transportation model.

Fleet

- Age profile per type of fleet per year:
  - Place example;
  - Indication of new acquisitions and sales (the change between two years).

Operational Expenditures (Opex)

- Opex per vehicles;
- Opex per personnel.

Capital Expenditures (Capex)

- Indication of acquisitions and renewals;
- Indication of acquisition values per depreciation type;
- Indication of acquisition values to be financed by financing alternative.

Fixed Assets

- Used for depreciation calculation;
- Must separate each item by depreciation category and rate.

Financing Schemes

- Interest rates;
- Tenor of loan;
- Grace period;
- Percent financed;
- Finance indexes, used by ECAs.

Financing Schedule

- Used to keep track of interest and principal repayment;
- Must separate and keep track of each loan individually (loan drawdown year and conditions).

14.4.3 Financial Sheet

Lastly, there is the financial sheet, which contains the necessary information for the financial appraisal of the system entity.

Income Statement and Cash-Flow Statement

- The income statement is used to calculate the yearly earnings, profit, accumulated profit, and taxes;
- The cash-flow statement is used in order to calculate the yearly free cash flow;
- For the cash-flow statement, it is recommended that one segregate the different cash-flow origins to properly calculate the cash requirements/overdraft or surpluses for the company:
  - Cash flow from operations;
  - Cash flow from investing;
  - Cash flow from financing;
  - Net cash flow.

Balance Sheet

- Used primarily to calculate increase/decrease in working capital;
- Can be used to calculate debt/equity ratios and other indexes to attest to company's health;
- Aids in validating the free cash flow and system appraisal, once all information is categorized and interrelated in the balance sheet;
- Discussion of how the balance sheet may be "omitted," as long as these calculations are performed elsewhere.

14.5 Modelling Issues

When modelling a concession, there are a couple of specific issues that arise which must be dealt with appropriately. Some of these issues affect the general model construction, but others are more specific to the beginning or end of the concession terms.

14.5.1 Year-End Modelling and Year Zero Until Year One Consideration

Financial modelling is usually conducted on a yearly basis, or what we call a year-end model. In other words, all that "happens" in the year is grouped at the "end" of the year, or December 31. This approach is convenient since the concession has many years, and it is possible to track all the yearly information in a column and compare and see the yearly evolutions side by side. In addition to that, a couple of system information inputs, such as revenue and subsidy, are also known and dealt with as yearly totals.

When one refers to year-end models, it is important to clarify exactly what is meant by year zero and year one. Given that it is a year-end approach, the year refers to the end of the year (end of the period). In other words, if a system becomes operational at the beginning of 2017, then year zero would equal the entirety of 2016. Given this, the year before year 0, or year -1, would refer to the entirety of 2015. In other words:

- Year 0 = Year -1 until year 0; or January 1 of year 0 (2016) until December 31 of year 0 (2016);
- Year 1 = Year 0 until year 1; or January 1 of year 1 (2017) until December 31 of year 1 (2017).

An important point here is how to consider initial capital expenditures and operational setup. In case one, when modelling the concession on a month-to-month basis, appropriating the investments on one month or the subsequent month is almost of no difference, since the "month" change will bear little impact on the results. However, when we are considering a year-end approach, these "month" differences may result in considering these expenditures for one year or another. Given that most appraisals consider a discounted cash-flow method, considering capital expenditures a year apart may impact the results significantly, especially in the beginning of the concession.

In order to address this, it is recommended that relevant expenditures that may occur at the beginning of the year be grouped in the year before. For instance, if relevant capital expenditures happen in January, they should be considered in December of the year before, since December of the year before (-1 month) is closer than December of the current year (11 months).

That being said, vehicles, garage depots, and other equipment that is acquired before a concession begins, be it three to four months before the start of the concession or even at the beginning of the concession, must be allocated in year zero. Once again, the reason for this is that year 0 considers the period between year -1 (preoperational) until "moment" 0, when the concession begins.

14.5.2 Inflation/Inflation-Free Implications

The consideration of inflation is another specific issue that must be treated appropriately while modelling. First of all, inflation rates relate to the rate of change that a particular cost or item might have suffered from one year to another. Given that each item behaves differently, each will be subject to a different inflation rate, which will also be different from year to year. As a result, it is difficult to assess the behavior of each item and especially difficult to project this trend accurately for the coming years.

Just as an example, fuel prices are driven by international market fuel prices, as well as specific governmental policies that affect how this international "price change" is relayed to the consumers. On the other hand, labor cost inflation is a result of a weighted price of goods-index analysis, which attempts to correct a loss of acquisition power by the employee. Both items will suffer inflation, but the rates will be different and will evolve differently over time.

In the financial model, the consideration of inflation affects the following aspects:

- Depreciation, which is not subject to inflation;
- Fiscal credits, which are not subject to inflation;
- Financing rates, which consider an "embedded" inflation rate in its rate;
- Operational expenditure (Opex) parameters, which are prone to different inflation rates;
- Capital expenditure (Capex) parameters, which are prone to different inflation rates;
- Appraisal index references, such as the IRR (internal rate of return) and NPV (net present value) discount, which are different in the case that the model considers inflation.

In case one were to consider an inflation-free model, the impact of inflation on the above items would still have to be considered, but differently. Just to straighten out terminology, for an inflation-free model, one would refer to it as being a model in "real" or "constant," whereas a model with inflation would be referred to as being in "nominal" or "current" terms.

For an inflation-free model, the Opex and Capex parameters, whose base value prices are already in real terms (which would have to be adjusted yearly by inflation in a nominal term model), would simply not be adjusted. In other words, one would not have to project different inflation rates, nor assume any simplified single inflation index for all cost items, no matter how diverse.

Items that are not subject to inflation in a nominal model, such as depreciation and fiscal credits (such as tax shields), would have their yearly calculation base value constant over time. For instance, if a car is acquired for a specific amount, its yearly depreciation value is the result of its acquisition value multiplied by its depreciation rate. This acquisition value does not change over the years; it is constant. Similarly, in case one has fiscal credits, the fiscal credits are carried forward in constant terms, not being "adjusted" in value. In other words, these values already are in nominal terms. As a result, since all the other items are subject to inflation, with the exception of these items, it is equivalent to saying that these items lose "respective" value over time as compared to the other items subject to inflation. Hence, in an inflation-free model, which is in real base terms, it is necessary to deflate these items over time, in order to keep all values in the correct perspective.

Financing rates are a bit trickier, since they already consider an inflation rate "embedded" in their nominal rate value. When a bank presents a rate of X percent, this rate considers roughly the national interest rate and the bank spread; however, both components already assume an inflation expectation. Thus, if one were to appreciate financing options in "real terms," then it is necessary to deflate the financing rate.

An advantage for the financing rates, depreciation, and fiscal credits is that the inflation assumption to "deflate" the terms may be the same, since it relates to a national inflation index and not product-specific inflation indexes. In other words, we have the following comparison:

- Inflation model/nominal terms model:
  - Different inflation rates for all the Opex and Capex items;
  - Financing rate, depreciation, and fiscal credit values already in nominal terms.
- Inflation mode/real terms model:
  - Constant terms for all the Opex and Capex items;
  - Single inflation index to deflate financing rate, depreciation, and fiscal credit value.

All things considered, there are three main reasons as to why it is recommended that the model be developed inflation free, in real terms:

- It is simpler and more correct, since there are fewer inflation assumptions made;
- All year-by-year values are in real terms and thus comparable, making it easy to identify trends and errors;
- Another specific point is that most commonly used appraisal indexes, such as IRR and discount rates for NPV, are in real terms. Hence, by developing an inflation-free model, one is in the same base of comparison, avoiding possible misinterpretations.

An important point to clear up is that tariff/payment adjustment formulas due to inflation must be considered in the contract, not in the model. Although both items pertain to inflation, projecting different inflation indexes and measuring different inflation indexes are independent actions.

14.5.3 IRR, Leveraged/Unleveraged Scenarios, and EBITDA Margins

The IRR (internal rate of return) of a project is the “rate” that makes the net present value (NPV) of all cash flows equal to zero. In other words, it is the discount rate at which the NPV of costs (negative cash flows) of the investment equals the NPV of the benefits (positive cash flows) of the investment. Because the IRR is a rate, it is an indicator of the efficiency or yield of an investment. The NPV, in contrast, is an indicator of value or magnitude.

For BRT projects, the IRR is generally used as a target value or reference value, in order to assess concessionary yearly payment amounts. Alternatively, given a specific set of conditions, one may appraise the variation of the IRR according to operational premise changes, as well as different financing options.

To properly assess each scenario, it is recommended that an unleveraged scenario be appraised first. In an unleveraged scenario, all capital expenditures are paid by equity. In other words, this is the true appraisal of the concession, considering solely the concession’s earnings and expenditures, without any external influence such as financing, for instance.

In addition to the unleveraged scenario, one must also appraise the leveraged scenario, considering the financing options that are available to the concessionary. It is through the leveraged analysis that one may assess the funding period of the concession, which is always critical, as well as the funding gap. In case the system has special financing options or, depending on the nature of the soon to be vehicle operating company, there might be maximum year funding periods of maximum funding gap analysis to be made. For instance, for smaller systems without established vehicle operating companies, the transition may be tough, and perhaps the funding gap must not surpass the current vehicles scrap values. In this case, certain restrictions may be applied in this leveraged/shareholder’s appraisal. It is possible that the IRR for the leveraged scenario may become excessively high, which leads to special considerations to be taken into account when analyzing high IRR values.

The problem with high IRR values is that the IRR assumes that yearly positive cash flows will be invested in projects that yield the same rate of return as the concession. This means that not only is this cash flow probably going to be invested in projects with other lower IRRs, but that reinvesting the values at the same IRR propels the IRR to even higher levels. As a result, the IRR may produce an unrealistically optimistic picture of the project that is being analyzed. Another issue with the IRR is that for projects with alternating positive and negative cash flows, which may be the case in a year of fleet renovations, sometimes more than one IRR may be found.

To address the issues above, a modified IRR should be calculated as well. In the modified IRR calculation, one assumes a financing rate and a reinvestment rate beforehand. That way, negative cash flows will be financed at a predetermined rate, and so will reinvestment rates. The modified IRR is then calculated as the nth square root of the future value of all the positive cash flows over all the negative cash flows. Thus, one obtains a more reasonable IRR, which corrects distortions of high IRRs or alternating positive negative yearly cash flows.

Another way around assessing the concession’s profitability is to check the concession’s EBITDA (earnings before interest, tax, depreciation, and amortization) margin index. The EBITDA margin index equals the EBITDA value, divided by the revenue. Since the EBITDA is a measure for “operational profit,” one will be looking at the “operational margin” for the concession. Usually, a healthy, stable concession will not only produce a stable EBITDA margin over the concession term (no effects of financing, acquisitions, etc.), but produce a value inside acceptable ranges. If the IRR is such that it is producing higher EBITDA margins, then perhaps the financing conditions or total operator payments may be excessive. Likewise, if the IRR is satisfactory but produces low EBITDA margins, then perhaps the Capex is underestimated.

14.5.4 End of the Concession

While modelling the depreciation, financing, and even fixed-asset sales, special considerations must be made at the end of the concession term. First and foremost, it is recommended that the concession term length be set in an attempt to match the end of the useful life of relevant capital expenditures. The reason for this is that it is not ideal to acquire items at the end of the concession, since there will not be enough time to have a return on the investment.

Regarding depreciation, it is sometimes allowed, depending on the country or concession type, to match the depreciation of all acquisitions and improvements to, at most, end with the concession term. For instance, in case there are some garage improvements made close to the end of the concession, some countries allow for an adjustment of depreciation rates in order to meet the concession end. As a result of this, aside from considering different depreciation rates per type of fixed asset in the model, it might be important to have a provision for being able to change these values depending on the year of acquisition and the time remaining until the end of the concession. This refinement is in the direction of “anticipating”/increasing tax shields and, thus, increasing IRR.

Similarly, the financing options must be adjusted in order to match the concession term. For instance, in case a ten-year loan is underwritten in the beginning of a ten-year concession, it is compatible. But let us consider that a loan for fleet renovation is to be underwritten in year seven of a ten-year concession. In this case, obviously, a ten-year tenor of the loan will not be available. The tenor of the loan needs to be adjusted to the remaining life in the concession, which would be three years. As a result, it may not make sense to underwrite a loan at the end of the concession term. Further, the financing rates and grace period for such a loan will probably be different than in the beginning of the concession, when acquisition numbers were also larger. That being the case, it may be important to consider two financing options, one for initial acquisitions and another for replacements.

In addition to this, it is important to understand how to consider fixed assets at the concession end. Items such as land acquisition, which are not depreciated, should be considered as being sold at the end of the concession for the same acquisition value. Vehicle sales, on the other hand, may be sold for a value different than their remaining accounting value.

Regarding vehicle sales, there are two different depreciation strings:

- Linear method, for determining accounting value, according to fiscal regulations;
- Nonlinear method, for determining vehicle market value:
  - As a suggestion, a sum-of-the-years-digits method may be utilized;
  - Usually, the bus market value follows an inverse function, which tends to be the residual value or scrap value of the bus.

At the end of the concession, it is necessary to calculate the difference between the sales value and the remaining accounting value for each vehicle. The reason for this is that this vehicle may have already been depreciated, having already generated a tax shield. If this vehicle is then sold for a higher value, it constitutes a capital gain, which is taxed. In any case, the situation is always favorable for the vehicle operating company, since the tax shield was probably utilized in a year or years before the moment where the capital gain, because of the vehicle sale, is due.

14.6 Vehicle Operating Company Input Parameters

The vehicle operating company input parameters may be broken down into two categories:

1. Operational expenditures (Opex);
2. Capital expenditures (Capex).

In addition to these parameters, the company is also subject to taxes, depreciation rates, and even different financing options, which may vary from city to city, or country to country.

14.6.1 Operational Expenditures (Opex)

Operational expenditures refer to expenses incurred in the course of ordinary business, such as sales, general, and administrative expenses. For the vehicle operating company, these expenses are directly dependent on the operation itself, as denominated in kilometer-dependent parameters. The expenses are also indirectly dependent on the size of the fleet/bus operation, which will be referred to as vehicle-dependent parameters.

Kilometer-Dependent Parameters

Kilometer-dependent parameters, as implied by the name, refer to sizing parameters that are directly and linearly dependent on the operational service.

Fuel

Out of these parameters, the biggest cost component is the fuel cost (US$), which can be calculated by multiplying the consumption rate (l/km) by the number of kilometers (km) and then by the fuel price (US$/l). Typically, the consumption rate is expressed as l/km, such that multiplying the consumption rate by the total number of kilometers gives the total number of liters used. This may be counterintuitive at first, since one usually thinks about consumption efficiency in terms of distance travelled per unit of fuel.

The consumption rate is different depending on vehicle specification:

- Vehicle size (eight meters, twelve meters, and eighteen meters);
- Front/rear engine specification;
- Air conditioning (AC), or not;
- Vehicle technology standard (Euro IV or Euro V);
- City conditions (altitude, humid/dry).

As a rule of thumb, a vehicle with AC will, aside from having a larger cost, also consume around 10 percent more fuel. That being said, as reference values, the consumption per vehicle should have values around those in Table 14.2.

Table 14.2. Costs Per Kilometer of Spare Parts by Vehicle Type

Bus Type	US$/km
Microbus	0.05
Minibus	0.05
Mid-Size bus	0.06
Conventional bus	0.06
Semi-Standard bus	0.08
Standard bus	0.09
Articulated bus	0.17
Bi-articulated bus	0.26

Source: Logit. Currency conversions from R$ to US$ with 2013 exchange rate: https://www.irs.gov/individuals/international-taxpayers/yearly-average-currency-exchange-rates

For the fuel price, one must consider the "bulk" price, because fuel will be purchased in great quantities. Usually, a fuel tank and pump will be installed at the garage depot and be supplied weekly by a tank truck.

Lubricants

Lubricants are also a relevant cost item and, for simplification purposes, may be considered as a percentage of the total fuel cost. As a rule of thumb, this amount ranges from 3 to 5 percent of the total fuel cost, but may be calculated from the bottom up though specific lubricant cost and engine lubrication rates.

Tires

Tires are another relevant cost parameter and depend on a couple of other parameters, which vary per vehicle:

- Number of tires per bus:
  - Smaller vehicles—four to six;
  - 12- to 15-meter vehicles—six;
  - 18-meter articulated vehicles—ten.
- Tire type:
  - Smaller vehicles—175/75 R17.5;
  - 12- to 13-meter buses—275/80 R22.5;
  - 18-meter articulated buses—295/80 R 22.5.
- Tire unit cost per tire type;
- Useful life per vehicle type;
- Number of tire retreading allowed per vehicle type;
- Tire retreading unit cost (approximately 25 percent of new tire cost);
- Consumption;
- Price—new/recap.

Tire retreading/regrooving are processes intended to prolong the useful life of the tire and thus reduce the cost per kilometer. The regrooving process is the initial step, and consists of cutting into the tread of a tire and tread a pattern deeper than the original, so as to prolong its useful life. Once the regrooving reaches its limit, the tire is subjected to a retreading process, which consists of reconditioning the tire by replacing the worn tread with new material.

The total useful life of a tire should be expressed considering the maximum number of retreading processes possible. As a result, one may calculate the tire cost per kilometer as follows:

Table 14.3. Tire Cost Per Kilometer by Vehicle Type

Vehicle Type	Number of Tires	Cost per Unit (US$)	Useful Life (km)	Number of Retreadings	Retreading Cost per Unit (US$)	Cost per km (US$)
Microbus	6	365.91	120,000	2.00	109.42	0.03
Minibus	6	676.30	120,000	2.00	164.52	0.05
Mid-Size bus	6	676.30	160,000	2.50	164.52	0.04
Conventional bus	6	676.30	160,000	2.50	164.52	0.04
Semi-Standard bus	6	676.30	160,000	2.50	164.52	0.04
Standard bus	6	676.30	160,000	2.50	164.52	0.04
Articulated bus	10	676.30	160,000	2.50	164.52	0.07
Bi-articulated bus	14	676.30	160,000	2.50	164.52	0.10

Source: Logit. Currency conversions from R$ to US$ with 2013 exchange rate: https://www.irs.gov/individuals/international-taxpayers/yearly-average-currency-exchange-rates

Parts and Replacements

Parts and replacements costs are strongly dependent on the quality and efficiency of the maintenance program. In other words, depending on the maintenance program, costs may vary considerably.

In order to size this item correctly, there are two parameters to consider:

- Vehicle acquisition value:
  - The parts and replacement costs must be correspondent to the makeup of a new vehicle;
  - The total vehicle acquisition value is superior to just the parts and replacements makeup of the vehicle, and must be considered without tires and without specific acquisition cost values.
- Kilometers travelled:
  - The cost driver for "wear" is usage, and thus, the more kilometers a vehicle travels in a year, the greater need of parts and replacements it should have.

That being said, the sizing of this item must then relate a percentage of vehicle acquisition value correspondent to an average of kilometers travelled per year. In case the vehicle travels more kilometers or, in case the vehicle acquisition cost is smaller or larger, the cost of parts and replacements per kilometer must vary.

Because of a couple of tariff readjustment studies in Brazil, it was identified that the parts and replacements costs vary from 3 to 5 percent of the vehicle acquisition value. In addition to that, for the cities considered, 78,000 kilometers per year (6.5 kilometers/month) is approximately the average kilometers travelled per year. Consequently, one may derive a cost per kilometer to be utilized per vehicle type.

Table 14.4. Cost Per Kilometer by Vehicle Type

	Value of Vehicle with Air Conditioning (US$)	Technical Coefficient	Average Annual Distance Travelled (km)	Cost per km (US$)
Microbus	113,130.46	4.0%	78,000	0.06
Minibus	98,184.95	4.0%	78,000	0.05
Mid-Size bus	129,126.92	4.0%	78,000	0.07
Conventional bus	135,915.96	4.0%	78,000	0.07
Semi-Standard bus	167,518.90	4.0%	78,000	0.09
Standard bus	199,171.00	4.0%	78,000	0.10
Articulated bus	350,349.31	4.0%	78,000	0.18
Bi-articulated bus	533,589.41	4.0%	78,000	0.27

Source: Logit. Currency conversions from R$ to US$ with 2013 exchange rate: https://www.irs.gov/individuals/international-taxpayers/yearly-average-currency-exchange-rates

Vehicle Dependent

Vehicle-dependent cost refers to items that are indirectly dependent on the fleet size. The rationale behind this is that the larger the fleet, the larger the number of mechanics, traffic supervisors, back office, and overhead that is necessary. As a result, the sizing parameter for these costs will be a personnel/vehicle or cost/vehicle, that must then be multiplied by the corresponding fleet.

The main cost item relating to the entire vehicle operation is personnel-related costs. One may say that a vehicle operating company is personnel intensive, usually having this cost account for 30 to 40 percent of the operator's total payment.

The employees may be divided into two different categories, which must be treated separately:

- Vehicle drivers and possible onboard fare personnel;
- Garage depot/back office personnel.

These employee/vehicle ratios must then be multiplied by the average salary per category, to company salary tax, 13th check, benefits, and other costs amount to the total cost of employment.

Vehicle Drivers

Vehicle drivers sizing ratio depends more on the system schedule than on predetermined sizing ranges. For starters, the operational personnel must be sized utilizing the operational fleet size, not the total fleet. The reason for this is that it is the operational fleet that is related to the vehicle timetables and schedule.

In order to properly size the number of drivers required for the system, a detailed analysis, bus route per bus route, must be conducted. However, in case the majority of the bus routes have a cycle time of around one hour, a simplified sizing method may be utilized. First, one needs the number of trips per hour for a working day, Saturday, and Sunday:

Table 14.5. Number of Trips Per Hour for Weekdays and Weekends

Hourly Range	Weekday Trips	Saturday Trips	Sunday Trips
00:00-01:00	48	48	48
01:00-02:00	59	59	59
02:00-03:00	57	57	57
03:00-04:00	44	44	44
04:00-05:00	456	259	231
05:00-06:00	2.584	1.500	1.173
06:00-07:00	3.496	1.865	1.289
07:00-08:00	2.960	1.852	1.320
08:00-09:00	2.067	1.642	1.260
09:00-10:00	1.721	1.507	1.200
10:00-11:00	1.662	1.494	1.193
11:00-12:00	1.825	1.548	1.234
12:00-13:00	1.893	1.634	1.276
13:00-14:00	1.806	1.620	1.276
14:00-15:00	1.806	1.621	1.284
15:00-16:00	1.910	1.625	1.320
16:00-17:00	2.539	1.690	1.317
17:00-18:00	3.095	1.723	1.346
18:00-19:00	2.802	1.664	1.308
19:00-20:00	2.164	1.509	1.245
20:00-21:00	1.614	1.278	1.121

21:00-22:00	1.442	1.152	1.018
22:00-23:00	1.372	1.016	905
23:00-24:00	944	851	781
Total:	40.367	29.259	23.305

Having the total trips per hour, one may assume that in the peak hour, 100 percent of the operational fleet is utilized. Consequently, one may calculate the percentage of the fleet utilization over the course of the entire day:

Table 14.6. Percentage of Fleet Utilization Per Hour for Weekdays and Weekends

Hourly Range	Weekday Trips	Saturday Trips	Sunday Trips
00:00-01:00	1%	1%	1%
01:00-02:00	2%	2%	2%
02:00-03:00	2%	2%	2%
03:00-04:00	1%	1%	1%
04:00-05:00	13%	7%	7%
05:00-06:00	74%	43%	34%
06:00-07:00	100%	53%	37%
07:00-08:00	85%	53%	38%
08:00-09:00	59%	47%	36%
09:00-10:00	49%	43%	34%
10:00-11:00	48%	43%	34%
11:00-12:00	52%	44%	35%
12:00-13:00	54%	47%	37%
13:00-14:00	52%	46%	37%
14:00-15:00	52%	46%	37%
15:00-16:00	55%	46%	38%
16:00-17:00	73%	48%	38%
17:00-18:00	89%	49%	39%
18:00-19:00	80%	48%	37%
19:00-20:00	62%	43%	36%
20:00-21:00	46%	37%	32%
21:00-22:00	41%	33%	29%
22:00-23:00	39%	29%	26%
23:00-24:00	27%	24%	22%
Total vehicle utilization hours:	**11.55**	**8.37**	**6.67**

Given that the driver utilization is directly dependent on the bus utilization, one may say that the "total" of total vehicle utilization hours equals the amount of driver working hours necessary.

Having calculated that, one must then verify the work regimen of the drivers in terms of daily working hours, weekly working hours, and also how these working hours may be spread out. In Brazil, for instance, many union agreements allow for a seven-hour working day (seven hours of work and one hour for lunch), a total of forty-four-hour working week and a 6 to 1 working regimen (work six days, rest one). That being the case, we can see that 11.55 hours (total weekday vehicle utilization hours) divided by 7 hours (workday hours) results in a ratio of 1.65. In other words, given the working scale alone, one could say that 1.65 drivers are necessary per bus in order to man the fleet in a working day. Given that this number is under 2, no overtime additional pay is necessary. If this number were over 2, then it would be necessary to calculate the daily overtime factor (total daily hours divided by 14 hours) and multiply that by the overtime pay.

From the total weekly hours, we can see that the Saturday and Sunday requirement totals a value over 14 hours (8.37 + 6.67 = 15.04). In other words, the total weekly work hours would be determined by the following equation:

Eq. 14.1 Total weekly work hours:

$$(5\text{days} * \frac{7\text{hours}}{\text{day}}) + \frac{15.04\text{hours}}{2\text{hours}} = 42.52\frac{\text{hours}}{\text{week}}$$

Since 42.52 hours per week is under the weekly regimen of 44 hours, no additional weekly hours are required. In case this number were over 44 hours, then one should calculate the “factor” of exceeding hours total hours per 44 hours and multiply that by the overtime pay.

Based on this number, one must also consider additional pay that may be required for the nighttime shift (10:00 pm to 5:00 am). For the above examples, one may calculate that 7.88 percent of the total weekly hours occur during the nighttime shift. To that amount, one may apply the nighttime shift additional pay and thus reach a nighttime shift factor. In Brazil, this overtime pay factor is 1.3714, which gives a global nighttime factor of 1.0293.

In addition to all of this, one must calculate the provision for vacation period, national holidays (if applicable), and yearly absentee days.

Eq. 14.2 Provision for national holidays or absentees:

$$\frac{365\text{days}}{[(\text{total days} \in \text{year})-(\text{missed work days})]}$$

For a 30-day vacation period, the ratio would be 365/335. All these provisions, calculated separately, must then be multiplied so one reaches a total coverage factor.

As a result, the sizing factor is calculated using the following variables:

- Daily work scale ratio;
- Daily overtime factor;
- Weekly overtime factor;
- Weekly nighttime factor;
- Coverage/absentee provision factor.

Having calculated the sizing factor, this number should then be multiplied by the union driver pay and benefits. As an orientation, for 44 hours/week working hours, the driver ratio could vary from 1.80, for an extremely peak-concentrated operation, up until 2.80, for a very distributed daily service (e.g., Rio de Janeiro City). In case the system is designed with onboard fare personnel, their sizing is similar to the driver sizing.

Operational Control

Operational control staff are responsible for the scheduling, inspecting, and release of the vehicles from the garage depot. The smaller the operation, the fewer inspectors are necessary; however, the following positions are nearly mandatory:

- Head of operational control;
- Controllers;
- Traffic inspectors/supervisors;
- Bus schedulers/programmers;
- Assistants.

Given that these are different positions, with different numbers of professionals per position, earning different wage amounts, there are two ways to address this sizing dilemma:

- Individually size each position, in terms of the number of employees and base salary;
- Adopt average ratios and average salaries, which are representative of the operation control as a whole.

In terms of convenience, it is always preferable to adopt average values; however, one must be careful in case the size of the companies varies greatly. The reason for this is that certain positions—such as the head of operational control, controllers, and bus schedulers—will have around the same number of professionals regardless of the fact if the vehicle operating company has one hundred vehicles or six hundred vehicles. Other positions such as traffic inspectors/supervisors are more directly dependent on the size of the company and fleet.

As an example, for the sizing of a vehicle operating company with an operating fleet of four hundred vehicles, one could expect the following sizing parameters:

Table 14.7. Sizing Parameters for Vehicle Operating Company (400 Vehicles)

Position	#	Salary (US$)	Salary/Minimum Wage	Total (US$)	Weight	Sizing Ratio
Head of operational control	1	3,557.14	11.8	3,557.14	8.40%	0.0025
Controllers	4	1,511.78	5	6,047.13	14.30%	0.01
Traffic inspectors/supervisors	30	800.36	2.7	24,010.67	57.00%	0.075
Bus schedulers/ programmers	6	978.21	3.2	5,869.28	13.90%	0.015
Assistants	6	444.64	1.5	2,667.85	6.30%	0.015
Average total salary	**47**	**896.85**	**3**	**42,152.07**	**100.00%**	**0.1175**

Source: Logit. Currency conversions from R$ to US$ with 2013 exchange rate: https://www.irs.gov/individuals/international-taxpayers/yearly-average-currency-exchange-rates

For this situation, one can derive a sizing ratio of approximately 0.12 in relation to the operating fleet, and an average salary of approximately US$900 (R$2,020). Given that the average salary is superior to the salary of the traffic inspectors/supervisors, which are the positions more directly dependent on the fleet size, one should expect that a different operating fleet size should produce a different sizing ratio different average salary.

As an example, the table below shows the sizing for a vehicle operating company with an operating fleet of two hundred vehicles:

Table 14.8. Sizing Parameters for Vehicle Operating Company (200 Vehicles)

Position	#	Salary (US$)	Salary/Minimum Wage	Total (US$)	Weight	Sizing Ratio
Head of operational control	1	3,557.14	11.8	3,557.14	12.00%	0.005
Controllers	4	1,511.78	5	6,047.13	20.50%	0.02
Traffic inspectors/supervisors	16	800.36	2.7	12,805.69	43.40%	0.08
Bus schedulers/programmers	5	978.21	3.2	4,891.06	16.60%	0.025
Assistants	5	444.64	1.5	2,223.21	7.50%	0.025
Average total salary	**31**	**952.40**	**3.2**	**29,524.23**	**100.00%**	**0.155**

Source: Logit. Currency conversions from R$ to US$ with 2013 exchange rate: https://www.irs.gov/individuals/international-taxpayers/yearly-average-currency-exchange-rates

For this smaller company size, one can see that the average salary had a 10 percent increase and the sizing ratio increased from 0.1175 to 0.1550. Of course, in cases where the vehicle operating company is smaller, the salary levels would most likely be lower and the number of controllers, for instance, might be lower as well, having other positions take on part of the work. For the financial model, what matters is the total cost of the operational control, so in case the ratio increase is offset by an average salary decrease, the result is the same.

In any case, a reasonable sizing parameter to be used is something in the range of 0.10 to 0.16. The average salary depends on the local condition, but as a proxy, in this case, it would equal approximately 3.0 to 3.2 times the minimum wage.

Garage Depot/Maintenance

The garage depot/maintenance staff is responsible for maintaining the vehicles in operational conditions, as well as aiming to reduce maintenance costs and breakdown occurrences. The garage depot/maintenance personnel sizing issues are similar to the ones addressed in the operational control sizing. The denominator, for the ratio analysis, is the operational fleet.

Typically, the expected positions should be:

- Head of maintenance;
- Maintenance supervisors;
- Mechanics;
- Assistant mechanics;
- Electricians;
- Panel beaters;
- Spray painters;
- Tire repairmen;
- Others.

As an example, for the sizing of a vehicle operating company with an operating fleet of four hundred vehicles, one could expect the following sizing parameters:

Table 14.9. Sizing Parameters for Garage Depot/Maintenance (400 Vehicles)

Position	#	Salary (US$)	Salary/Minimum Wage	Total (US$)	Weight	Sizing Ratio
Head of maintenance	1	3,557.14	11.8	3,557.14	5.30%	0.0025
Maintenance supervisors	8	1,511.78	5	12,094.26	18.00%	0.02
Mechanics	32	978.21	3.2	31,302.80	46.50%	0.08
Assistant mechanics	32	293.46	1	9,390.84	13.90%	0.08
Electricians	12	1,067.14	3.5	12,805.69	19.00%	0.03
Panel beaters	12	889.28	2.9	10,671.41	15.80%	0.03
Spray painters	8	1,067.14	3.5	8,537.13	12.70%	0.02
Tire repairmen	8	622.50	2.1	4,979.99	7.40%	0.02
Others	56	444.64	1.5	24,899.96	37.00%	0.14
Average total salary	**169**	**699.64**	**2.3**	**118,239.22**	**175.60%**	**0.4225**

Source: Logit. Currency conversions from R$ to US$ with 2013 exchange rate: https://www.irs.gov/individuals/international-taxpayers/yearly-average-currency-exchange-rates

For this situation, one can derive a sizing ratio of approximately 0.42 in relation to the operating fleet, and an average salary of approximately US$700 (R$1,575).

The overhead of the garage depot/maintenance department, which differs from the operational control, is smaller and most positions have a larger dependency on the number of vehicles.

As an example, the table below shows the sizing for vehicle operating company with an operating fleet of two hundred vehicles:

Table 14.10. Sizing Parameters for Garage Depot/Maintenance (200 Vehicles)

Position	#	Salary (US$)	Salary/Minimum Wage	Total (US$)	Weight	Sizing Ratio
Head of maintenance	1	3,557.14	11.8	3,557.14	5.30%	0.005
Maintenance supervisors	5	1,511.78	5	7,558.92	11.20%	0.025
Mechanics	17	978.21	3.2	16,629.61	24.70%	0.085
Assistant mechanics	17	293.46	1	4,988.88	7.40%	0.085
Electricians	7	1,067.14	3.5	7,469.99	11.10%	0.035
Panel beaters	7	889.28	2.9	6,224.99	9.20%	0.035
Spray painters	5	1,067.14	3.5	5,335.70	7.90%	0.025
Tire repair men	5	622.50	2.1	3,112.49	4.60%	0.025
Others	28	444.64	1.5	12,449.98	18.50%	0.14
Average total salary	**92**	**731.82**	**2.4**	**67,327.70**	**100.00%**	**0.46**

Source: Logit. Currency conversions from R$ to US$ with 2013 exchange rate: https://www.irs.gov/individuals/international-taxpayers/yearly-average-currency-exchange-rates

As a result, one may see that the average salary is roughly the same and the ratio sizing parameter had a small increase from 0.4225 to 0.4600. Of course, in case the vehicle operating company were considerably smaller, or larger, probably the salary levels would change and the number of personnel would be altered as well. In any case, it is safe to size the garage depot/maintenance to something in the range of 0.420 to 0.480, with an average salary of approximately 2.3 to 2.4 times the minimum wage.

Back Office Personnel

The back office personnel are assigned the responsibility of managing the company and performing the roles of recruiting and procurement, among others. Since the back office size relates to the overall size of the company, one could argue using as a denominator for the ratio parameter the total number of buses, considering the operational and reserve fleet. However, in order to keep coherence with the other personnel sizing above and considering that the back office is usually more dependent on people than assets, it is recommended the use of the same driver index: personnel/operational fleet.

The back office, similar to the operational control department, is less scalable than other operational positions. Independent of the size of the company, a minimum structure is required, which is usually sufficient for a larger "leap" in overall employee numbers. In other words, the back office increases in steps.

Typically, the expected positions for the back office personnel are:

- Back office manager;
- Secretary;
- Head of employee relations;
- Accountant;
- Nurse;
- Work safety engineer;
- Work safety technician;

- Assistants:
  - Accounting;
  - Financial;
  - Employee relations;
  - Data processing;
  - Procurement;
  - Administrative;
  - Other assistants.

As an example, for the sizing of a vehicle operating company with an operating fleet of four hundred vehicles, one could expect the following sizing parameters:

Table 14.11. Sizing Parameters for Back Office Personnel (400 Vehicles)

Position	#	Salary (US$)	Salary/Minimum Wage	Total (US$)	Weight	Sizing Ratio
Back office manager	1	3,601.60	11.9	3,601.60	11.00%	0.0025
Secretary	2	500.22	1.7	1,000.44	3.10%	0.005
Employee relations head	2	1,600.71	5.3	3,201.42	9.80%	0.005
Accountant	1	2,000.89	6.6	2,000.89	6.10%	0.0025
Accounting assistant	2	800.36	2.7	1,600.71	4.90%	0.005
Financial assistant	2	1,000.44	3.3	2,000.89	6.10%	0.005
Employee relations assistant	4	500.22	1.7	2,000.89	6.10%	0.01
Data processing assistant	3	800.36	2.7	2,401.07	7.30%	0.0075
Procurement assistant	1	800.36	2.7	800.36	2.40%	0.0025
Administrative assistant	5	800.36	2.7	4,001.78	12.20%	0.0125
Other assistants	8	333.48	1.1	2,667.85	8.20%	0.02
Nurse	2	500.22	1.7	1,000.44	3.10%	0.005
Work safety engineer	1	1,600.71	5.3	1,600.71	4.90%	0.0025
Work safety technician	6	800.36	2.7	4,802.13	14.70%	0.015
Average total salary	**40**	**817.03**	**2.7**	**32,681.19**	**100.00%**	**0.1**

Source: Logit. Currency conversions from R$ to US$ with 2013 exchange rate: https://www.irs.gov/individuals/international-taxpayers/yearly-average-currency-exchange-rates

For this situation, one can derive a sizing ratio of 0.10, in relation to the operating fleet, and an average salary of approximately US$820.00 (R$1,840.00). As mentioned before, there is less room for scalability due to size and most positions still require at least two employees.

As an example, the table below shows the sizing for vehicle operating company with an operating fleet of two hundred vehicles:

Table 14.12. Sizing Parameters for Back Office Personnel (200 Vehicles)

Position	#	Salary (US$)	Salary/Minimum Wage	Total (US$)	Weight	Sizing Ratio
Back office manager	1	3.60	11.9	3,601.60	15.10%	0.005
Secretary	2	500.22	1.7	1,000.44	4.20%	0.01
Employee relations head	1	1,600.71	5.3	1,600.71	6.70%	0.005
Accountant	1	2,000.89	6.6	2,000.89	8.40%	0.005

Accounting assistant	2	800.36	2.7	1,600.71	6.70%	0.01
Financial assistant	2	1,000.44	3.3	2,000.89	8.40%	0.01
Employee relations assistant	2	500.22	1.7	1,000.44	4.20%	0.01
Data processing assistant	2	800.36	2.7	1,600.71	6.70%	0.01
Procurement assistant	1	800.36	2.7	800.36	3.30%	0.005
Administrative assistant	3	800.36	2.7	2,401.07	10.00%	0.015
Other assistants	3	333.48	1.1	1,000.44	4.20%	0.015
Nurse	1	500.22	1.7	500.22	2.10%	0.005
Work safety engineer	1	1,600.71	5.3	1,600.71	6.70%	0.005
Work safety technician	4	800.36	2.7	3,201.42	13.40%	0.02
Average total salary	**26**	**919.64**	**3.1**	**23,910.63**	**100.00%**	**0.13**

Source: Logit. Currency conversions from R$ to US$ with 2013 exchange rate: https://www.irs.gov/individuals/international-taxpayers/yearly-average-currency-exchange-rates

As a result, one may see that the average salary is slightly higher, which is consistent with the inability to shed the upper level positions. The ratio sizing parameter thus has a 30 percent increase, going from 0.10 to 0.13. In any case, it is safe to size the back office personnel in the range of 0.090 to 0.150, with an average salary of approximately 2.7 to 3.1 times the minimum wage.

Directors Pay

Lastly, there is the sizing of the cost related to the company's directors. This sizing parameter could be considered within the back office personnel, but since this item is even less scalable and more dependent on the specific operation/country conditions, it is best to treat it separately.

As an example, for a vehicle operating company with approximately 400 vehicles in Brazil, it is possible to observe payments to directors totaling up to US$40,000 per month (about R$90,000 per month)—approximately 65 minimum wages. If the company were half that size, in terms of vehicles, and thus generating less revenue and profits, this total director payment amount could be reduced by 30 to 50 percent. Since for the financial model what matters is the total cost related to the directors, one could have more directors earning less each, or the opposite. In any case, this is a less sensible item in terms of total Opex and is strongly dependent on regional conditions.

In addition to the expenses mentioned above, there are other operating expenditures that are less significant but that should be considered.

Licensing/Insurance/City Taxes

Usually, each vehicle is subject to yearly licensing, obligatory insurance, and city taxes. Licensing and insurance tend to have a fixed value per vehicle. Hence, at a given time in the year, the vehicle operating company will be required to renew these licenses for the entire fleet (operational and reserve). City taxes may also be fixed, or possess descending yearly values per vehicle, based upon on vehicle age. These unit values are specific to each city and country. Moreover, there are additional insurances that may be contracted by the vehicle operating company that may be paid monthly.

Onboard Surveillance and Fare Maintenance

Depending on the system attributes, it may be the operating vehicle company's responsibility to maintain the onboard fare system and surveillance equipment, as well as paying for the data communication fees.

This is not a substantial value, and in Brazil, these values may amount to about US$245 per month (approximately R$550 per month).

Other Costs

Finally, there are many other overhead costs, whose individual sizing is not recommended. Usually, these costs amount to 3 to 8 percent of total operational expenditures and, as such, it is recommended to treat them as a percent markup on total operating costs.

A list of items included in this estimation is presented below:

- Water and sewage;
- Electric energy;
- Communications costs (telephone and internet);
- Building upkeep;
- Security;
- Certifications;
- Land tax;
- Accounting and legal support;
- Other equipment/machinery maintenance;
- Banking expenses and money transport;
- Other support vehicle expenses;
- Food;
- Marketing and public relations;
- Office supplies;
- Data processing;
- Environmental protection/waste management;
- Publications;
- Travel;
- Other.

14.6.2 Capital Expenditures (Capex)

Capex refers to expenditures whose aim it is to create future benefits. A capital expenditure is incurred when a business spends money either to buy fixed assets or to add to the value of an existing asset, with a useful life that extends beyond the tax year.

Vehicles

Acquisition

For the vehicle operating company, the initial vehicle acquisition is the single most important capital expenditure of the operation. Since the vehicles must be acquired before the operation commences, they happen before the "zero" date mark, occurring between the year before year zero and the moment year zero starts. As discussed previously, this implies that the vehicle acquisition cost be considered at year zero. For the financial analysis, this consideration is of paramount importance; otherwise, profitability indexes may be considerably overestimated.

Regarding the vehicle acquisition cost, it is important that the vehicle make, year, engine technology, emissions standard, seat capacity, and possession of an air conditioning system be clearly defined. Depending on the engine technology and emissions standard, vehicle cost may increase substantially. Also, if the vehicle is equipped for air conditioning, not only will there be an additional air conditioning equipment cost, but windows and doors may have to be fitted differently, further increasing assembly cost.

As an estimate of these values, one must not rely entirely on quotation values, since they are generally overestimated unless there is a firm intention of buying or request on the table. It is recommended that one try to obtain actual vehicle transaction values for similar specifications in similar regions, in order to obtain a better vehicle price estimation.

Replacements

Ideally, vehicles should be replaced when they reach their useful life. In some systems, which have been operating under the same concessionaire over a long period, the public agency may establish a maximum fleet average age, to gradually replace the older vehicles without having to impose a drastic fleet renovation. This practice is satisfactory for an evenly distributed or old fleet; however, if the fleet is new, it may cause a suboptimal fleet usage. The reason for this is that one would have to replace vehicles just slightly over the target average age to maintain the overall fleet age below the average target age. This situation should be avoided if possible.

The vehicle useful life may vary per the vehicle typology (18-meter articulated bus, 12-meter bus, etc.), if it runs in mixed traffic, and the quality of the pavement, among other variables. One usually establishes the useful life as the tipping point before major repairs are needed to the chassis and engine. For modern/latest series engines, this is said to be on average one million kilometers, which for articulated vehicles running in segregated lanes 65,000 kilometers per month on average, this translates roughly to twelve years. However, with proper maintenance and vehicle care, the useful life can be extended past this projected useful life.

Once the useful life is reached, the vehicles must be replaced with new vehicles, whose purchase order must be made at least six months before the actual moment these new vehicles are required for operation. Consequently, if the vehicle is to be replaced at the end of year eight, for instance, then the new vehicle acquisition must also be concluded in year eight.

At the moment of vehicle replacement, it is possible that the financing conditions available at year zero are no longer the same. The reason for this is twofold:

- Sometimes special conditions are given for new systems, where the government assumes part of the investment risk and hence the interest rates and conditions are better;
- Usually, for a diverse fleet, the replacement of all vehicles does not happen simultaneously, hence the total investing amount is different. That being said, for lesser amounts, perhaps certain credit lines may not be available.

In any case, these financing considerations are only pertinent in a leveraged/shareholder appraisal. In that case, it is important to treat the financing options accordingly.

Depot and Other Capex

In addition to the vehicle acquisition costs, there are other significant capital expenditures worth noting. Most of these other capital costs are incurred at the beginning of the operation or at the system's startup.

Land/Depot Acquisition

The first other capital expenditure worth mentioning is the land/depot acquisition cost. For this item, it is important to determine if the land is to be leased/donated by the city, or if it will be the vehicle operating company's responsibility to procure it.

The argument in favor of the city donating/leasing the land or, better yet, renting it, is that the city may make "one off" investments and clear well-positioned land in order to maximize system efficiency. In the case that the depot is well positioned, the system's dead kilometers (the distance from the depot to the routes) may be reduced to a minimum, which in return minimizes the variable, nonproductive, operational cost. Since the total vehicle operating cost determines the technical fare and, consequently, the fare price or system subsidy, it is in the system's best interest to minimize avoidable costs to the fullest.

Once the system is established, densely populated "prime" real estate locations close to the corridor have dramatically higher land acquisition costs. The vehicle operating company will be inclined to set up its depot facility at places "close enough" to the system that possess an accessible land acquisition price. As a result, these locations may be suboptimal. Also, leasing/renting the land is a way of reducing the start-up cost, and hence improve the operating company's profitability, which in return allows for lower tariffs or subsidies. The argument in favor of the vehicle operating company procuring and setting up its own depot greatly simplifies the whole process, with much less city bureaucracy involved.

In any case, leaving the above issue aside, it is necessary to determine the size of the land needed for the depot. As a rule of thumb, one may use the following sizing correspondence:

- Small vehicle—about 30 square meters;
- 8-meter vehicle—about 80 square meters;
- 12- to 13-meter vehicle—100 square meters;
- 18-meter articulated vehicle—150 square meters;
- Double articulated 24- to 28- meter vehicle—200 square meters.

It is important to state that the correspondence above is based upon average values and includes necessary areas for bus parking, fueling, maintenance, and the administration building. Once a total amount of square meters is determined, it is necessary to obtain a market price per square meters at that location's whereabouts in order to calculate the total land acquisition capital cost. In the case that the responsibility lies with the vehicle operating company, then the land acquisition would be a onetime acquisition to take place at year zero.

Depot Setup

Once the depot land is determined, the next capital expenditure is the depot setup. Depot setup may be divided into two components:

- Building/edification costs;
- Equipment and installation costs.

It may be a bit tricky to separate, at times, the edification costs from installation costs and, likewise, the equipment costs from installation costs. However, one should attempt to at least separate the building/edification costs, since they possess different depreciation and renewal rates.

Building/edification costs refer to the infrastructure setup of the garage depot. In order to size the total cost ideally, a block layout for the depot should be developed/made available. This would indicate how the depot is to be set up, the paving and covering, among other definitions. However, garage depots do not require special or complex setups, and based upon other garage depot reference investment values, it is possible to approximate the sizing of the investment for a new location. Since the driving parameter for garage depot investment amount is the required depot area, and that in return is dependent on the total fleet size, one may use the fleet size as the driving parameter for depot building/edification costs. As is the case of the land acquisition, the depot building/edification Capex are a onetime acquisition to take place at year zero.

The other component of the depot setup is the equipment and installation costs. For an initial setup, the installation costs are considerably more and may amount to as much as two-thirds of the equipment costs. However, it may be a bit tricky to separate the two, hence one can regard them jointly as equipment and installation costs. The equipment side of this equation will need replacing over time and, through observation, one may consider a periodic renewal rate of 20 percent of the total cost related to equipment and installation every five years. This means that in addition to the initial acquisition at year zero, there should be subsequent renewal rates at years five, ten, and so forth. Given that the equipment acquisition is also proportional to the fleet size it needs to service, the driving parameter for the equipment and installation Capex may also be the fleet size.

Based upon other systems' information, in Brazil, the total expenditure for building/edification, equipment and installation costs may range between about US$9,000 to US$13,000 per vehicle (R$20,000 to 30,000 per vehicle—currency conversions from R$ to US$ with 2013 exchange rate). Of this amount, roughly 50 percent relates to depot building and edifications, 20 percent to installation costs, and approximately 30 percent to the equipment costs. In any case, a more detailed analysis should be conducted to validate these ballpark numbers.

Equipment—ITS per Vehicle

Together with the depot setup capital expenditures, the additional relevant "other" capital expenditure has to do with the intelligent transportation systems (ITS). With ITS, one encompasses the onboard fare system (necessary, especially for feeder buses), the monitoring system (CCTV, onboard computer), and the bus panels for variable messaging. This cost may vary according to system specifications. For instance, an onboard fare system may not be required or more sophisticated components with additional functionalities may be necessary. In any case, the three functionalities mentioned above serve as good references for what is generally needed.

Since this equipment is to be mounted on the vehicles, the driving parameter for its sizing is also total fleet size. Given that the equipment is prone to wear and tear, one may consider a periodic renewal rate of 20 percent every five years. In other words, in addition to the initial acquisition at year zero, there should be subsequent renewals rates at years five, ten, and so forth.

The total cost per bus for this equipment installation may vary depending on if it is to be installed on an existing fleet or on a new fleet. Ideally, the equipment should be installed during vehicle assembly, since the installation itself is of better quality, and this reduces the cost. In Brazil, the approximate ITS Capex is approximately US$6,600 to US$5,300 (R$12,000 to R$15,000 per vehicle—currency conversions from R$ to US$ with 2013 exchange rate). This value is roughly 50 percent related to the fare system, 35 percent related to the monitoring system, and 15 percent related to the variable messaging panels.

14.7 Regional Parameters

In addition to the sizing parameters discussed above, there are specific regional parameters that must also be considered. Depreciation rates, taxes, and financing options vary from country to country and, depending on the country, their parameters may impact profitability significantly.

14.7.1 Depreciation

Depreciation is a method for allocating the cost of the "use" of a fixed asset over the course of its useful life. Depreciation is thus an accounting principle, since no monetary transactions occur, and it is used as a tax shield to reduce the basis for tax calculations.

Usually, the depreciation rates should be such so as to match the asset's useful life. However, specific regulations determine standard maximum rates (the maximum rate equals minimum useful life) that should be used per category. That being said, one may choose to depreciate an item over a longer period of time if that better reflects the item's useful life (less tax shield benefit). Generally speaking, a vehicle operating company should have the following depreciation categories:

- Vehicles: four years (Brazil);
- Building/edifications: twenty-five years (Brazil);
- Installations: ten years (Brazil);
- Equipment: five years (Brazil);
- Computers/furniture/others: three years (Brazil).

14.7.2 Financing Options

Financing options may vary depending on country risk, industry risk, and company/government liability. These issues mentioned above may affect the interest rate, financing period, grace period, and financing type: constant amortization system or constant payment system.

For this item, it is best to refer to considerations made in other chapters of this guide.

14.7.3 Taxes

Lastly, the tax system may also vary from country to country. The general taxing structure is similar in most countries, but the rates and fiscal credit limits are usually different. One may break down the taxing system in the following categories/moments:

- Profit taxes—applied upon company's profit;
  - The profit basis for taxation may be subject to tax shields originated from depreciation, fiscal credits, and losses brought forward;
  - Regarding losses brought forward, some countries limit the number of years the losses may be brought forward and the percent that it may deduce forms the profit basis.
- Face value taxes—applied upon company's gross revenue;
  - The basis value for face value taxes may be reduced due to fiscal credits.
- Tax shields—may vary per country;
- Fiscal credits—may vary per country;
- City taxes—not all face value taxes; for instance, some may be country taxes. Certain taxes may be defined at a municipal level and vary city to city.

15. Fare Policy and Structure

"Price is what you pay. Value is what you get."

— Warren Buffett, businessman, 1930–

Defining fare policies can be a tricky subject. There must be an adequate balance between the technical and political aspects that may come into play when defining them. It is often the case that mayors have the authority to define public transport fares but do not necessarily consider all the technical aspects related to such an important decision.

The fare policies must take into account issues such as:

- Will the system receive subsidies or will it generate profit?
- If the system is profitable, what will be done with this profit?
- Will there be discounted fares for population groups (seniors, students, etc.), either now or in the future?
- How will the system be affected by political climate change in the future?
- Who are the system's stakeholders, and which of those will receive payment and how (i.e., vehicle operating companies, feeder operators, security and maintenance providers, fare collection operator, BRT authority, trust fund manager, others)?

Since each case is different, every city should develop its own set of questions before implementing a fare policy, always taking into account that this is the decision that will probably affect users the most.

Once the questions are answered, implementers must do an analysis of all the possible costs and revenue sources of the system. This will allow cities to have a more precise idea of what the "fair fare" should be and allow them to start considering possible financing sources, such as private or public investment.

In the following sections, we will discuss objectives, techniques, and points to consider when deciding on a fare policy for a BRT system.

Contributors: Fabio Gordillo, *GSD+*

15.1 Fare Structure Options

"Whatever affects one directly, affects all indirectly. I can never be what I ought to be until you are what you ought to be. This is the interrelated structure of reality."

— Martin Luther King Jr., civil rights leader, 1929–1968

15.1.1 Objectives of Establishing a Fare Structure

The fare structure will, in a large manner, define the income of the system. Careful consideration must be taken when defining the fare structure in order to have a cost-efficient system that takes into account the purchasing capacity of the users. Fare structures can be used as mechanisms of income distribution and should be used by local governments as part of their tools to reach development goals.

Depending on sources of finance, the fare structure may serve the objective of either making the system financially viable or even profitable.

15.1.2 Cost Recovery and Profitability

As with any project, costs to be incurred can be divided into two: Capital Expenditures (Capex) and Operational Expenditures (Opex). Capex will be all investments on equipment or infrastructure that will create future benefits. These include all infrastructure investments, vehicle purchases, fare collection equipment, control centers, etc. Opex, on the other hand will be the ongoing expenses the system incurs due to its regular operation. These include all personnel costs, utility bills, petrol, maintenance, financial costs, etc.

The BRT system will have, as other projects, several sources of income to cover Capex and Opex. The most evident one is the customer fare (when not considering free systems). Others may include publicity on stations, vehicles, or on the fare collection medium, cross-subsidies from other transport mediums (car usage, parking, and petrol taxes), and government subsidies, among others. The BRT authority has a responsibility of balancing the expenditures versus the income that the system generates based on the objectives that the system has. If no public funds will be used, the other sources of income generated by the system must be sufficient to cover both Capex and Opex.

Having a profitable system may entail certain benefits: the system is able to provide a higher quality system (technologically and infrastructure-wise), be less prone to political swings, benefit vulnerable populations, and be less of a burden to taxpayers.

If the only source of revenue for the system, however, is the customer fare, the political viability of charging all costs to it may not be an option. BRT authorities have to balance both the technical and political aspects to reach a truly "fair fare" for their BRT system.

Developing countries should try to target fare structures that cover most, or all, of the system's expenses, due to the lower availability of government funding. This may be politically difficult, however, because it would put the entire system's cost burden on the customer fare.

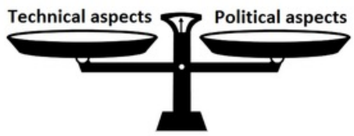

Figure 15.1. How do BRT authorities manage to balance the technical and political aspects when defining the fare policy structure? *ITDP.*

15.1.3 Fare Types

The fare type must be decided taking into account the objectives of the local government and access to funding. Several options exist and, as explained before, can serve purposes such as making the system financially viable (even profitable) or as an income distribution tool.

Open Fare (Free Fare)

As the name implies, free fare systems involve charging nothing for public transport use. Some public transport systems in Belgium have realized that their fare collection process is so costly that it makes sense just to provide a free service. By eliminating the fare charges for public transport, there is no need for fare collection and fare verification equipment, no staffing requirements for fare operations, no smart cards or other payment mediums, and no customer wait times for fare purchases.

Further, the design of vehicle interiors and stations is void of the requirements from the fare system. For the vehicle interiors, there is much more space for seating. The implications for station design mean that an open rather than closed design can be utilized. An open design means that there is less visual and physical severance from the station (Figure 15.2). These types of stations are also less costly to construct.

Of course, the main benefit from fare-free systems is the impact on customer numbers. In Hasselt, Belgium, bus patronage jumped from 23,000 customers per month to 300,000 customers per month with the introduction of fare-free service. About 25 percent of private vehicle users have switched to public transport since the implementation of this scheme. Likewise, urban rail fares have also been eliminated

Figure 15.2. The Orlando LYMMO system charges no fare, and thus the station designers had considerably more freedom to create an intriguing and open design. *Lloyd Wright.*

in certain areas of Belgium. An added benefit of free fares can derive from considering that, if occupancy rises, it will do so by shifting away from other modes of transport, mainly the use of private cars. This may entail positive externalities such as CO_2 emission reductions, fewer car crashes, and reduction in public transport times, among others.

The basis of the decision in Belgium was the fact that approximately 60 percent of the system's revenues were being used to print, distribute, and inspect fares. If other externality costs, such as impacts on station design and customer wait times, are considered, then the case for fare-free travel will be even stronger.

Fare-free systems have become increasingly common in both Europe and North America. In the United States, cities such as Denver, Miami, and Orlando have some services that operate fare free.

The development of a fare-free system does not mean that the overall business structure must radically change. Private operators can still bid competitively for providing the services. Payment to the operators can still be based on the number of kilometers travelled. The only change is the origin of the revenue stream, which instead of being from the customers will be from other sources, such as road pricing, gas taxes, and parking fees. For example, Orlando pays for its LYMMO service entirely through a parking fee.

In the case of lower-income economies, there is likely to be less of a case for a free-fare system, principally because the cost of fare collection will likely be less. With lower labor costs, there will be fewer instances in lower-income economies where the costs of fare collection begin to approach the revenues gained, thus justifying the elimination of fares.

However, there are examples of cities such as Bogotá utilizing free-fare structures for feeder services. Since feeder services will typically operate with open rather than closed station environments, any fare collection will likely have to occur onboard the vehicles. This arrangement implies that fare readers are required at the doorways. An exit reader may also be required if the transition from the feeder service to the trunk service passes through an open area. All this onboard fare equipment means that the vehicle costs are considerably higher. Additionally, onboard fare collection and verification may also imply a required intervention from the driver (such as providing change) that will slow dwell times and overall travel times. For all these reasons, free-fare systems have a fairly wide applicability to feeder services in both higher-income and lower-income economies.

The main arguments against free-fare systems relate to financial viability, security, and economic principle. First, for many lower-income economies, the ability to secure system financing from other sources besides fares may be limited. In most cases, though, the growth in private motorized vehicles does provide significant scope for using some form of vehicle fees as a revenue source, even though this may be politically hard to accomplish.

Second, some argue against free fares on the economic principle that free goods always lead to market inefficiencies. If a product is not priced, it simply will not be valued by the public, thus the public transport system will be seen as an inferior good. Again, though, one could extend this argument to many other aspects of public space such as footpaths, public parks, and even city streets. Few people would suggest charging pedestrians for using a footpath or families for using a park. In the same way, public transport could also be viewed as an essential public good that should not be burdened by a fee.

Flat Fare vs. Distance-Based Fare

Many cities often debate whether to apply a flat fare or a distance-based fare. A flat fare means that a single price applies to any trip within the system. By contrast, a distance-based fare means that the fare level varies by the number of kilometers travelled.

Each of these options involves a different set of trade-offs. Flat fares can be equitable if low-income groups tend to take long trips and reside at the urban fringe. These peri-urban areas offer property at substantially lower costs than central areas. The long distances between the peri-urban communities and employment opportunities in the city can inhibit access to jobs, health care, and education. If a distance-based fare were implemented in such a situation, the poor at the urban fringe would end up paying the highest transport costs. In order to achieve greater social equity, a flat fare helps to give such low-income groups access to services and opportunities in the city center. In such instances, a flat fare acts as a cross-subsidy from higher-income residents in the central parts of the city to lower-income residents located in peri-urban areas. One of the principal reasons that Bogotá instituted a flat fare was to promote a greater sense of social equity within its public transport system. As TransMilenio's system has expanded, however, the average trip distance within the system is increasing, as is the cost of providing each trip. This trend is putting upward pressure on the base fare.

A flat fare also permits the use of simpler fare collection technologies. Ticketless options, such as coin-based machines (please refer to Chapter 18: Fare Systems), are possible with a flat fare. Further, a flat fare implies that no distance-verification step is required upon exiting the system. The lack of this verification step reduces queues and thus improves overall system efficiency. In general, a flat fare scheme reduces the level of complexity in fare collection by an order of magnitude.

Distance-based fare systems are utilized quite frequently in higher-income economies, as well as in some rail systems in lower-income economies, such as the SkyTrain in Bangkok, and the Metro in Delhi. Distance-based fare structures most closely mirror actual operating costs, thereby providing a truer measure of expenses for system operators. A longer journey implies that more fuel and labor is required. Thus, distance-based systems do not involve the implied cross-subsidy that exists in flat fare systems.

A distance-based fare will likely get the planned system closer to full cost recovery than a flat fare. So long as the fare revenue is higher than the cost of operating the system, the fare can also vary based on trip distance. More complex fare structures offer the possibility of optimizing the profitability and equity of the system.

The principal disadvantage of complex fare systems, such as distance-based fares, is that these can lead to customer confusion over the actual cost of a given trip. In order to indicate the system fare structure, typically a complex matrix of fares must be posted at the stations. Customers may enter the system without knowing exactly how much their trip will cost. In turn, the result may be that a customer arrives at a destination without sufficient funds on their fare card. This situation may imply the need for a fare adjustment machine at the exit area. It may also imply that customers may be liable for penalties and fines, which will stir customer anger and/or embarrassment. Such incidents can be quite effective in discouraging future use of the system. In Washington D.C., for example, the fare table for the Metrorail can be quite overwhelming for non-regular users, and it requires some knowledge of the city and the system, which is not very likely of tourists (see Figure 15.3).

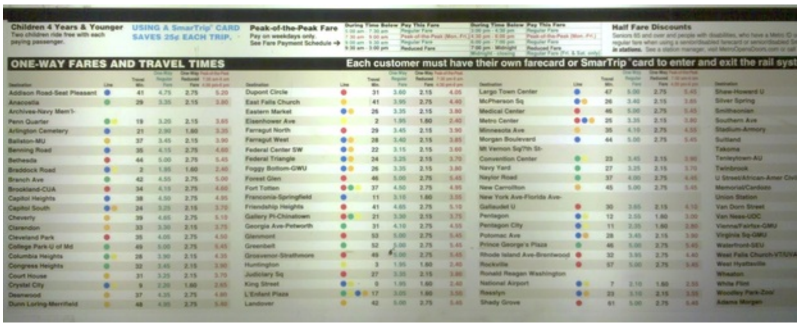

Figure 15.3. The Washington, D.C., Metrorail fare table. *ITDP.*

The complexity also means that more things can go wrong with the system, adding to maintenance costs and potential system shutdowns. In the case of cities such as Jakarta, the complexity of the fare system meant that it did not work properly during its first year of operation.

It is also possible to have a mix of both flat fares and distance-based fares. The base fare can be set quite high, and the additional distance–based fee can be set quite low relative to the overall fare price. Alternatively, a flat fare may be utilized within a well-defined urban area while journeys extending to regional locations, such as other municipalities, can require an additional charge. A mixed fare system can be appropriate when a metropolitan area includes satellite commuter cities. If such cities are predominantly middle- or higher-income in nature, then the justification for cross-subsidies is less. For example, the busways in São Paulo charge a flat fare in central areas but revert to a distance-based scheme for continuing on to satellite destinations.

Before deciding on a flat fare, it is worth testing the impact of different fare structures on total system profits. Different fare structures can have widely different impacts on ridership under different conditions.

For example, on the first corridor of the TransJakarta system there are a lot of customers going very short distances, as it is a major shopping area, and people are going from shop to shop. TransJakarta, which adopted a flat fare system, loses a lot of customers because there are minibuses that offer a competing service at a price below the fare for TransJakarta. For short distance trips, customers tend to use the minibuses, but for longer trips where the time savings becomes a major issue, customers tend to use TransJakarta. These short trips on the corridor, however, are generally a highly profitable sort of trip to serve.

On the other hand, on Corridors 2 and 3, most customers were making a very long trip from the periphery to the city center. On these corridors, the flat fare structure gives TransJakarta a competitive advantage over other commercial operators who charged a zone-based fare. This flat fare also attracted a lot of ridership from low-income residents who live at the city's periphery and who are highly price sensitive.

Therefore, TransJakarta wished to test the impact of a distance-based fare on profit. Table 15.1 shows the results of this analysis. These results clearly show that shifting to a fare structure with a reasonably high minimum fare combined with a distance-based fare would yield substantially more profit than a flat fare system. Figure 15.4 highlights the amount of ridership that each of the different fare strategies would generate.

Table 15.1. Comparing Different Fare Structures on Transjakarta

Option	Base fare (Rp)	Variable portion of fare (Rp/km)	Demand (paying customer)	Collected fare (US$)	Average distance (km)	Operating cost (US$)	Profit (US$)	Max. peak frequency (buses/h)
Flat fare	Rp 2,500	0 Rp/km	11,523	$3,201	13.47 km	$1,973	$1,228	40
Variable fare 1	Rp 1,500	70 Rp/km	13,653	$3,283	9.87 km	$1,927	$1,356	46

Variable fare 2	Rp 1,000	110 Rp/km	16,374	$3,719	7.94 km	$2,054	$1,666	53
Variable fare 3	Rp 1,500	50 Rp/km	18,270	$4,129	10.68 km	$2,521	$1,607	62

Doing this analysis requires a public transport model with an OD matrix of public transport trips. If average public transport trip distances along the planned BRT corridor can be closely estimated, then the technical fare can be recalculated using a distance-based fare.

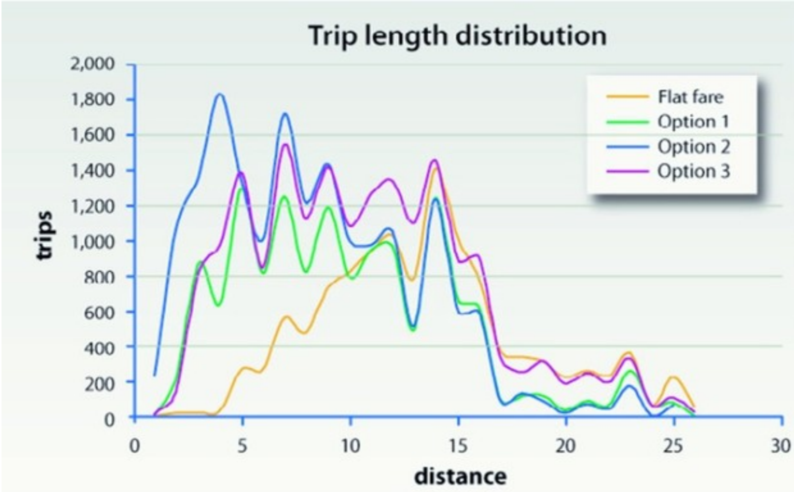

Figure 15.4. Analysis of the impact of different fare structures on TransJakarta's Phase II ridership. *ITDP.*

Zonal Fare

Zonal fares are sometimes touted as a simplified version of a distance-based fare. In the case of a zonal fare, customers are charged by the number of zones that are crossed. Thus, if a customer travels from one city district to another, he or she is charged more than someone who only travels within a single district.

The principal advantage of a zonal system is its simplicity, both in terms of reducing customer confusion over fares, as well as in terms of the fare technology required. It is easier to understand the cost implications of travelling in a city with a few zones as opposed to a significant number of permutations related to distance-base combinations.

The principal disadvantage of a zonal system relates to peculiarities in the fare structure, where very short trips between zones can cost double a long trip inside a zone. This type of situation leads to an inequitable application of fare policy and can lead to anger among customers. This very scenario has occurred in Santiago, Chile, and has resulted in some dissatisfaction with the system. As with distance-based systems, this can lead to social inequities if lower-income citizens live on the outskirts of the city and need to travel downtown for work, and hence will need to pay a higher fare. To a certain extent, the advent of the smart card has made the zonal system unnecessary.

Time-Based Fare

While fares can vary by distance, they can also vary by time. The most typical form of time-based pricing is to have a peak-period fare and an off-peak fare. Charging more for peak periods tends to be more profitable in part because roads are most congested during peak hours, creating the strongest incentive to use a BRT system then. Peak-hour customers are also mostly commuters, who have the least flexibility in their travel schedule. Being less flexible means they are less price sensitive, and will pay more to make the trip.

Public transport services that are heavily used during peak hours also have higher operating costs than services with demand that is more smoothly distributed throughout the day. The higher costs occur mainly because more vehicles are needed to service the peak period and because of the impact on labor needs. Bus drivers and other system operators tend to want to work an eight-hour day, whereas the morning and evening peaks will require extra labor. The less peaked the demand, the fewer the number of additional workers that are required to cover the peak periods. A fare system that encourages people to travel during nonpeak periods will help better distribute demand in a way that is more operationally efficient.

Santiago has defined a 20 percent discount during nonpeak hours, so transport users prefer to ride during nonpeak hours, reducing system congestion and improving the efficiency of the fleet. TransJakarta also offered a discount for early morning customers; before 7:30 in the morning, the fare was reduced from Rp 2,500 to Rp 1,500. This type of pricing acts to help spread the peak. Additionally, the lower price served social equity purposes, since early morning riders tend to be from the lowest income groups. Special attention needs to be paid since cross-subsidies may end up coming from lower-income populations because they generally have less flexible travel schedules, and will most likely end up travelling during the peak time.

Other systems use a time-based fare where the fare card buys the right to use the system for a maximum amount of time. This type of fare has much application when it is desirable to provide transfers in systems without physical integration between stations. Thus, transfers between rail services, trunk BRT services, and feeder BRT services can take place without the need for physically closed transfer environments. This is discussed further in the following section.

The advantage to a time-based system is the savings provided to certain customers, especially those travelling at nonpeak periods or those making linked trips using various modes. A time-based restriction also sometimes is useful to prevent some customers from loitering in the system.

If such a scheme is used, the technology must adjust for incidents when it is not the customer's fault that the time has been exceeded. For example, if a serious delay occurs in the system due to a breakdown, customers will become irate if they also have to pay more. Also, additional time may be given to senior or handicapped citizens. These adjustments can easily be handled by a smart card–based system (see Chapter 18: Fare Systems).

15.1.4 Discounts

Multi-Trip Discounts

One of the main cost advantages that private motor vehicle travel has over public transport is that once the customer has sunk the investment into the procurement of the vehicle, the marginal cost of using the car goes down the more the vehicle is used. This situation creates an incentive to drive more. Public transport fares that force people to pay per trip create the opposite incentive—to use the system as little as possible.

Daily, weekly, and monthly passes, and multi-trip discounts are a good way to create incentives among public transport customers to use the system more. Studies show that such incentives will have a particularly large impact on discretionary travel during nonpeak periods. Multi-trip passes can also have significant benefits in terms of reducing queues at the fare booths and the amount of labor needed to staff ticketing sales.

If such passes will be used, careful consideration needs to be given to the way the contracts with vehicle operating companies are structured, ensuring that financing is secured. In Bogotá, for example, since vehicle operating companies are paid based on kilometers, there is no financial impact on implementing such passes. Conventional vehicle operating companies, however, will be paid with a combination of kilometers and customer numbers, meaning that a time-pass will have a big impact on the finances of the entire system.

Transfer-Discounted Fare for Intermodal Transfers

In many cities today, fare structures between different modes, such as rail and bus services, are not well integrated. However, the increasing sophistication of cash cards and modern fare systems is creating many possibilities for giving special discounts for customers transferring from other public transport systems. Such forms of integration can even take place without necessarily having to integrate these public transport systems from a management perspective. This issue is particularly important in the growing number of cities that are building metro systems on some high demand corridors but are considering BRT on other corridors.

In the past, providing a discount for metro or commuter rail system users on the BRT system required a high level of interagency coordination, and discussions frequently broke down on these grounds. For example, in São Paulo, there were bus services, commuter rail service, and the metro system operated by the State of São Paulo, but another, bigger bus system operated by the Municipality of São Paulo. Fare system integration between these systems remains elusive even today, even though these systems are all currently governed by the same political party.

True fare "integration" between different modes is sometimes confused with fare "compatibility." Fare integration implies that a customer pays for a multimodal fare that does not incur any penalty for changing from one mode to another. Seoul's fare system comes quite close to achieving this level of integration. Fare compatibility instead just means the various modes share the same payment medium. With fare compatibility, the customer will pay multiple fares according to the number of systems utilized in the journey. Thus, with fare compatibility the customer gains some convenience with a single fare card, but the customer incurs another full fare cost whenever transferring between systems.

The city of Bogotá, with the implementation of its integrated public transport system, Sistema Integrado de Transporte Público (SITP), plans to enforce a time-based discount fare for intermodal transfers. This means that customers will be able to travel among the different transport modes offered by the city at a discounted fare as exemplified in Equation 15.1.

Eq. 15.1 Bogotá's SITP transfer discounts example (2011 prices in Colombian Pesos):

$$\text{BRT}+\text{Conventional Bus} = COP1700 + COP1400 = COP3100 \text{(No transfer discount)}$$

$$\text{BRT}+\text{Conventional Bus} = COP1700 + COP500 = COP2200 \text{(With transfer discount)}$$

Customers will be able to save COP 900, which is nearly a 30 percent savings. This becomes very useful in a city such as Bogotá, where lower-income citizens tend to live on the outskirts of the city and are more likely to require at least one transfer to reach their destination. This scheme results in a cross-subsidy from customers or, depending on the contract type defined for the bus operators, may need direct subsidies from the local government. Again, this may be used as an income distribution scheme; however, careful consideration must be taken to ensure that the income sources for this type of subsidies are secured.

Perhaps the greatest challenge to fare integration between different public transport modes is not the payment technology but the significant differences in operating costs. Attempting to combine systems with dramatically different per kilometer operational costs raises many equity issues. This incompatibility is especially true when one system requires a significant operating subsidy and another system does not. For example, in Seoul, the underground rail system requires a massive operational subsidy while the bus system operates with no subsidy. In order to equilibrate an integrated fare and business structure, the underground metro operator receives a much higher payment per passenger-kilometer served than the vehicle operators. Such inequities may be acceptable in some cases, but it does raise questions about fairness, especially if two services are of comparable quality but of radically different cost structures.

User Profile Discounts

Providing fare discounts to special groups is a relatively common practice in public transport systems around the world. In some countries, while sometimes socially desirable, the requirement that a BRT authority accept special discount fares creates a difficult challenge for any public transport agency. Controlling fraud in the use of discount passes poses a difficult technical challenge.

The determination of discount eligibility for children and the elderly is typically based on age limits. For example, system managers and operators may decide that children under five years of age and adults over sixty years of age qualify for special discounts. The determination of student eligibility is often predicated on either age limits and/or the possession of valid student identification. Student discounts may be limited to only certain student segments, such as primary, middle, secondary, and university levels of education.

Discounts to children, students, and the elderly are typically given for reasons of social equity (Figure 15.5). Economically, a discount strategy can make sense so long as the discounted fare covers at least the marginal cost of each customer. If fare levels are to be reduced below marginal cost levels, then some sort of subsidy system will need to be put in place. Subsidies can take the form of cross-subsidies between customer user groups or direct subsidies from the government to the operators. In either case, the introduction of subsidies significantly increases financial complexity within the operation of the system, and subsidies also create complications with respect to operator incentives. Thus, if a discounted fare structure is to be utilized, it is usually best for the discounted fares to at least cover marginal costs. Otherwise, the resulting cross-subsidy can effectively render the discount meaningless, while simultaneously increasing the management costs of the system. For example, providing a below marginal cost subsidy to a child may simply mean that the parent must pay more to cover the subsidy. In effect, no social equity is being achieved.

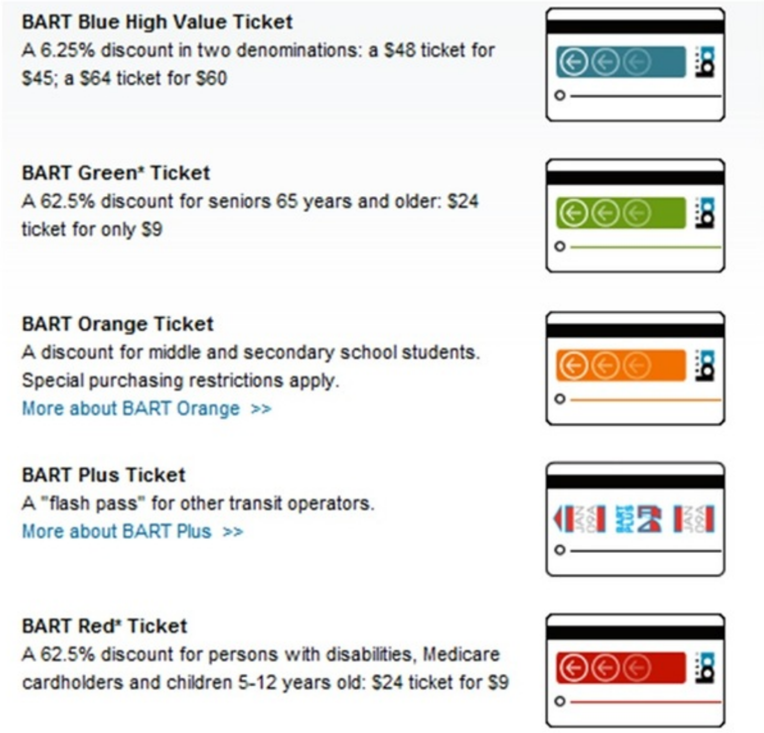

Figure 15.5. Bay Area Rapid Transit (BART) system tickets including senior, student, and handicapped discount tickets. *BART (http://www.bart.gov/).*

Chile and Brazil, for example, both place a legal obligation on the public transport operators to accept special discounts for students and the elderly. In Brazil, private vehicle operators are not compensated for the provision of this service, and the cost burden related to this service and its fraudulent abuse is a continuing cause of operator claims that they need fare increases. In many instances, operators will simply not stop if they see many students at a stop.

If the BRT system does not have a reliable mechanism to track the number of trips made using such discount passes, it has no way to place a valid claim to the government for compensation. This situation has created an ongoing justification for requiring government subsidies, but no clear basis on which to determine an appropriate level. The subsidies are thus a source of ongoing tension between the government and the operators.

On the other hand, Brazil has another subsidized fare that goes to employed workers called “Vale Transporte.” Vale Transporte is a public transport voucher that is as good as cash to any vehicle operator. Recently the Vale Transporte voucher system has been extended and can even be used with some formerly informal sector minivan services. As this increases demand for public transport services and does not adversely affect bus system profits, it is generally supported in the public transport community. Critics of the program are unhappy about the fact that it targets middle-income people with jobs rather than the very poor, and it costs the government a lot of money to administer, but these are not problems from the point of view of public transport operations. Voucher systems are therefore the preferred route for subsidizing categorical discounts.

Discounted fare systems are also highly susceptible to fraud. As noted above, the qualifications for a child, student, or elderly discount are based upon age or a special identification. However, once the discount passes are issued, it is extremely difficult to ascertain exactly who is using the pass. The discount passes can be “lent” to family or friends who otherwise do not qualify for the discount. More worrying is the development of a gray market for discount passes in which persons obtain passes and sell them to others. Likewise, certain types of monthly passes for frequent users can be abused. If the monthly pass allows unlimited travel on the system, then the pass may end up being shared among several persons.

There are mechanisms to combat fare fraud to an extent. First, the avoidance of discount passes that allow unlimited travel is one option. Instead, discount fare passes that deduct credits for each trip undertaken can somewhat help avoid shared passes. Or, a discount pass could limit its use to no more than two trips per day (i.e., the number of trips in a typical commute).

Second, formal registration and photo identification on the discount card can be the basis for a verification process. The verification could be conducted randomly when customers are inside the system. Also, when a discount card is read at the turnstile area, an indicator light could alert the platform staff. A random verification of such persons could help to stem fraud.

An exception to these recommendations is travel for very young children as designated by a certain age. Requiring a travel pass for a very young child is problematic since it can create a burden on parents. Further, small children who sit in the lap of a parent are not necessarily adding significantly to the operational cost of the system, although certainly space for any strollers can more than compensate. Also, given that the appearance of young children changes considerably in the earliest years, photo passes are not particularly useful. Undoubtedly, some parents will insist that their six- or seven-year-old is only five, but the scope of this sort of deception is usually not significant enough to warrant a stringent approach.

In summary, fare discounts are well-meaning attempts to increase affordability and social equity within a public transport system. In some cases, though, the added costs and complexity of implementing a fare discount strategy can negate these intended benefits. Before committing to a fare discount system, cities should carefully consider the full ramifications.

15.1.5 Other Sources of Income

Fares for Feeder Operation

The fare handling system for feeder services will often follow a different operational process than the fare system for trunk lines. As noted earlier, cities such as Bogotá and Quito now compensate feeder operators by a combination of the vehicle kilometers travelled and the number of customers carried. This compensation package attempts to balance incentives in order to motivate operators to provide high-quality service.

Within this model, feeder operations have a range of options for fare collection and fare verification. In Bogotá, feeder operators do not collect the fares from customers boarding at feeder stations. Instead, customers only pay once they reach the terminal stations or intermediate transfer stations. For the return trip home, customers pay upon entering the trunk-line corridor and then transfer for free to the feeder services. However, for the return trip, entry into the feeder service is restricted to those persons who have previously marked their card upon leaving the station. This system holds the advantage of not making the feeder operators handle any revenues from customers. By avoiding fare collection and fare verification at the feeder level, there is considerable time savings, as well as the avoidance of any corruption.

However, the system has the disadvantage of allowing customers to travel from one feeder stop to another feeder stop without paying anything. This situation occurs because payment is only made once customers reach a terminal. In some ways, the “free ride” between feeder stops could be viewed as a positive marketing point for TransMilenio, since people will enjoy having a free neighborhood service. However, the number of persons taking advantage of this free service is now reaching 15 percent of total feeder ridership. TransMilenio has changed feeder operator contracts from being based exclusively on kilometers travelled to being a combination of kilometers travelled and customers carried. It is possible that the addition of customers carried to the contract will provide an incentive for operators to curb the free use of the feeder services.

There are other options for feeder fare control that can avoid some of the issues faced by TransMilenio. Another option is for feeder services to collect fares when customers board the feeder vehicle. While it would likely not be practical to make the driver handle fare collection and/or fare verification, the addition of fare collection staff to the vehicle could be a solution. Boarding the vehicle could take place at a single doorway (e.g., the rear door). Likewise, alighting the vehicle would then only be allowed at the other doorway (e.g., the front door).

The fare collection staff (i.e., conductor) could be from the fare collection company and not from the feeder operating company. This separation of interests would help to avoid any mishandling of fare revenues. Customers boarding the feeder vehicle would enter a closed reservoir area in the bus, and then proceed through a turnstile once payment to the fare collection staff is made. The reservoir concept allows the vehicle to continue to the next stop while customers are being processed through fare collection. The reservoir concept is already utilized extensively in Brazil for conventional bus services. The disadvantage of this option is the cost of adding another staff person to the vehicle and the cost of the fare collection infrastructure within the vehicle. However, in many developing cities, the lower labor costs, in conjunction with political needs to maximize employment, make this option a viable possibility. Further, if the free ridership problem experienced in Bogotá was of such a magnitude, then the additional fare collection staff could be fully cost justified.

If the feeder customer volumes are sufficiently high, then other options utilizing more sophisticated fare technologies may be possible. These options include:

- Fare collection vending machines at feeder stations (either open or closed stations);
- Smart card readers upon entering a closed feeder station;
- Smart card readers upon entering the feeder vehicle.

Cities such as London are utilizing coin-fed fare collection machines at conventional open bus stations (see Chapter 18: Fare Systems). This type of technology could be adaptable to feeder services in some developing cities. If the station was closed (i.e., no entrance without fare payment), then a coin-based or even smart-card-based system could permit entrance to the station. Alternatively, a fare card purchased at a vending machine in an "open" station could then be verified inside the vehicle. The verification could either be done in a closed reservoir environment on the bus or by way of an honor system, where customers self-validate their fare tickets. If smart cards are utilized, then again, the fare verification could take place through a self-validating machine inside the vehicle.

All of these technological solutions, though, do have limitations in the developing city context. First, the cost of the technologies for feeder services may be prohibitive from both a capital and operating cost standpoint. Second, creating "closed" stations at feeder stops may not be practicable from either a spatial or a cost perspective. Third, the effectiveness of "honor" payment and verification systems in developing cities is still not proven. Fourth, costly fare collection machines left unprotected at feeder stations could be subject to maintenance issues and even theft.

Publicity

Publicity can be used as a means of generating additional income for the system. The BRT infrastructure, including stations, vehicles, and fare collection medium can all be used. Furthermore, the system can be used to communicate important messages from the local government or as means of art galleries to enhance the user experience (Figure 15.6 and Figure 15.7).

All contracts between the different actors need to consider where the profits from publicity will go. In Bogotá, for example, publicity in vehicles belongs to the vehicle operating company.

Figure 15.6. Cleaner diesel campaign on the TransMilenio system buses. *Ecopetrol.*

Figure 15.7. A publicity and marketing campaign used in a BRT station for the 2011 FIFA U20 World Cup in Colombia. *La Casa Editorial El Tiempo (CEET).*

Government and Cross-Subsidies

As described in the previous chapters, there are several instances where subsidies can be implemented in the system, whether directly to the fare or to user groups, for long distance travel and others.

Decision makers need to be very careful about which strategy to use when implementing subsidies. Special care needs to be taken with the sources of income to be used. Subsidies that come from the fare may have negative results, since this will mean that the entire population is paying for something that will only benefit public transport customers. When implementing cross-subsidies for income distribution purposes, the “giver” and the “receiver” must be clearly identified.

The preferred sources of income for subsidies should then be from other less beneficial modes of transport to the city (that produce large negative externalities), such as private cars. These subsidies would be in the form of congestion charging and pollution taxes, among others. If subsidies are given to the operation of the system, they should be given as a constant and guaranteed income flow that is supported by technical analysis, as opposed to being given based on only political grounds, which would generate a hole in the city’s future finances.

Other forms of subsidies can be given to the Capex of the system. By building infrastructure and charging the vehicle operators for the right of use of this infrastructure, the local government will be subsidizing the operation of a BRT system without the need to have a constant income flow. Again, the contractual obligations of the vehicle operators must be considered carefully in order not to subsidize the companies themselves in detriment of the end users.

Multilateral Organizations

Multilateral organizations can often provide good credit access and conditions for public projects. These can be taken generally by the city itself, or sometimes are available to the private sector, with the city as collateral. This is a good way of financing the infrastructure of the BRT system at a lower cost than what the financial market offers.

15.2 Fare Parameters

> *“Never let anyone define what you are capable of by using parameters that don’t apply to you.”*
>
> — Chuck Close, artist, 1940–

The business structure of the BRT system should do what it can to ensure long-term high-quality service to its customers. BRT systems are vulnerable to being used for political purposes, other than providing high-quality service to their customers. A profitable system might see its resources reallocated to other purposes. Procurement decisions can be made for political rather than technical reasons. Even the exclusive use of the road right-of-way is vulnerable to being revoked by new political administrations. A good business structure backed by enforceable contracts can play a critical role in protecting good quality BRT service over the long term.

Because BRT usually aims to create a “market,” the business model for the BRT system as a whole must be developed, and this business case has to be built up from the business case of the separate components of the system: the trunk operations, feeder bus operations, fare systems, and possibly security services as well. The development of the system's business model will require some initial analysis of projected operating costs and projected revenues. This analysis will help identify the conditions in which operating companies can reach profitable (and thus sustainable) revenue levels. The calculation of operating costs and projected revenues will also allow initial estimates of the fare levels that will allow the system to cover its operating costs.

One of the key purposes of the business plan for the system as a whole will be to estimate the overall profitability of the system. Knowing how profitable the planned BRT system will be in advance is a critical first step in defining which elements of the system can be financed in a sustainable manner from the fare box revenue, and which elements of the system need to be paid for by other investment.

The operational costs of the BRT system as a whole are potentially composed of the following components:

- Payment to trunk operators;
- Payment to feeder operators;
- Payment to the BRT public authority;
- Payment to fare collection operator;
- Payments to trust fund manager;
- Credit reimbursements.

These components are illustrated in Figure 15.8.

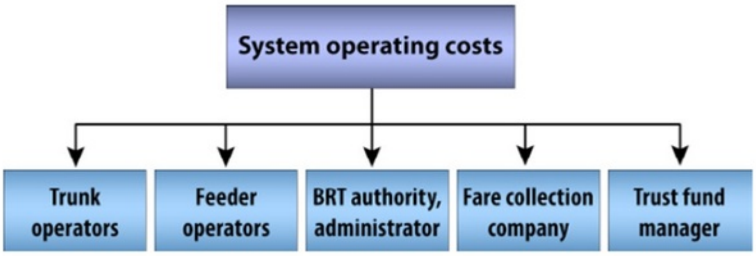

Figure 15.8. Distribution of operating costs among the principal cost centers. *ITDP.*

15.2.1 Trunk Operator Remuneration

From the point of view of the system as a whole, the cost of vehicle operations on the trunk lines depends on the contractually determined rate that the BRT authority has agreed to pay the vehicle operator per kilometer, multiplied by the projected total annual kilometers of operations that are programmed. This relationship is outlined by the following equation:

Eq. 15.2: Payment to trunk operators:

$$\text{Pay}_{\text{Trunk Operators}} = \text{Distance}_{\text{Daily}} * \text{Fleet} * (\text{cost}_{\text{Operating}} + ROI)$$

Where:

- $\text{Pay}_{\text{Trunk Operators}}$: Total payments to trunk operators;
- $\text{Distance}_{\text{Daily}}$: Projected needed daily vehicle kilometers;
- Fleet: Projected total number of vehicles;
- $\text{cost}_{\text{Operating}}$: Estimated operating cost per kilometer;
- ROI: Return on investment.

15.2.2 Feeder Operator Remuneration

Similarly, from the point of view of the feeder operators, the operational cost will simply be the amount that the BRT authority has contractually agreed to pay the feeder operators per kilometer (or per customer, whatever the contract stipulates), multiplied by the total projected customers or kilometers provided by the planning of the system.

Both for feeder and trunk operators, the revenue they receive should be enough to cover operational expenses plus the return on investment markup (Table 15.2).

Table 15.2. Trunk and Feeder Services Cost Breakdown.

Cost item	Trunk services	Feeder services
Fuel	24.6%	17.3%
Tires	4.7%	5.2%
Lubricants	1.5%	1.7%
Maintenance	9.0%	10.8%
Wages	14.7%	29.2%
Station services	0.0%	2.6%
Other fixed costs	45.5%	33.2%
Total	**100.0%**	**100.0%**

Source: TransMilenio SA.

15.2.3 Fare Collector Operator Remuneration

Payment to the fare collection company will similarly be determined by whatever payment was negotiated at the outset. In the Bogotá system, for example, a percentage of the fare collection is paid to the Fare Collector Operator. This operator may also provide additional services such as Fleet Management or Passenger Information Services, and must also be remunerated for them. For TransMilenio Phase III, the Fare Collector Operator is paid for the additional services based on a fixed amount for installed equipment both onboard and in-station.

15.2.4 BRT Authority Remuneration

The administrative expenses of the BRT authority are principally the cost of salaries for the staff. Whether the operating costs of the BRT authority is paid from the fare revenues depends on how the business plan is initially organized. In some cases, the system administration may be simply part of the transport authority's general budget. As with vehicles and other components, the viability of including administrative costs as part of the revenue distribution depends on the expected system profitability and the targeted customer fare level.

15.2.5 Trust Fund Manager Remuneration

The trust fund manager is an independent entity that receives the revenues collected from the fare collection company. The trust fund manager is then responsible for distributing the revenues to each party based on the prior contractual agreements. In many cases, the trust fund manager is a bank or other trusted financial institution. The trust fund manager receives a fixed percentage of the total income of the system for providing these services. Figure 15.9 shows a summary of a BRT's operational income sources and costs.

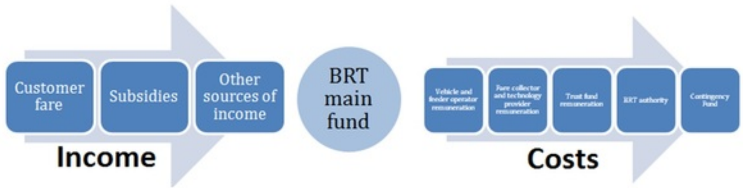

Figure 15.9. Summary of a BRT system's operational income sources and costs. *ITDP.*

15.3 Technical Fare and Customer Fare

"But surely for everything you have to love you have to pay some price."

— Agatha Christie, writer, 1890–1976

15.3.1 Calculating the Technical Fare

The total revenues distributed to the various contracted parties are based on the amounts collected from the system's "technical fare." The technical fare is equivalent to a flat fare that the system would be required to charge in order to break even. By contrast, the "customer fare" refers to the fare paid by the users of the system. As will be discussed in this section, the technical fare and customer fare are likely to be slightly different values.

The technical fare represents the actual cost per customer of providing the service. It is the basis for the subsequent distribution of revenues to the operators. It is calculated by simply adding up the full estimated operational costs calculated for the trunk operators, the feeder bus operators, the fare collection company, the trust fund manager, and the administration costs of the BRT authority (if the BRT authority costs are to be included). These operational costs include both the ongoing operational costs and any operational investments that will be the financial responsibility of the private investors, including the depreciation of the vehicle value and financing charges. The following equation summarizes this basic relationship.

Eq. 15.3 Basic form of technical fare calculation:

$$\text{Technical fare} = \frac{\text{cost}_{\text{operational}}}{\text{Customers}_{\text{Daily}}}$$

Where:

- $\text{cost}_{\text{operational}}$: Total BRT system daily operational costs;
- $\text{Customers}_{\text{Daily}}$: Total projected daily customers.

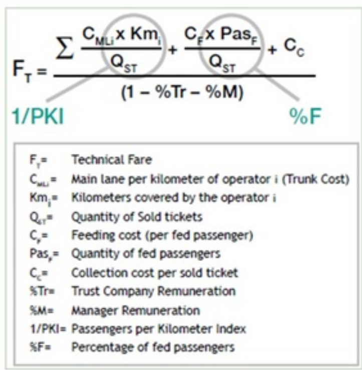

Figure 15.10. Detailed form of technical fare calculation; passengers per kilometer index. *TransMilenio SA.*

Figure 15.10 provides a more detailed and expanded calculation of the technical fare.

The contracts for the private operating companies are likely to be nonuniform. Some companies will invest only in ninety vehicles, while others will invest in more. In the case of TransMilenio, it was decided that there would be four trunk operating companies in the first phase. The number of vehicles purchased by the four different companies was: (1) 150 vehicles; (2) 120 vehicles; (3) 100 vehicles; and, (4) 90 vehicles. System planners estimated, based on projected demand, that each vehicle would operate roughly 247 kilometers per day, and they used this estimate as the basis of the calculation of the technical fare. Contractually, however, the operators were not guaranteed any minimum number of vehicle kilometers per day, or they would not have been exposed to any demand risk. Rather, they were guaranteed 850,000 vehicle kilometers within a 15-year period.

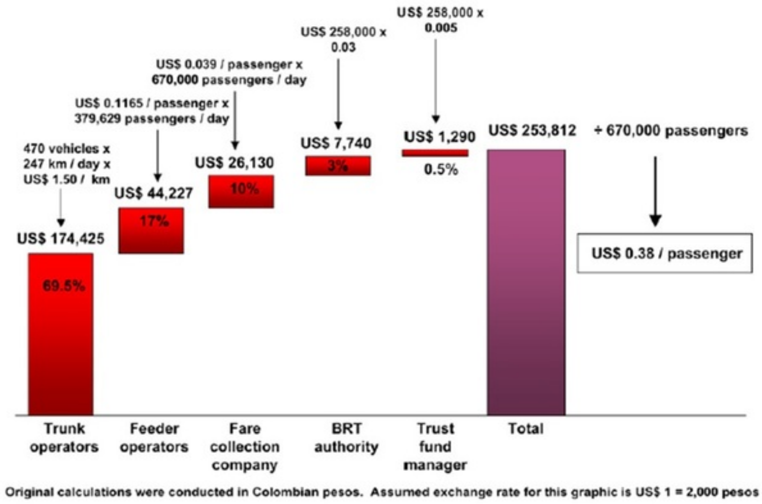

Figure 15.11. Calculation of technical fare for Phase I for TransMilenio. *TransMilenio SA.*

Because the operator is paid per vehicle kilometer, this meant that the cost of trunk operations to TransMilenio was the total number of vehicles times the total number of vehicle kilometers. The actual formula to calculate the technical fare is depicted in Figure 15.11.

The example given in 15.11 is specific to the first phase of the Bogotá TransMilenio system. Each system will have its own cost structure based on the amount of the service that is provided by the trunk line vehicles vis-à-vis the feeder vehicles, the fare collection costs, the negotiated service rates of each component, and the cost of administration. In the case of TransMilenio's Phase I, 69 percent of the cost of operating the entire system resulted from payments to the trunk line operators, but this will be different for each system. This value also changed with the addition of the Phase II corridors in Bogotá.

The technical fare, calculated on a cost-plus basis from the overall operating costs of the system, is the basis for the distribution of fare revenues. In other words, each component of the TransMilenio system was promised a fixed percentage of the total fare revenues based on the calculation of the technical fare. In this way, these companies became shareholders with a collective stake in maintaining ridership.

15.3.2 Adjusting the Technical Fare

An operator concession agreement will typically be in the range of ten years, the estimated life of a vehicle, though it could be shorter if the vehicles can easily be resold. During that period, many of the input costs can change (e.g., fuel costs, labor costs, etc.). Since the concession agreements stipulate that revenues are paid based on the vehicle kilometers travelled, both the BRT authority and the operators must be protected against dramatic changes in input cost levels.

The technical fare goes through a process of modification depending on cost swings in both system inputs and operational factors. Fuel price volatility is one of the most significant risks. Spare parts that need to be imported will be subject to currency risk, a major factor in some countries. Base labor costs will vary in step with the local economy. Accurately predicting these cost levels over a long period is a nearly impossible task due to the great number of external influences. Thus, as base cost conditions change for the operators, the technical fare will go through adjustments.

Table 15.3. Factors Affecting Changes in the Technical Fare

Category	Cost item
System inputs	Diesel price;; Consumer price index; Minimum wage standard;Producer price indexes (lubricants, tires, maintenance).
Operational factors	Passenger per kilometer index (PKI); Percentage of passengers using feeder services.

On a periodic basis, such as every two weeks, the technical fare is updated based on the changes in the base factors. The calculation for the changes in the technical fare is given in Equation 15.4.

Eq. 15.4 Calculating changes in the technical fare:

$$\Delta F_T = \%C_{ML}\frac{\Delta C_{ML}}{\Delta PKI} + \%C_F(\Delta C_F + \Delta\%F) + \%C_C\Delta C_C - 1$$

Where:

- ΔF_T: Change in the technical fare;
- $\%C_{ML}$: Proportion of the main lane cost (%);
- ΔC_{ML}: Change in the cost per kilometer (main lane);
- ΔPKI: Change in the passengers per kilometer (main lane);
- $\%C_F$: Proportion of the feeder cost;
- ΔC_F: Change in the feeder remuneration, by passenger that use feeding services;
- $\Delta\%F$: Change in the percentage of passengers that use feeding services;
- $\%C_C$: Proportion of the collection cost;
- ΔC_C: Change in the collection cost.

15.3.3 Customer Fare and Contingency Fund

As noted above, the “customer fare” is the payment required by the customer for a single trip on the system. Unfortunately, costs tend to rise over time, implying that fares must also rise. For reasons of customer clarity, as well as political considerations, the fare paid by the customer should not be changed frequently, perhaps no more than once or twice per year. Customers would be quite confused and angry if the fare changed every time world fuel prices changed. Further, raising customer fares can have a range of social equity impacts that must always be considered. If a public transport company needs to obtain political approval for each fare increase, then the adjustments may never happen. In turn, the entire system will eventually become financially untenable.

To overcome such an inherent stalemate, the system for fare adjustments should be relatively automatic in nature, based on contractual obligations linked to key trigger points. TransMilenio has worked out a mechanism for adjusting the fare automatically to such changes. In the case of Bogotá, all operating costs are calculated on a biweekly basis. If a particular trigger point is reached, such as the technical fare exceeding the customer fare, then a fare adjustment is authorized by the municipality. The mayor and other political officials are still involved in the authorization through the public company's board of directors, but the stipulation of a fare adjustment is reached through the operating cost calculation.

However, at the same time, some political discretion is required. As noted, fare level changes should not be frequent events. Also, it is probably sensible to establish fare levels that are round numbers in order to coincide with denominations of the local currency. For example, a fare of US$0.375 is not a possibility. Further, a fare level that requires handling many small coins means that both fare collection and fiduciary handling of the revenues will be slowed down. This inefficiency will in effect increase costs even more. Thus, fare levels should only increase at prescribed trigger points, and the increase should be significant enough so that no further increases will be likely over the short term. A fare adjustment system should be ideally designed so that increases do not occur more than once or twice per year.

If unusual events occur (e.g., hyperinflation) that require frequent adjustments, a contingency fund should be in place to bridge revenue shortfalls. The contingency fund thus provides a buffer that allows the system management company to stabilize fare levels even in turbulent times. It is this need for some buffer against unexpected contingencies that led to the development of a contingency fund in the case of TransMilenio. The difference between the technical fare in Bogotá and the customer fare is simply that an additional charge has been created to pay into a contingency fund (Equation 15.5).

Eq. 15.5 Relationship between customer fare, technical fare, and contingency fund:

$$\text{Customer fare} = \text{Technical fare} + \text{Contingency fund payment}$$

Figure 15.12 graphically illustrates the relationship between the customer fare and the technical fare. In general, the customer fare should be slightly greater than the technical fare, and this difference is deposited into the contingency fund.

The contingency fund is designed to handle unexpected events such as unusual low levels of service demand, extended hours of operation, terrorism and vandalism, and problems associated with hyperinflation. In general, the customer fare will be greater than the technical fare, and thus the contingency fund will build up a positive balance. When unforeseen circumstances occur and the technical fare exceeds the customer fare, then proceeds from the contingency fund will be drawn upon for a temporary period. The contingency fund effectively acts as a safety net in times of unusual cost fluctuations. As the contingency fund becomes exhausted, the board of directors of the system will have to act in order to avoid a financial crisis.

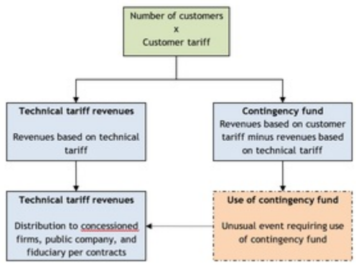

Figure 15.12. Understanding customer tariffs and technical tariffs. *ITDP*

The standard remedy would be to raise the customer fare to a point securely above the technical fare. The operation of the contingency fund provides a level of security and confidence to the operators as well as any outside funding entities to the system.

Figure 15.13 tracks the technical fare and the customer fare in the TransMilenio system. As expected, the customer fare is generally greater than the technical fare. As the technical fare has increased with time, the customer fare has also increased in order to maintain a comfortable margin. The graphic also demonstrates the difference in fluctuations between each fare type. The customer fare only increases in discrete amounts since these represent points of actual fare increases to the customer. By contrast, the technical fare will likely vary to some degree each month, as the constituent cost categories will change with economic conditions and input prices.

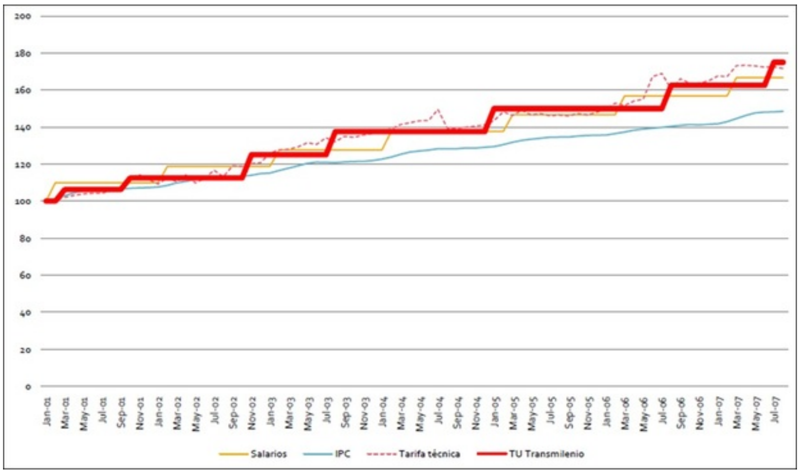

Figure 15.13. Changes in the customer (red) and technical (dotted) fares for the TransMilenio system. *TransMilenio SA.*

15.3.4 Fare Elasticity

In general, elasticity is the degree to which a demand or supply curve reacts to a change in price. Elasticity is not a fixed value, and it varies among products and services depending on how essential they are to the customer. Products and services that are essential are less sensitive to price modifications because customers would continue buying these products despite price increases. Products that are not essential are more sensitive to price modifications; if the price rose too much, people would stop buying or consuming these products.

When it comes to transport planning, elasticities have several applications. They can be utilized to estimate the ridership and revenue effects of changes in public transport fares. They are also used in modelling to estimate how changes in public transport service will affect the vehicle traffic volume. And finally, they can be useful when evaluating the benefits and impacts of mobility management strategies such as new public transport services, road tolls, and parking fees, among others.

Some of the factors that affect public transport elasticities are summarized below:

- Trip Type: Non-commute trips tend to be more dependable on price changes than other kind of trips such as commute trips. Elasticities for off-peak public transport travel are typically 1.5 to 2 times higher than peak intervals elasticities. This is because peak-period travel largely consists of commute trips;
- User Type: Public transport-dependent riders are generally slightly less price sensitive than choice or discretionary riders (these are the people who own a car and can use it for that trip). Some demographic groups, including nondrivers, people with low incomes, people with disabilities, high school and college students, and elderly people are more likely to be more public transport dependent. Generally, public transport-dependent people are a relatively small part of the total population but a large portion of public transport users, while discretionary riders are a potentially large but more price elastic public transport market segment;

- Geography: Unlike suburbs and smaller cities, large cities tend to have lower price elasticities, because they have a greater portion of public transport-dependent users. This is due to increased traffic congestion and parking costs, and improved public transport service due to economies of scale.

Phil Goodwin, in the document "A Review of New Demand Elasticities with Special Reference to Short and Long Run Effects of Price Changes," produced the average elasticity values summarized in Table 15.4. He noted that price impacts tend to increase over time as consumers have more options (related to increases in real incomes, automobile ownership, and now telecommunications that can substitute for physical travel). In 2006, Peter Nelson, Andrew Baglino, Winston Harrington, Elena Safirova, and Abram Lipman found similar values in their analysis of Washington, D.C., public transport demand.

Table 15.4. Transportation Elasticities

	Short-Run	Long-Run	Not Defined
Bus demand WRT fare cost	-0.28	-0.55	
Railway demand WRT fare cost	-0.65	-1.08	
Public transport WRT petrol price			0.34
Car ownership WRT general public transport costs			0.1 to 0.3
Petrol consumption WRT petrol price	-0.27	-0.71	-0.53
Traffic levels WRT petrol price	-0.16	-0.33	

Source: Todd Litman, Victoria Transport Policy Institute.

One key thing to keep in mind is that no single public transport elasticity value applies in all situations. Various factors affect price sensitivities, including type of user and trip, geographic conditions, and time period. Available evidence suggests that the elasticity of public transport ridership with respect to fares is usually in the −0.2 to −0.5 range in the short run (first year), and increases to −0.6 to −0.9 over the long run (five to ten years). These are mostly affected by the following factors:

- Public transport price elasticities are higher for discretionary riders than for dependent riders;
- Elasticity values are about twice as high for off-peak and leisure travel as for peak and commute travel;
- Cross-elasticities between public transport and automobile travel are relatively low in the short run (0.05), but increase over the long run (probably to 0.3 and perhaps as high as 0.4);
- Due to variability and uncertainty, it is preferable to use ranges rather than point values for elasticity analysis;
- A relatively large fare reduction is generally needed to attract motorists to public transport, since they are discretionary riders. Such travelers may be more responsive to service quality (speed, frequency, and comfort), and higher automobile operating costs through road or parking pricing.

15.3.5 Adjusting the Technical Fare

Whenever the BRT authority finds that the technical fare is too different from the expected fare (taking into account the different objectives of the system), the BRT authority can take the following actions in order to adjust the technical fare:

- Operational or logistical adjustments in the system;
- Reduction in operational expenditures. This means reductions in any of the items included in the technical fare shown in Section 15.3.1: Calculating the Technical Fare;

- Reduction of the level of service (pax/m2). This should be taken carefully since this could affect in a negative way the reputation of the system;
- Subsidies for Capex and/or Opex. In this point it is strongly recommended that the BRT authority chooses a subsidy that covers the Capex rather than an Opex one, so that the system does not have to incur in a monthly dependency from the subsidy to operate.

As has been suggested, setting the fare level requires analyzing two different values:

- The technical fare, or the fare needed for full cost recovery;
- The optimal customer fare, or the fare that maximizes the system's profits.

Ideally, the business and operational model of the BRT system should bring the technical fare as close to the optimal customer fare as possible.

16. Informal Transit Transition to BRT

"If you don't create change, change will create you."

— Anonymous

Many of the best BRT systems in lower-income economy systems emerged out of weakly regulated and informal sector-dominated private transport services. In several of these cities, the introduction of a BRT system was simultaneously used to bring about a transition of the affected part of the informal transit industry from individual informal operators to modern competitive companies operating under contract to the governmental BRT authority. This chapter is intended for cities wishing to implement BRT systems on corridors currently dominated by such informal private operators. As such, it is primarily of interest to the cities of emerging economies.

The level of government regulation of informal public transport varies widely. At one extreme, there are cities where the operators of minibuses may not even have a driver's license or basic insurance. More typically, a municipal department of transportation issues a commercial operating license to the driver, and another license giving them the right to operate on a specific route or in a specific zone. However, it is often the case that there is no roadworthiness testing, and the operators are individual owner operators who lack basic business practices, rarely pay taxes, lack insurance, and repair their vehicles on the roadside.

Inevitably, in a weak regulatory environment, informal types of regulation end up allocating the best routes and access to bus terminals and minibus waiting areas or "taxi ranks." Sometimes these informal regulators are known as "bus enterprises." Other times they are known as "unions" or else "associations" or "cooperatives." Sometimes these regulators own the vehicles, sometimes only the route licenses, and sometimes they do not own anything. Often the owners of the vehicles, the controllers of the licenses, or those that control access to terminals and taxi ranks are not easily discovered. Often, they are well-placed politicians, police officers or military personnel, or other people in the government using the industry as a form of savings for their retirement. In South Africa, rival gangs of operators have used firearms against each other to establish control over certain routes, leading to customer injuries and even death. Many people, both rich and poor, are likely to be affected by changes in the public transport services industry that are inevitably brought about by the introduction of a new BRT system, so it is critical to a project's success to understand as much as possible about how the existing industry works.

Figure 16.1. The plethora of many small vehicles providing public transport services in cities such as Manila translates into significant system inefficiencies. *Lloyd Wright.*

Informal public transport services have certain benefits. They require no government operating or capital subsidies, and they tend to be reasonably responsive to changes in demand, opening new routes as needed.

On the other hand, they have some well-known issues. Private informal operators tend to undersupply service during off-peak periods and to neighborhoods with lower demand, while oversupplying services on major arterials during peak hours. The public transport market is frequently divided into zones of control that make it impossible for a single operator to service a route that passes through multiple zones, forcing needless transfers and increasing customer costs. The services rarely follow a schedule, waiting instead until their vehicles are full before departing, and refusing to pick up additional customers once full. This makes services unpredictable. They often compete at the curb for customers, leading to a dangerous pedestrian environment. Small individual operators are also often not able to achieve returns to scale from operating large vehicles and from maintaining a single large fleet of the same vehicle. The informal nature of their operations sometimes means that the drivers operate without insurance, and sometimes even without a driver's license, making it hard to enforce traffic violations.

Figure 16.2. Prior to the development of the TransMilenio BRT system, Bogotá's public transport services were of a chaotic and low-quality nature. *Lloyd Wright.*

Informal public transport operations also face pros and cons as businesses. Their financial sustainability is often a function of the fact that they do not pay corporate taxes; they do not pay full payroll taxation or social security benefits for their employees; they do not pay for insurance; or they do not pay for many of the basic administrative functions such as formalized accounting that formal businesses face. On the other hand, informality creates a low profit margin trap. Profits tend to be highly risky. If a driver becomes ill, or a vehicle breaks down, the business earns nothing. Profits are encroached upon by insufficiently regulated access to the market by new market entrants. As a high-risk business, attracting finance for vehicles or spare part procurement tends to be difficult, forcing these informal businesses to rely either on cash or informal credit markets with very high real interest rates. As such, informal public transport is generally a risky and low profit margin business.

In some instances, each vehicle is owned separately, often by the person who does the driving. In other instances, the bus owner employs a driver who pays for fuel and gives the owner a daily "target" amount, and keeps the balance of the fare revenue. In others, the public transport vehicle is operated by a driver who leases the vehicle from the owner. Where the driver pays a flat fee for access to the vehicle, he or she then has an incentive to drive the vehicle as much as possible during the day in order to maximize fare revenues. Usually these drivers have to pay some sort of mafia for the right to operate a particular route, and sometimes they have to pay off one or more sets of traffic police. Drivers will thus work as much as sixteen-hour days. Often these vehicles are not insured, and if the customers are injured they have little recourse in the courts.

When the income of vehicle drivers is directly related to the number of customers they pick up, several problematic behaviors emerge as a result of the "battle for the cent." The drivers have an incentive to drive as rapidly as possible to make as many round trips as they can. Further, drivers will cut off other vehicle operators in order to prevent competitors from capturing customers. Vehicle drivers will also sometimes stop at random places along the road rather than just at bus stops, in order to capture more customers. Often, they will wait at the beginning of a route until the vehicle fills completely, making the scheduling of trips very unpredictable.

Not surprisingly, the long hours, high speeds, and aggressive driving lead to extremely hazardous road safety conditions. At the same time, the captive riders have few options other than to wait for the day that they can purchase their own private vehicle.

Figure 16.3. Control of routes within the South African minibus taxi industry has at times meant armed violence among different operators. *Lloyd Wright.*

In the process of introducing BRT projects, there has generally been an effort to make these traditional existing operators part of the new system. The approach has been to encourage them to consolidate into corporate entities that can form partnerships with others and enter into contractual arrangements with the BRT authority. The process of consolidating the thousands of registered and unregistered small operators into a modern BRT system took several decades in Curitiba. In Bogotá, the transition was made all at once with the construction of the BRT system. For a history of the transformation processes in Bogotá and Curitiba, see *Transit Planning in Curitiba and Bogotá: Roles in Interaction, Risk, and Change* by Arturo Ardila-Gómez (Ardila-Gómez, 2004). This transition has taken a variety of paths in different countries, with different outcomes. This chapter provides guidance to BRT project managers.

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16.1 Balancing BRT Project Implementation and System Regulation

> *"Everything has boundaries. The same holds true with thought. You shouldn't fear boundaries, but you should not be afraid of destroying them. That's what is most important if you want to be free: respect for and exasperation with boundaries."*
>
> — Haruki Murakami, novelist, 1949–

In many lower-income cities that are considering BRT, decision makers struggle with the dual priorities of improving the regulation of the existing bus and minibus system and the development of a new BRT system. Often there is a desire to shift from route licenses to more formal operating contracts between the city and corporate bus service providers throughout the city, and there is also a desire to develop a high-quality BRT on just one corridor. Mayors often want to do both at once because of a common political imperative: if services for one group of users are to be radically improved, what is going to be done for everyone else that is still facing poor-quality services? As a government administrator or consultant, this frequently means being asked to respond to two enormous administrative challenges at the same time, frequently an impossible task.

The reason the two issues sometimes become related is that BRT historically has created an opportunity to renegotiate the city's relationship with its private bus operators. The city has a new "carrot," namely access to the new BRT infrastructure, which increases operator profits. Skilled administrators have used this "carrot" to force entrenched operators to consolidate and form modern, accountable companies, as well as to purchase new vehicles, sign operating contracts with quality of service provisions, and make other contractual concessions. If the administrator is lucky enough to succeed in renegotiating operating contracts on a BRT corridor, the political leadership frequently would like to extend these contractual forms to the rest of the public transport system, but without providing any additional leverage to their administrators.

As such, many of the most successful BRT systems have separated these two reforms. Curitiba changed the regulatory structure of bus operations throughout the entire city in 1962, forcing 321 separate private informal bus companies to consolidate themselves into ten consortia that had control over different parts of the city. Only in 1974, when the system was already better regulated, did they build the BRT system on one corridor.

In Bogotá, the mayor made a critical decision not to reform the entire public transport regulatory structure at the same time as implementing TransMilenio, and instead decided to regulate it step-by-step, one BRT corridor at a time. In other words, the corridors not yet slated for BRT were left with informal operators under the regulatory control of the Department of Transportation, while the new corridors were put entirely under the regulatory control of TransMilenio SA, the BRT authority. TransMilenio banned the old vehicles from operating directly on the BRT corridors, and this ban was enforced with police powers. TransMilenio SA later tried to implement the SPTN, a system-wide reform, which attempted to change the operating contracts for the remainder of municipal bus services to mimic the TransMilenio contracts. Without the new BRT infrastructure as leverage, however, most of the entrenched operators complained that their services were not sufficiently profitable to procure new vehicles and improve the quality of service, and as a result only a few of the non-BRT routes switched to new quality of service contracts.

Because both transitions require a dramatic increase in the capacity of governmental bodies, tough negotiations, skilled staff, and political capital, it is generally too much for a single mayor and his or her staff to do both at once. In fact, one of the key purposes of BRT is to gradually break down regulatory logjams.

On the other hand, the political will for urban public transport reform is rarely summoned by a politician, and from a political perspective as many reforms should be implemented as possible during a political window of opportunity. Subsequent mayors may be less inclined to continue the reform process. There is some advantage to going through the painful process of system conversion once rather than through several difficult transitions.

Notable examples of citywide reorganizations done while implementing BRT systems include Seoul, São Paulo, and Santiago. All of them faced significant administrative difficulties initially, but later stabilized the systems. All of them only achieved “bronze” ratings or lower in the *BRT Standard*.

The Seoul Metropolitan Government introduced basic BRT corridors into the city on July 1, 2004. At the same time, it completely reorganized all bus services, improved coordination between bus services and its extensive metro services, and introduced a new fare system and fare structure that integrated routes and modes. It greatly increased public control of the bus services (Pucher, et al., 2005). The reforms were a response to the financial pressures arising from rapid expansion of its metro network (a system of 487 kilometers carrying 8.4 million customers a day in 2004). The city was seeking to rely more extensively on lower cost bus services to both improve their speed and quality and increase public sector control over them. For decades, bus services in Seoul had been operated by a large number of private firms with virtually no government control over routes or schedules (although they received operating subsidies). They drove recklessly to chase customers and many of their four hundred routes duplicated each other, and were not adequately integrated with each other or with the metro services.

The reforms in 2004 driven by the new mayor, Myung-Bak Lee, involved an entire redesign of the bus network. Four types of color-coded service were introduced, along with a GPS-based new bus management system, and a central bus control center. The private bus companies were retained, but put onto a vehicle kilometer-based payment system, instead of payment by customer trips. In addition, 36 kilometers of BRT median busways were built spanning four different corridors. A multipurpose, stored-value smart card (T-money) was introduced at the same time for use on all bus and rail services, allowing free transfers between trip segments (Pucher, et al., 2005). Tremendous disruption and confusion accompanied the first weeks of the implementation, and high levels of dissatisfaction among customers ensued. The BRT corridors were overcrowded, there were significant teething problems introducing the new fare system, and services were poor initially. Over time, however, these problems were corrected, and the reforms were ultimately successful. Within four months almost 90 percent of Seoul residents were expressing general satisfaction with the restructured bus services and new fare system (Pucher, et al., 2005, p. 57).

São Paulo introduced a system-wide total reorganization and improvement of its extensive bus network in a phased way between 2002 and 2005, known as the *Interligado* project. The reforms were a mixed success. Most successful was the introduction of free transfers between bus routes, made possible by a new smart card. This led to a huge increase in ridership: 136 percent increase in the number of bus users (Custodio, et al., 2007) as well as an increase in public transport modal share between 2002 and 2007 from 47 percent to 55 percent (Embarq, 2009), but it also increased the amount of subsidies the municipality had to pay to bus operators.

The Passa Rapido corridors (which do not qualify as BRT but have many BRT elements) were more of a mixed success. BRT corridors with bilateral stations were reconstructed with single central median platforms. They did not have at-level boarding or off-board fare collection, and some stations were built too close to intersections. Taxis were also allowed to enter the bus lanes, which caused problems at intersections as vehicles were unable to reach the station. As a result, in a few locations large bus queues resulted.

Figure 16.4. São Paulo’s Passa Rapido corridors had severe station saturation problems until reconstructed. *BRT Planning International, LLC.*

There were also changes to the bidding and contracting process. São Paulo has had zone-based contracts since 1991, but more of the routes were restructured into trunk-and-feeder services. The operators were also required to compete to win their operating contracts rather than being allowed to maintain control over their customary zones. Though in the end, all zones ended up under the vehicle operating companies that had controlled the zone by custom, they were compelled to at least buy new vehicles and sign operating contracts with the municipality. They also started to regulate some of the local minibus services. The silver-rated Espresso Tiradentes was only implemented later, under the Serra administration, on the advice of Jaime Lerner, the former mayor of Curitiba.

The Transantiago system of Santiago, Chile, undertook a whole system transformation in which some parts operated on busways and other parts operated as conventional services. Since Santiago is a megacity of six million, transforming its entire public transport system at one time was not an insignificant task. Contracts were restructured and routes were changed significantly, often without careful consideration of existing travel patterns. The result was initial confusion and operational problems, with decidedly negative reviews in both the national and international press (*Economist*, 2007). However, many of the mistakes were corrected over time. Integrated operations are now working at acceptable quality levels after several structural changes and the introduction of operational subsidies, so the outlook is now positive (Hidalgo and Gutiérrez, 2013).

While it is not impossible that some municipality will develop a gold standard BRT and simultaneously transform bus regulation in the rest of the city, the prevailing wisdom is to try to achieve either one or the other, or risk not doing either particularly well.

Figure 16.5. The citywide transformation of the Santiago public transport system created a great deal of chaos and customer confusion during its initial periods. *Lloyd Wright.*

16.2 Developing an Industry Transition Strategy

"Life is one big transition."

— Willie Stargell, professional baseball player, 1940–2001

In most cases, a new BRT project is going to have a significant impact on any existing transit businesses in the same area. The public authority managing the BRT project will need to have sufficient control over any existing public transport service providers to bring new BRT services onto the corridor. In most cases, BRT systems are operated by private vehicle operating companies (VOC) under contract to a BRT authority or other government body. This VOC may be a consortium composed of some or all of the existing owners, or a VOC may be an outside company that wins a competitive tender. In many situations, BRT projects have devoted considerable resources and effort to transforming the existing informal or traditional operators for new roles in the BRT system, such as shareholders in the consortia or companies running the BRT services. This is what is referred to in this chapter as "Industry Transition."

Normally, for political purposes, it is advisable to involve at least some of the existing bus and paratransit operators with routes in the corridor in the new system. How they are included, however, matters critically. On the one hand, if they are not included at all, they will resist the system politically. On the other hand, they should not be given veto power over design decisions or contracting decisions to the point where the cost of the system becomes unsustainable or the quality of service is compromised.

Ultimately, the role of the BRT project team is to get the best deal for the public from private operators that they can. As such, the process is ultimately a *negotiation*. Negotiating effective contracts for the public is a skill that is not something most transportation professionals have been trained in. As such, it is generally a good idea to bring in an experienced labor negotiator and legal counsel with experience in negotiating public sector contracts.

16.2.1 Objectives of Industry Transition Process

BRT projects in lower-income cities will have a profound impact on the owners and employees of affected existing public transport services. Where the transition process is handled successfully, the following goal can be achieved:

- The BRT operating companies are formed primarily out of the old informal owners and their staff, but in partnership with other vehicle operating companies that have the investment and skills needed. They are able to win a competitive tender and create internationally competitive, well-managed new companies that provide a high quality of service for many years. They procure and hire locally, developing into strong new local businesses with significant economic development and community revitalization benefits both upstream and downstream.

There are two worst-case scenarios to be *avoided*:

- A single monopoly private company with little bus operating experience is brought in from the outside. This firm does nothing to involve the existing affected industry, antagonizing local vested interests. The local affected industry resorts to violence to stop the project. The project is delayed for years, finally implemented with the help of massive police power, and the service is poor, with few upstream or downstream economic benefits to the city.
- The affected industry takes control of the new BRT services. They never form a real company, and remain an informal collective without integrated fleet ownership and management. Despite the government paying this incompletely formed company significantly more than the service costs to operate, in a few years, vehicles procured for them by the government fall apart for lack of maintenance, and the quality of service is so bad that finally services are suspended.

Both of these scenarios are not in anybody's interest. Ideally, the transition process should achieve all of the following objectives (ITDP, 2009) listed below.

- *Avoid violence*: In some countries, the threat of violence is remote; in others, it is very real. In some countries, elements of existing informal regulatory structures involve the threat and use of violence. These industry actors may be neither owners nor drivers. While every effort needs to be made to include as many affected industry actors in the new system as possible, it may not be desirable to include rogue or criminal elements in the new system. Avoiding violence from destroying a project requires a clear strategy to involve key affected actors, but also to be prepared to use police powers when necessary.
- *Maximize quality of service:* The success of the system is determined by the quality of the service provided to public transport customers. Defending and protecting the quality of service is the highest priority after avoiding violence.
- *Minimize service costs:* For BRT operating companies, profits are most often realized through a set fee per kilometer, which must be paid by the government, and is often reflected in the fare. A successful transition will allow operating companies to be profitable but through minimal costs to the government over the long term.
- *Maximize investment:* In order to minimize the burden on the government of providing BRT services, investment from BRT operating companies, normally into the vehicle procurement, should be maximized over the long term.
- *Create robust companies:* The transition process should result in well-managed, well-governed, sufficiently capitalized, internationally competitive, and profitable companies.
- *Involve impacted operators:* In order to ensure that the existing industry is involved and is being provided with improved opportunities, every effort should be made to involve as many as possible of the impacted former paratransit operators in the new companies, both as shareholders and as employees.
- *Improve working conditions:* As BRT provides an opportunity to create jobs and formalize working environments, one objective of a transition should be to expand employment and improve the conditions of the labor force.

16.2.2 The Industry Transition Process and Public Policy

Since there are many sometimes conflicting public policy objectives at stake when a new BRT system is implemented, it is a significant help to the project team if the government can provide clear policy guidance, particularly with respect to the industry transition. There have been many BRT projects where a policy vacuum has left public administrators unsure of which course to pursue. Ideally, the priorities of the transition should be written down by the government body responsible for implementing the BRT project so that project administrators have clear policy guidance to follow.

As a first step, the policy or strategy adopted will need to be aligned with the prevailing public transport strategies and policies that have already been determined at various spheres of government. Many BRT system implementations and the associated system reorganization or reregulation have required new laws or regulations to be introduced. It is therefore prudent to begin the creation of a transition strategy with a review of all relevant existing government policies.

There is likely to be extensive existing policy regarding the extent and manner that public transport operations can be or must be competitively tendered and contracted out to private operators. For instance, a new law at the end of 1990 in Chile allowed the new government to franchise public transport services through a tender process. South Africa's National Land Transport Act of 2009 included a section enabling contracts to be negotiated under a much wider set of circumstances than allowed in the previous act, specifically to advance the new BRT projects launched in the country starting in late 2006. Also in South Africa, a new Public Transport Strategy approved by the national cabinet in 2007 and an accompanying Action Plan, proposed far-reaching reform of the public transport systems in major cities, featuring gross cost contracts rather than the previous net-based contracts. It also proposed the incorporation of informal minibus-taxi operators into contracts through negotiation, to operate rapid transit system contracts.

If the project is funded by a donor agency or a development bank, then the policies, goals, and procurement rules of that donor agency may also apply and need to be taken into consideration. Most likely to have an impact on the project are procurement rules, environmental review, and resettlement rules and procedures. Development banks have become very sensitive to resettlement issues, and generally require greater compensation and community outreach than is required under national legislation.

There are many other areas where policy guidance is generally absent, but where clearer policy guidance from the political leadership will be helpful in forming the transition strategy. Most important is to first determine the following:

- Which routes and license holders are "impacted" by the planned BRT services, and to what degree?
- Are impacted owners of licenses and vehicles legally due any compensation, and if so, what?
- If not, will impacted owners of licenses and/or vehicles be given any form of redress because they are impacted anyway?
- Will any other public transport industry employees impacted by the BRT system be given any sort of redress? Drivers only, or also others in the industry?
- How will the impacted owners be positively identified?
- How will the legal representatives of positively identified owners be identified?
- What sort of redress will be given to impacted owners?
- What does the impacted owner need to do to be eligible for these benefits?
- How will this be communicated?

16.2.3 Determining Which Routes Are Impacted

The service plan for the new BRT system should specify the degree to which any existing public transport operators are affected by a new BRT project. In other words, it should make clear what existing routes have been incorporated into the BRT service, and hence the old route should be cancelled; which have been rerouted; and which have been left unaffected. The terms of reference for the BRT system designer should require that this be specified, as it will greatly simplify the transition process. If this has been included in the BRT service plan, *the official service plan should be the document that determines which existing transit service providers are directly and indirectly impacted*.

If this has not been done, then the first step is for the BRT system design team to decide which existing routes will be cancelled, which will be rerouted, and which will continue to operate as is. This should be specified in a document called an "official service plan." It can be a living document—in other words, subject to modification—but it should reflect the most up to date thinking of the BRT system planning team.

Services to be cancelled and fully replaced with BRT are often labelled "impacted." If the service is to be rerouted, or if it will keep the same route but lose customers, the route or zone is considered “partially impacted.” If the service will remain on its current route or be given a roughly equivalent route, it will be considered “not impacted.” It is important that this determination be made very clear, as being labelled “impacted” will carry certain benefits, to be determined.

Generally, a BRT project will restructure or replace the services currently operating in the corridor or on the network it will serve. Most of the best-known BRT systems cancelled numerous bus or minibus routes and their licenses and replaced these services with the new BRT services. There are two reasons for this. First, allowing buses to continue to operate in mixed traffic when a lane has already been provided for buses tends to aggravate congestion in the mixed traffic lanes. Secondly, services in parallel to the BRT tend to be services that should have been integrated into the BRT system service plan so that these customers could also benefit from the BRT infrastructure investments.

TransMilenio relocated all vehicle operators that were not BRT operators under contract to TransMilenio off of the BRT corridors. While this successfully minimized direct competition on the BRT corridors, it did not end competition entirely. Many affected operators simply moved over to parallel corridors, which initially were badly congested with an oversupply of old poorly maintained vehicles. Some of these old routes provided more direct services than TransMilenio’s trunk and feeder service, and remained competitive for some trips. Quito also removed most competing routes from their BRT corridors.

In other cities, existing operators were allowed to continue operating in mixed traffic alongside the busway or on parallel routes, in competition with the BRT. One of the reasons for the low demand on the Jakarta BRT system is that *TransJakarta allowed all but ten minor bus routes to continue in the new BRT corridor in the mixed traffic lanes*. In Perreira, Colombia, the reorganization of the remaning bus routes was poor, traditional services were not integrated, and the system faces competion (Hidalgo and Carrigan, 2010). In China, many of the BRT systems (other than Guangzhou, Lanzhou, and Yichang) allow the majority of bus routes to continue to operate in mixed traffic lanes in parallel to the BRT service on the same corridor. In Ahmedabad, Janmarg was initially built on a road with no bus services, so there were no impacted operators.

Whatever decision about services is finally made, the affect that the BRT system has on specific route license holders should be identified and spelled out in the official service plan, and this should become the basis of determining which routes and which license holders are “directly impacted” or “indirectly impacted.”

16.2.4 Determining the Legal Claims of Impacted Owners

Typically, there are two possible scenarios. Either informal or semiformal operators have legal claims if their route or zone is taken away, or they do not. If impacted operators are not holding a route or area license, or they are holding route or area licenses that will expire before the implementation of the BRT, then the BRT project sponsor is not legally liable for any compensation claims. From the perspective of the BRT project team, this situation is generally favorable as it reduces the cost of the project and strengthens the hand of the government during negotiations. However, in some countries, even if the operators do not have legal licenses, or the licenses have historically been renewed every year, the courts may recognize a “customary” right to operate their business, and they may still accept that impacted operators have a legal compensation claim.

On the other hand, if there are already individual owner operators or companies holding valid route or area licenses with service areas that overlap with the planned BRT services, hence are “directly affected,” then they are likely to have a legal claim for compensation if their license is revoked. This also applies if the license is either open ended or of a duration likely to last beyond when the BRT system is supposed to open. Clarifying this situation is the first priority.

Normally, the government agency responsible for issuing the route or area licenses, if they exist, will keep records of these licenses, with varying degrees of transparency. It is important that the BRT project team review the status of these records, and make a determination as to the likelihood that they are exposed to risk of litigation. It is a good idea to get a determination from a lawyer of the degree of exposure to legal claims of this type. If the records are poorly kept, as is quite common, the government may not have a clear handle on how many licenses are held by private individuals that the courts may recognize as valid. If, however, all licenses are only valid for one or two years, as is sometimes the case, the holders of these licenses are unlikely to have much of a legal claim.

One of the reasons for including the impacted operators in the ownership structure of the new BRT authority is that by taking on shares in the new BRT operating company and willingly turning over their existing route or zone license, the BRT project can insulate the BRT agency from the risk of litigation or compensation claims.

16.2.5 Determining Whether to Recognize the Customary Claims of Impacted Owners

For most BRT projects in lower-income economies, governments decide to give the owners of impacted zone or route licenses some form of compensation that goes above and beyond whatever legal claim they may have. They do this partially in recognition of a customary claim. Whether or not an impacted operator has a legal route license, if they have been operating the route for a long time, then their license has been renewed without question from year to year, and custom recognizes their right to operate on a corridor or in a zone, governments sometimes recognize the implicit legitimacy of their claim. Because this is sometimes recognized by courts out of concern for social equity and as a way of minimizing the level of political opposition to the project—in some cases to comply with the policies of development banks or aid agencies—some sort of redress for impacted transit owners is generally considered.

If the government decides that the existing owners of route licenses have no legal claims for compensation, and they do not want to give them any form of compensation or role in the new BRT operators, then the government needs to carefully assess the risk of stiff political opposition to the project and possible social unrest. In many countries, large numbers of the emerging middle class hold their savings in the form of a minibus and an operating license, and many of these owners are also government employees who can obstruct the BRT project in a variety of explicit and implicit ways. The BRT project team should make an assessment of the political strength of the existing operators and their representatives. It is possible that these operators are poorly organized and politically weak, and with the minimal application of police powers trouble can be avoided. However, it is also possible that violence will result and the project will fail as a result. This decision, therefore, should not be taken lightly.

When Quito implemented its first BRT corridor, for instance, the city decided to create a new government trolleybus operator to run it, and to revoke the operating licenses of the current operators. This was legally within the city's power to do, but it provoked public transport operators to strike, sometimes violently, which immobilized the city for more than a week, and required the intervention of the National Guard.

For this reason, most BRT projects have decided to give some sort of redress to any operator deemed "impacted" by a new BRT system. This redress is generally only extended to the owners of the impacted route licenses or zone licenses, and only secondarily to the owners of the vehicle, as the vehicle can be relocated, and it is the route license more than the vehicle that the BRT authority normally needs to remove.

In some cases, these licenses are attributed to a specific vehicle, and only given to the owners of the vehicles. In other cases, the route licenses are not tied to a specific vehicle, in which case the owner of the route license may not be the owner of the vehicle. In this case, consideration has to be given as to whether and how the owners of impacted vehicles who are not the owners of licenses should be compensated, if at all. This was the case for TransMilenio in Bogotá. As the route licenses were held by legal bus enterprises that then rented the licenses to informal bus owners, a mechanism had to be found to ensure that bus owners as well as bus route license holders were given special consideration. *Special treatment has generally been limited to only the owners of the licenses, and secondarily to the owners of the vehicles.*

16.2.6 Deciding Whether to Redress Other Industry Participants: Drivers and Touts

The owners of vehicle route licenses will not be the only economic interests in the existing public transport industry that may be adversely affected by the transition to BRT services. Drivers and touts may also lose their jobs. Upstream and downstream industries such as repair shops, vehicle and parts suppliers, and others are all likely to face a new business environment.

One of the most positive impacts of the BRT can be the creation of formal and better paid working conditions for drivers and other BRT service providers like station managers, fare system sales personnel, and so forth. As part of the BRT service plan, the whole system needs to be staffed—not only the vehicle operating company (VOC), but also those who manage and maintain the stations, the control center, and the BRT entity. The number of positions created will therefore be roughly known. The number of jobs that are likely to be impacted can also be estimated from the service plan.

In most BRT projects, the BRT project service planning team decides that it is enough to ensure that the total project roughly creates about as many jobs as it destroys, and is therefore employment neutral. Most projects do not go further to affect the project's social outcomes. Generally, the power in the industry rests with the owners of licenses and secondarily the owners of vehicles. It is generally assumed that if the owners are taken care of, that they are likely to redeploy similar staff with whom they have had a relationship in the past, without further government intervention.

The government should not automatically promise to reemploy all of the affected drivers in the informal public transport industry. Part of creating a new corporate culture is to offer labor a new deal: a better, more stable formal sector job with benefits, but in exchange for this employees are expected to meet a higher level of qualification and need to show up to work on time, well dressed, washed, and not inebriated, and they need to possess a driver's license, and so forth. Not everyone in the existing industry will be able or want to conform to this new labor environment.

However, in some cases governments have gone a bit farther to reassure affected industry employees that they will still be able to find work. In Johannesburg, an "employment framework agreement" signed in the negotiations on Rea Vaya Phase 1A provided that each shareholder could nominate one employee per vehicle surrendered, to benefit from Rea Vaya employment opportunities, to the extent that they were qualified and suitable for the positions. A database was established with CVs of all the nominees. The agreement bound the VOC to recruit drivers from this nominated employee database for a further two years as vacancies arose. It also required the VOC to employ 80 percent of its unskilled staff from that source and 20 percent from others, with particular preference being given to residents in the communities in which Phase 1A operated. The city committed in the agreement to try to fill 40 percent of the positions for station managers, marshals, and cashiers from the database. It also undertook to specify in the station security and cleaning contracts a target of employing 60 percent of the staff from the database. The city agreed to maintain the database of those who were unsuccessful for a further two years, or until everyone had been employed, if that came earlier.

In the context of South Africa, where the political context was extremely challenging, and the informal public transport industry was highly organized but also highly divided, the government decided that this degree of intervention was the safer course. The BRT project team and the policy makers in the government in each city need to carefully consider the degree to which they can or should socially engineer the employment outcomes of the project.

16.2.7 Positive Identification of Impacted Owners

Once the government has decided to offer some sort of special treatment to impacted route or zone license owners, and or impacted bus owners or drivers, it then becomes imperative that these impacted owners or employees are clearly identified. If the precise identity of impacted license owners and bus owners is not clarified, the government may end up offering compensation of some type to those who are not in fact eligible, increasing project costs, while ignoring people who are in fact eligible.

Ideally, the license holders, their contact information, the license number, the expiration date, and the routes and vehicles associated with these route or area licenses have all been clearly recorded. Unfortunately, in most cases, they have not. Frequently much of this information is missing. Often licenses may run for many years, and yet the expiration date is not recorded. Sometimes there are zone licenses and route licenses covering the same territory. Sometimes, a license holder will operate several vehicles with the same license. Sometimes the license holder has falsified the identity of the owner in order to hide the fact that the owner is a government employee.

For all these reasons, once the government makes a decision that an impacted owner or operator is due some sort of special treatment, a clear identification of this person becomes necessary. Normally this is done by a separate reregistration process.

Generally, all of the affected routes are published in the newspaper, and impacted operators are given a fixed period of time to visit the government office and register as an "impacted" operator. In order to be certified as either a fully impacted or partially impacted owner, the owner will need to present the following:

- Copy of the current route operating license or area license;
- Copy of the owner's vehicle registration indicating that the person is indeed the owner of the vehicle;
- Proof of vehicle insurance;
- Copy of the leasing agreement or certificate issued by the leasing company identifying the legal owner, if the vehicle has been acquired under leasing operation;
- Proof of identification, current address, and contact information.

This reregistration process is itself frequently quite difficult and time consuming. The project team has to decide how to handle situations where one or more of these items are not in place.

Some cities have no licensing process at all. In this case, the BRT project team has little recourse but to ask the assistance of existing unions or associations in the registration process.

In other cities, it is quite typical that some operators may have a valid license, but are not currently using it as their vehicle may have broken down some time ago and they never replaced it. They may be operating a vehicle that does not pass basic roadworthiness requirements that are specified in the license. The authority may also not want to recognize license holders who have outstanding criminal warrants, unpaid moving violations, or otherwise been engaged in illegal activity. The operator may not have insurance for the vehicle, even if they are supposed to. They may not be able to produce a vehicle registration with their name on it, and so on. However, the BRT project team decides it wants to treat these cases, the BRT project becomes an opportunity to clean up the regulatory structure for at least a part of the city being affected by the BRT project, if not more of the city.

16.2.8 Identifying the Legal Representatives of Impacted Owners

Whatever way in which the government decides to give special treatment to impacted owners and operators, it is likely to become cumbersome for the government to communicate with all of the individual owner operators. Certainly, there will be times when all owner operators will need to be given access to information, but ultimately a contract or contracts will need to be negotiated, or compensation paid, and this will involve some form of negotiation, for which it will be necessary to identify a smaller group of the legal representatives of the impacted owners.

Typically, the impacted transit owners will already have been organized into some form of association. These associations will range from democratic, transparent cooperatives with clear governance structures to protection rackets controlled by armed criminals. Sometimes the transit owners have a very tense relationship with these self-appointed representatives. Given the choice, in some instances impacted owners would choose to be represented by the heads of their association, and in other cases they would never agree to be represented by the heads of their association.

For this reason, once impacted owners have been identified, these owners then need to further certify who they would like to act as their legal representative in any negotiations with the government. In this way, the BRT project can serve to improve the quality of the representation of informal labor. Most affected owners lack the business and legal training to effectively represent their interests in such negotiations.

The legal representatives of the impacted owners may end up playing a key role in representing the affected owners in several critical forums. They might be allowed to review and comment on the tendering process, and they are likely to ultimately become voting members on the board of directors of one of the two BRT operating companies.

In general, the impacted owner will be asked to sign an affidavit formally recognizing a specific individual or association as their legal representative. If they recognize an association rather than an individual, this association should have clear bylaws, a clear governance structure, and the legal representative of this association needs to be formally recognized by the affected owner members of the association in signed affidavits. The bylaws of the association must stipulate that the affected operators can decide to convene at any time and replace their leadership on a majority vote.

If the legal representatives are not clearly identified by the owners, it is quite possible that self-appointed representatives who do not in fact represent impacted owners will take over negotiations. Additionally, they will not have the ability to follow through on agreements as the actual impacted owners do not recognize their legitimacy. Examples of where these problems emerged follow.

16.2.8.1 Identifying Impacted Owners and Their Representatives: The Case of Johannesburg

Lack of a clear system initially to identify affected owners and their legal representatives caused a major political problem in Johannesburg, which led to civil unrest, project delay, and substantially increased project costs. The national government, including President Zuma as an election promise, made a public political commitment to keep existing operators from becoming worse off. This was generally interpreted to mean that the owners would be given shares in the new operating companies, and the drivers would be given priority access to employment in the new system.

To honor this political commitment, it became necessary to determine which owners and which drivers would be adversely affected. Until the affected owners and drivers were defined, the city did not actually know with whom to negotiate.

In Johannesburg, the owners of minibus taxis were organized into associations, but not the drivers. Therefore, the owners had most of the power in the industry. The City of Johannesburg's (CoJ) Department of Transportation depended on the Rea Vaya Service Plan to determine that 575 minibus taxi routes had to be cancelled and the taxi ranks out of which they operated shut down. Another 660 had origins and destinations that did not compete with Rea Vaya Phase 1 services, and were allowed to continue on part of the Rea Vaya Phase 1 corridor.

Table 16.1. Taxi Associations and Vehicles Impacted by Rea Vaya Phase 1A and Proposed Number of Vehicles to Be Withdrawn (Pro Rata Basis)

Taxi Association	Number of vehicles on impacted routes	Percentage of total	Proposed number of vehicles to be withdrawn from operation
Soweto Taxi Services (STS)	388	31%	180
Witwatersrand African Taxi Association/Johannesburg Taxi Association (WATA/JTA)	277	22%	129
Nancefield-Dube-West Street Taxi Association (Nanduwe)	165	13%	77
Meadowlands Dube Noord Street Taxi Association (MDN)	196	16%	90
Diepmeadow City Taxi Owners Association	127	10%	59
Bara City Taxi Association	28	2%	13
Noordgesig Taxi Association	18	2%	9
Dobsonville Roodepoort Leratong Johannesburg Taxi Association (Dorljota)	14	1%	7
Faraday Taxi Association	12	1%	6
Johannesburg Southern Suburbs Taxi Association (JSSTA)	10	1%	5
Total	**1235**	**100%**	**575**

The CoJ did research to determine which taxi associations controlled those routes. They took photos of all the licenses of minibus taxis operating on the corridor and at the ranks affected by the Phase 1A system. They then cross-checked this with the municipal taxi associations to identify the affected owners. Identifying a specific set of individual owners and drivers associated with those routes was not easy. The route licensing system had broken down almost completely. Only about one in eight minibus taxis operating in the Rea Vaya Phase 1A BRT corridor had operating licenses. Some licenses were area licenses that could not clearly be attributed to a single route, and some licenses were rotated among several operators. As such, the CoJ needed the help of the taxi associations to identify affected owners, but they had a hard time deciding which association to talk to.

The CoJ had to contend with four levels of minibus taxi associations, which in turn were divided into two often warring factions at each level. At the national level, there were two competing associations, South African National Taxi Council (SANTACO) and National Taxi Alliance (NTA), and under them SANTACO also set up provincial and municipal structures. At the provincial level, the Provincial Taxi Councils (PROTACOS) are affiliated with SANTACO, and the one in Gauteng is called Gauteng Taxi Council (GATACO). There were municipal-level associations under these two rival associations, the Greater Johannesburg Regional Taxi Council (GJRTC, which is under SANTACO) and Gauteng North Taxi Association (GNTA, under the NTA). Under these municipal associations, there were also district-level associations that controlled specific taxi ranks in specific districts. These were affiliated with one or the other municipal, provincial, and national associations. All of these membership associations figured that involvement in Rea Vaya would be lucrative, so all wanted to have some sort of status in the negotiations for the operation of Rea Vaya Phase 1, all wanted to get shares, and so on. To give everyone status and shares would have made the entire project untenable.

Negotiations began with the leadership of the two main municipal associations who in turn brought in the heads of the affected local associations. This group was named the "Taxi Negotiating Steering Committee." The heads of these two associations had been sent to Bogotá and Curitiba to talk to BRT operators in those countries to better understand the process. Over the course of the negotiations, these municipal-level associations replaced these leaders with others who were hostile to the BRT project. The CoJ therefore no longer had legitimate representatives of the affected owners with whom to negotiate, negotiations broke down, and the entire process of creating operating companies collapsed. SANTACO, the national association of minibus taxi drivers, declared itself to be the representative of the affected minibus taxi industry, and appealed to the president of South Africa to give them voice in the negotiations over the creation and selection of vehicle operating companies. The president intervened to delay negotiations, and six months passed until the minister of transport intervened and said that the national government had no role in the negotiations. The president also stated that the CoJ's executive director for transport, acting on behalf of the mayor and city manager, was recognized as the lead on all matters pertaining to Rea Vaya negotiations. The City of Johannesburg determined that since the municipal-level associations were opposing the project, and some of the affected district-level taxi associations were divided in their support of the project, the city would only recognize the legitimacy of those organization heads listed on the chart above as representing "affected owners" if and when the affected owners specifically recognized those association heads as their legal representatives. The CoJ initiated a process where the city published the affected routes and allowed that all "affected taxi operators" (owners) could come to the city by July 31 to register. The owner, as a minimum, when registering, had to show proof that the operator was the owner of each vehicle, and had a valid operating license authorizing operation on a route affected by Phase 1A, or else can show proof of having applied for one.

Registrants at this point were subjected to a "light" screening process managed by the original taxi negotiation steering committee and a CoJ-financed consultant, to determine if they were legitimately affected owners. This "light screening" process was really only aimed at demonstrating that they did indeed operate their taxi along the planned BRT corridor. About 250 owners with about 450 vehicles turned up to register by July 31, 2009, and by August 25, 2009, about 293 owners with 566 vehicles had registered.

In fact, the Taxi Negotiating Steering Committee did not change very much as a result of this certification process because most of those who registered were induced to do so by the leadership of the old taxi industry negotiating steering committee. Most affected owners recognized the heads of their associations as their legal representatives, but a few did not and the associations split, and new representation was found by the affected owners. The duly elected representatives of the registered affected owners from the two most powerful associations, WATA and STS, both did not want their association heads to enter into the negotiations. They were, they said, gangsters who are only trying to disrupt the process. Heated negotiations ensued as to whether or not they should be allowed to participate fully, as observers, or only if they were nominated by affected owners. The CoJ determined that they could only enter the negotiation process if they followed the same procedure as the others, collecting the signatures of registered affected owners recognizing them as their representatives.

The people who registered by the July 31 deadline were not all of the operators who were actually affected. In fact, by July 31 not enough people had signed up to fill the minimum number of minibuses that needed to be removed. As such, the CoJ continued to accept registrations from affected owners until well into October, though no formal extension was given, nor a new deadline established as of November 2009. The official closing off of applicants to be formally registered as "affected owners" did not occur finally until June 2010. By this time, the total numbers were sufficient to reach the target of 575 taxis that needed to be removed.

16.2.8.2 Identifying Impacted Owners and Their Representatives: The Case of Bogotá's TransMilenio

In Bogotá, the Bogotá Department of Transportation held the legal responsibility for issuing route licenses, but it did not do this directly. Rather, the department issued all the route licenses to several large bus enterprises, which owned the licenses that in turn allowed individual bus owners to use them. These enterprises were already legally constituted companies with clear legal representation, and, in collusion with the Department of Transportation, they rented the licenses to the owners for a fee. They and the Department of Transportation had the names of all of the affected route license holders. On the road, roughly 80 percent of these were legitimate, and maybe only 20 percent of them were fakes or somehow tampered with. It was important to clear out the fake licenses and not give them any status in the bidding or the formation of companies.

Two groups were affected: the owners of vehicles using the licenses (bus owners) and the owners of the licenses (the enterprises). As such, the way in which these two groups were brought into the business was different. The owners of the vehicles were not organized independently of the owners of the operating licenses, but the enterprises that distributed the licenses were powerful legal companies. In Phase 1, in order to ensure that both groups were involved in the new companies, the competitive tender for the operating contracts was written in such a way that the bidding company needed to show that they had experience in operating vehicles in the affected area. In order to demonstrate this, they only needed to turn over all the affected route licenses. It was no problem for the bus enterprises to turn over the licenses, which they legally owned. However, this would not give any compensation to the owners. For this reason, and also to get the oversupply of old vehicles off the road, TransMilenio also required that the bidding company turn in a number of vehicles for scrap. The requirement to scrap the old vehicles ensured that the bus enterprises would compensate the bus owners, either in the form of shares in the new company they created to bid, or in the form of a cash payment. In this way, TransMilenio did not need to know who the bus owners were or deal with them directly in any way. As such, the TransMilenio staff did not have to go out and determine who exactly the affected owners were. This was particularly important because it meant that the staff only had to negotiate with four bus enterprises and not hundreds of drivers. Also, the Department of Transportation was not supportive of TransMilenio, as it made illicit fees from distributing these route licenses to the enterprises, and the department refused to cooperate with TransMilenio. The mayor had to fire several DOT heads and still it was hard to get them to comply. In Phase 2, TransMilenio's bidding documents also required the affected drivers to sign affidavits that they were willing to affiliate with the bidding company in order to "show experience." This was to add greater assurance that the owners as well as the bus enterprises were fully represented in the ownership of the new company.

16.2.8.3 Identification of Impacted Owners and Their Representatives in Mexico City's Metrobús

Identification of affected owners in Mexico City was relatively simple. The Service Plan for Metrobús Phase 1 decided that if a bus route only overlapped the corridor for less than 50 percent of the route, it was not pulled out of the operation and the operator was unaffected. If the bus route overlapped for 50 percent or more of the corridor, it was pulled out of operation and hence was considered fully affected. There were 262 vehicles that operated in that corridor that needed to be removed, and these were owned by 180 bus owners. The Mexico City Department of Transportation issued route licenses to each of these bus owners, and was responsible for identifying which route license holders were "affected" and which were "unaffected."

However, there was still some ambiguity with respect to the actual owners of the licenses. For this reason, the City Department of Transportation needed to rely on the corridor-specific bus association to help the department clarify the specific affected owners. Legal representation of the affected owners was reasonably clear because all of the affected owners were under one association called Ruta 2 Insurgentes. Ruta 2 functioned like a collective in the traditional sense that these bus owners got one vote per vehicle they owned in the association. Inside the association there were different sub-associations controlling different territories.

Not all of Ruta 2 was impacted—only Ruta 2 Insurgentes. Ruta 2 Insurgentes had one general manager who was himself a bus owner and who also represented all the bus owners in Insurgentes in the citywide Ruta 2 association. Ruta 2 Insurgentes had a clear leadership structure, all of the affected owners were members of this local association, and all of them accepted the authority of the local general manager of Ruta 2 Insurgentes. The City Department of Transportation had to decide whether to negotiate with the head of the Ruta 2 Insurgentes Association or the citywide Ruta 2 association head. The general manager of Ruta 2 Insurgentes supported the BRT project, and in fact this caused him to lead a breakaway faction within the Ruta 2 parent association that supported the BRT effort. Because of this, because the governance structure of Ruta 2 Insurgentes was clear, the general manager had a clear mandate, and because he was the more direct representative of the specifically affected owners, the City Department of Transportation decided to negotiate with the local association and not the citywide association. Since that time, due to the success of the project, the head of the Ruta 2 Association has become the head of the city wide Ruta 2 Association.

16.2.9 Determining the Type and Amount of Compensation

Whether the city has found that it is legally necessary to pay compensation to the affected operators for giving up their existing business, or the city has decided to do so for political or social reasons, the nature and level of this compensation needs to be determined. Typically, this takes three forms:

- Compensation in the form of the opportunity to become a shareholder in one of the new BRT VOCs;
- Cash compensation to turn over the route license (and possibly the vehicle for scrap) and exit the business;
- Compensation in the form of a new route license somewhere else deemed to be of roughly equivalent value.

It is most common in BRT projects for the primary compensation given to the impacted license and bus owners to be shares in the new BRT VOCs. This can be done in several ways. Either, the BRT VOC is simply turned over, through negotiation, to a consortium of the impacted transit license owners and/or bus owners, or the impacted owners are given special advantage in a competitive bid due to their "experience." In either case, when the contract with the new BRT VOC is signed, the old licenses and vehicles have to be turned over to the government, thereby insulating the government from any further compensation claims.

One big advantage of handling compensation in the form of special advantage in a competitive tender is that there is no need for the BRT project team to figure out the value of the compensation due: the value of the compensation is determined by the bidders. Normally, the bidder must turn in a certain number of valid route licenses and a certain number of vehicles for scrap to qualify or to receive extra points in the bid. The head of the bidding company or consortium then has to buy up the licenses and the vehicles for scrap from the impacted operators, and negotiate their value with the owner of the licenses and the vehicles. This process is more likely to lead to a reasonable market value being paid.

Where the government decides to turn over the BRT VOC to a consortium of impacted operators through a negotiated contract, it is more likely that the BRT project team will need to get involved in the valuation of the compensation due. The BRT project team may also decide that it is impossible to accept all of the existing impacted license owners into the ownership of the new BRT company. If there is a glut of people employed in the public transport industry, and none of them make a reasonable living, the BRT project team may decide it is better to agree to provide compensation to impacted owners if they turn over their license and vehicle and exit the industry, rather than having too many shareholders in the new VOC. Alternatively, the project team may decide there are a lot of under-served routes in newly developing areas, and may want to encourage some impacted industry to relocate to these areas by giving them a new route license in a new area.

16.2.9.1 Compensation through Competitive Advantages in a Tendered VOC Contract: Example of TransMilenio, Bogotá

In the competitive tender for the BRT VOC, TransMilenio established eligibility criteria that mandated a certain minimum working capital and vehicle operating companies to be legally incorporated as formal businesses. These requirements prompted small operators to seek out partners and to professionalize their business. Bid categories such as the equity contribution of previous operators and the experience level on a particular corridor gave value to the inclusion of the existing operators. However, the participation of the existing operators was not assured. This uncertainty created political risk so that the impacted industry would not accept this approach, which had to be mitigated with the threatened use of police powers. However, it provided the necessary risk of losing the market to the impacted owners that they were compelled to meet the necessary bidding requirements in a timely way, and the competition drove down the ultimate fee for the service.

Nonetheless, in the Phase 1 bidding of TransMilenio, 96 percent of all the local transport companies (62 out of 66 companies) acquired stock in the four consortia that were awarded trunk line concessions (Hidalgo, 2003). Thus, even within a competitive bidding process, the existing operators were able to compete extremely well.

The bidding process was based both on qualifications and price and vehicle operating companies with "experience" in public transport provision. "Experience in operation" refers to the bidding firm's direct experience in providing public transport services. The experience can be in Bogotá, the greater metropolitan area, or in another Colombian city where vehicles of more than ten customers are utilized. Experience in the affected corridors was considered to be more qualified and given more points in the scoring, but this did not exclude other operators from bidding.

Companies were also awarded for partnering with international transport providers. For example, the principal transport operator in Paris, RATP (Régie Autonome des Transports Parisiens), is a partner with one of the TransMilenio vehicle operating companies. The idea is to encourage a sharing of knowledge that will improve the performance of the local operators.

In the case of Bogotá, there was a glut of old vehicles operating on the TransMilenio corridors. In order to help eliminate the more polluting older vehicles from the city, while ensuring that informal operators were not going to compete on the TransMilenio routes, the private vehicle operating companies also bid on the number of old vehicles that they are willing to destroy. The older vehicles are to be physically scrapped so that these vehicles do not simply move to another municipality. In some instances, the private operators will be able to scrap their own vehicles. In other cases, it will be more economical to “buy” older vehicles from others. The idea is to find the lowest cost vehicles to destroy. Since the lowest-cost vehicles also tend to be the oldest and most polluting, the incentive works well in achieving its goal of reducing the oversupply of outdated vehicles. The vehicle scrapping process is quite formal. The older vehicles must be taken to a designated scrapping facility where a legal certification is awarded once the vehicle is destroyed. The process is designed to avoid any corruption or any “leakage” of vehicles to other cities.

The bidding firm receives more points for the higher number of shares owned by small bus operators. The bidding firm’s “equity share” held by small operators is a key incentive to encourage the participation of existing operators. This bid category essentially gives value to these small operators and their existing resources.

Figure 16.6. As part of the competitive tendering process, companies compete to destroy the greatest number of older vehicles. Image *TransMilenio SA*.

The tendering process did not predetermine the value of a route license, a bus needed for scrap, or the value of a share in the new company. This is a big advantage because some routes are more profitable than others and some vehicles are worth more than others. During the negotiations between the bidding firms and the small operators, the existing assets of vehicles, drivers, and capital that the owner is willing to invest in the new company, all played a role in the determination of the number of their shares.

16.2.9.2 Compensation by Giving Impacted Owners Control of the BRT VOC: Examples of Metrobús, Mexico City; Rea Vaya, Johannesburg; and Lagos, Nigeria

Mexico City’s first BRT corridor, Avenida de los Insurgentes, was originally serviced by two operators: the municipally owned RTP and Ruta 2, one of the largest bus owner collectives in Mexico City. The government of the Federal District of Mexico City (D.F.) decided to avoid the need for any compensation or the risk of political problems by giving the BRT operations in the corridor to these same two operators without a competitive tender, splitting the market proportionally based on the share of the pre-BRT market on the same corridor. The fee per kilometer of service provided was set based on negotiation. Negotiations between Ruta 2 and the city transportation authority were premised on the understanding that the bus operators would earn at least the same amount of money by participating in the BRT as they were earning before. Eventually, 180 individual owners with rights in the corridor were identified and agreement reached that their average profit in the corridor, per month, per vehicle, was US$1,155 (converted from MXN$15,000 with a January 2014 rate on XE.com). The variance in the profitability of the services was low, as almost all were serving roughly the same route, so having a uniform value per license and per vehicle was relatively unproblematic. The majority of them joined to create Corredor Insurgentes (CISA) and 180 of their vehicles were scrapped under the substitution program. In March

2005 the Mexico City government awarded CISA a ten-year concession without competitive tender to operate the corridor. Each owner got one share for each vehicle they turned in.

This concession also provided that RTP would be the only other operator allowed on the corridor with one bus to every three of CISA's. Consultants calculated a fee per kilometer such that it was sufficient to sustain payments of US$1,155 (converted from MXN$15,000 with January 2014 rate on XE.com) a month per each Ruta 2 bus operating on the corridor. The second line began operations in December 2008 following a similar deal with the existing operators on the Eje 4 Oriente corridor but at a relatively low guaranteed profit to each incumbent operator, as a result of which many demanded to participate without scrapping their vehicles.

Faced with operating deficits, the authorities adopted a different strategy for Line 3, which began in February 2011. Existing owners were forced to partner with Autobuses de Oriente (ADO), the country's largest private bus company. It was brought in without tendering after it offered to operate the route without subsidy and to include existing operators as minority shareholders with guaranteed monthly stipends and to hire former operators in the new company as drivers, mechanics, and administrative staff. In this deal, the former owners got shares not only in a relatively small BRT-specific consortium, but in the parent company of a big Mexican company, which made this approach an attractive option for the impacted owners. In implementing Line 4 in 2012, the authorities for the first time did not require the selected BRT company to reserve shares for and guarantee profits to incumbent owners affected by the project (Flores-Dewey, et al., 2012).

On the Johannesburg Rea Vaya Phase 1A, the impacted owners had been told by the national government that they would be no worse off. To realize this, the VOC contract was turned over to a consortium of the impacted owners through negotiation rather than through a tendering process. As in Mexico City, the city had to determine a fair amount to pay per kilometer in negotiation with the representatives of the impacted owners. To do this they created a financial model that showed the cost of operating the required services. The financial model determined a fee per kilometer that would pay out monthly dividends to the shareholders that equaled the monthly profits they were presently making. Unlike in Mexico, however, different routes and different vehicles differed greatly in value. Also, the owners did not belong to one association with a clear leader, they belonged to ten competing associations representing different areas, and these associations in turn were affiliated with rival municipal, provincial, and national associations.

In addition, the route licenses were extremely poorly managed. Some owners of route licenses operated several vehicles with a single license, some had licenses but did not operate any vehicles under the license, some had licenses that had no expiration date while others expired, some had no specific route while others had routes, and still others had areas. As such, the impacted owners had trouble agreeing on how much value to attribute to these licenses and vehicles, and hence could not determine a reasonable distribution of shares in the new consortium between the impacted operators and their affiliated associations. As this was leading to extended delays, the city had to intervene and set the value of the shares as well as the way they would be distributed among the impacted members of different associations. The city decided to follow the Mexican approach of one vehicle, one license, and one share. This was easier to understand though it differed significantly from their implicit market value. Because no one could be made worse off, the monthly payment per share had to be the equivalent of the most profitable route to satisfy everyone, so it ended up driving up the ultimate operating cost. The total profit margins were therefore well above what they should have been, had everyone received profits equivalent to their former profits. The fee was about 25 percent higher than such a fee would have been.

In Johannesburg, the city agreed to pay out these agreed profits every month directly to the shareholders for the first four years, so that they did not have to come out of the VOC dividends when the company was not making sufficient profits. The VOC was required to pay for the vehicles, and the high loan repayment costs in the early years made the VOC unprofitable for the first few years. A reduced fee per kilometer was also agreed for the remaining eight years of the contract. This created an incentive for the company to be run efficiently, as profits were linked to the financial performance of the company, and it is not a straight profit guarantee (McCaul C. and Ntuli S., 2011).

The city hired a bus leasing firm to manage the scrapping requirement. There was a national scrapping program that was cumbersome to use, so the bus leasing company received the vehicle from the impacted operators and paid them either the scrapping value provided by the national program, or the value of the vehicle if it was worth more than the scrapping allowance. In order to raise operating capital, in Johannesburg's case the investment into the VOC was set at about US$5,157 per share (converted from R54,000 with a January 2014 rate on XE.com), which was the government scrapping allowance paid in terms of a national recapitalization scheme to minibus-taxi owners who turn in an old vehicle for scrapping.

The Lagos "BRT-Lite" similarly compensated impacted owners by awarding the VOC franchise directly to a cooperative formed by existing operators. The 22-kilometer busway was termed "BRT-Lite" because it does not comply with all aspects of the definition of BRT. The Lagos Metropolitan Area Transport Authority (LAMATA) awarded a franchise for the operation to a newly created cooperative company called Lagos NURTW (First BRT) Co-operative Society Limited (FBC). The company was formed by officials and owners from the association of informal minibus operators called the National Union of Road Transport Workers (NURTW). This is one of the two bodies representing transport operators in Nigeria (the other is called Road Transport Employers Association of Nigeria [RTEAN] and represents owners). The operators represented in NURTW lease vehicles from owners and pay a daily fee to them. Its local branches control local routes organized in zones and the operations at the route terminals. FBC is wholly owned by the NURTW, but controlled by fifty members who subscribed equity. Subsequent members are only admitted with the agreement of existing members and on payment of the same equity.

The franchise was a negotiated one. In this case, the contract was a net cost contract: the VOC owns all the fare revenue, and is not paid an operating subsidy. The fare revenue is expected to sustain the operation as well as redeem the loan for the fleet purchase. Furthermore, FBC is expected to pay franchise fees to LAMATA as well as fees to it for the use of depot and workshop infrastructure. In addition, FBC makes rebate payments to the NURTW Lagos State Council and to the FBC membership. Fleet was acquired by NURTW with commercial loans (100 Ashok Leyland vehicles), and because demand was so great, 160 additional Marco Polo vehicles were leased from Lagbus Asset Management Ltd., a state-owned enterprise that had been established for the purpose of procuring vehicles for lease to private operators. Though the fare revenue is owned by the VOC, it is collected by the banks that made the loan to the VOC for the vehicle procurement, and payment is made to the VOC only after the loan repayment has been deducted (Integrated Transport Planning Ltd., 2009; Mobereola, D., 2009; and Venter, C. 2009).

16.2.9.3 Other Forms of Direct Compensation: MyCiti, Cape Town Example

In some cities, the BRT project team decided it was better to separate the question of compensation from the question of who is eligible to bid and operate the BRT services. To take this approach requires that the BRT project team, on behalf of the city but in negotiation with impacted operators, estimate the value of the route license or area license and the value of the vehicle being turned over for scrap.

In the case of the City of Cape Town, for instance, the strategy was to first identify "impacted owners" of licenses and vehicles, and then pay compensation separate and up front to these impacted owners. In this way, those owners wishing to exit the business could do so. In addition, the question of the value of compensation could be separated from the question of the value of the shares in the new company. The shares in the new company could have a uniform share value while the compensation payment could be valued closer to the market value of the route and the specific vehicle. This had several benefits. First, it lowered the number of shareholders, which meant that each remaining shareholder could be paid less and still earn as much as they were earning before. This lowered the operating cost in the longer run. Secondly, by decoupling the value of compensation from the value of shares, the total value of the compensation was lower.

After Phase 1 of the system opened, MyCiti was still facing competition from minibus taxis for a variety of reasons. Some people had area licenses that were still valid that included MyCiti routes, and though initially they operated their vehicles on other corridors, they found it more lucrative to shift to a MyCiti corridor after the system opened because the other minibus taxi competition was reduced. Secondly, due to weak enforcement, many minibus taxi owners continued to operate unlicensed services on MyCiti routes. As such, the idea of compensation payments as of this writing is to assist in the removal of the remaining valid area licenses that are competing with MyCiti operations.

16.3 Managing Competing Public Transport Routes

> *"The only way to make sense out of change is to plunge into it, move with it, and join the dance."*
>
> — Alan Watts, philosopher, 1915–1973

One of the key issues with respect to managing any affected informal industry is whether to remove it from competition with the new BRT service. Ideally, the BRT system's service plan should indicate the existing minibus or bus routes that should be incorporated into the new BRT system, the routes that should be cancelled, and the routes that should be modified or rerouted to avoid direct competition with the new BRT services.

One of the key reasons to involve the affected informal public transport operators in the new BRT services is to give them a vested interest in removing their existing services from competition with the new BRT system. Even if the service plan calls for the removal of competing informal public transport services, it is frequently quite difficult to implement this in practice.

There are a few main reasons why competition with informal public transport operators is generally (though not always) removed from the mixed traffic lanes on BRT corridors. First, the more bus routes that use the BRT infrastructure, the more customers that benefit from the new BRT infrastructure. The more customers, the more profitable the system is likely to be, and the fewer subsidies the BRT operations may require. Second, the more public transport vehicles that remain outside of the BRT lane, the more they will contribute to mixed traffic congestion. An oversupply of public transport services on trunk corridors, leading to unprofitable, low-quality public transport services and greater than necessary traffic congestion, is a well-known market failure known as "destructive competition." Ideally, the services of the new BRT system are so good that pure free market competition would induce almost all customers to switch to the new BRT system, but if they are less than ideal, it still may be better to limit this competition.

If impacted operators are given some extra advantage in a competitive tender, then turning over a significant number of the affected route licenses upon signing of the operating contract can be a requirement of the contract with the new operator. If the new operator includes the informal power structure that originally controlled access to the corridor, then the requirement to withdraw competing routes should be reasonably self-enforcing.

If the decision has been made to turn over the operations to a consortium constituted from affected operators through negotiations, a plan for the scheduled withdrawal of competition from the BRT routes is one of the agreements that should be reached. This should detail which existing routes will be completely withdrawn, those that may need to be restructured and how (because of partial coverage by the BRT network), and those that should continue because they served different origins and destinations to the BRT, but which may need to be relocated from the BRT busway onto different roads. The affected operators who become shareholders in the VOC will need to demonstrate that they have withdrawn their existing services according to the plan. This can be done in various ways, including submitting the vehicle for sale or scrapping to the city or proof that the vehicle has been sold, submitting existing operating licenses or permits for cancellation by the relevant government entity, and signing of restraint of trade agreements. Where compensation is paid out for withdrawal of existing services, it becomes even more crucial that the withdrawal can be demonstrated.

Where regulation is weakly implemented or enforced by government entities, the effective withdrawal of existing services is not easy to achieve. If large numbers of operators do not have operating permits in any event, and if the system is weakly enforced, then the city may find it difficult to prevent competition from developing again on the route. In these situations, the city may need to embark on a process to reregulate public transport, beginning with the BRT corridor in question. Reregulation would need to commence prior to implementation so that existing operators on the route are known and formalized before some are taken off.

Sometimes an institutional conflict of interest can prevent the withdrawal of existing services. For example, in Jakarta the Department of Transport, under whose control TransJakarta falls, earns significant revenues from the allocation of bus routes to bus companies. As a result, there was great reluctance on its part to cut parallel bus routes in the TransJakarta corridor, as the department lost revenue from each new line allocated. No competing services were therefore withdrawn, and they run in the mixed traffic lanes parallel to the busways.

In the Lagos BRT-Lite project, the approach was to involve the existing operators in delivery as much as possible, and to avoid marginalizing existing operators on the corridor. The *danfo* and *molue* (informal minibuses and midibuses) were not removed, but were banned from the main busway, and restricted to the parallel service roads. This meant that the limited capacity of BRT-Lite in early operation was supplemented and that existing vehicles could continue operating (the trips on the BRT-Lite only make up a quarter of all the trips in the corridor). A regulation finalized prior to the start of operations prohibited the operation of vehicles other than those franchised for the BRT-Lite scheme (and certain emergency services) in the busways, and also restricted the informal minibuses and midibuses to the service lanes (Integrated Transport Planning Ltd., 2009; Mobereola, D., 2009).

If, as a practical matter it is impossible to prohibit the use of informal public transport operations parallel to the BRT system, then it will be even more incumbent on the BRT system to provide a service that is competitive in terms of cost, speed, comfort, and convenience for its customers. In addition, all demand projections and financial projections should take this fact into account.

16.4 Outreach to Impacted Operators

"The art of communication is the language of leadership."

— James C. Humes, author and former presidential speechwriter, 1934–

How the BRT project team approaches the impacted existing public transport industry can have a significant impact on the success of the project and quality of the ultimate contract signed. The better organized the BRT project team is and the more information it has about the future system it wants, the greater the likelihood is that the BRT project team can negotiate a good deal for public transport customers. Managing this communication process requires balancing the government's dual role as the guardian of the public interest, where it is the government's responsibility to negotiate the best deal for the public as possible and wanting to keep the impacted operators happy to avoid political resistance to the project or the risk of social unrest.

Outreach to incumbent operators can be separated into various stages:

- Broad engagement;
- Negotiations or tendering process.

A new BRT project in a city is likely to cause considerable anxiety among existing operators about the future of their businesses, not just in the short term in the initial corridor affected, but in the long term as the system expands. On the one hand, it is helpful to engage the representatives of all existing operators in the city in the initial stages of engagement about the project. In this way information can be widely disseminated about the immediate and long-term planning, so that concerns can be discussed and addressed. On the other hand, the BRT team needs to make very clear any critical government positions on a number of key matters, and also make clear those areas that have not yet been decided or are open for negotiation.

For instance, it is very useful if the planning team has already mapped out the long-term plans for the BRT network and is able to indicate phasing and implementation timeframes. Outreach should prioritize those owners who are likely to be impacted by the first phases. Simply figuring out the existing structure of power and control on impacted corridors is sometimes not very easy. The first priority then is to understand as much as possible about the affected informal public transport industry, who its leaders are, and which ones are likely to be more favorably disposed toward the project, and can be used to bring along others less favorably disposed.

If the corridor has not yet been selected, then engagement would need to be with all of the operators. It is also useful if the routes likely to be affected by each phase are documented so that this information can also be shared, and impacted operators targeted for outreach. If the BRT project is planning on not competitively tendering the operations, but to give experience points for impacted operators, then it needs to make this clear from the beginning. Otherwise, the impacted operators will try to form a block to retain control of their current market, significantly weakening the leverage of the government to demand the creation of stronger companies or quality of service provisions in the contract.

16.4.1 Industry Engagement in Bogotá, Colombia

In Bogotá's TransMilenio, the transition process began in 1998. Mayor Peñalosa hired a businessman named Ignacio de Guzman to learn what he could about the structure of the bus owners and the bus enterprise owners. He established a task force that approached the heads of several of these associations to explain the new BRT system.

De Guzman's research indicated that there were some eleven affected associations active in the field. Some of them were drivers' unions, but the most important were five associated enterprise unions:

Table 16.2. Associations and Members

Association	Number of Members
CONALTUR	National group, comprises about 60 percent of all the companies in the country
ASONATRAC	Some 10 companies
ASOTUR	Some 16 companies
FECOLTRAN	Some 15 companies
APETRANS	Small bus owners (a few hundred)

Source: Bocarejo, Pablo. Ingenieros Consultores - EUROESTUDIOS S.A. – ETT S.A., Mejoramiento del Sistema de Transporte Público Complementario a TransMilenio de Bogotá Informe Final.

The associations and their members were invited to discuss the initiative with the City of Bogotá. In these early meetings, virtually all of the associations rejected the idea of TransMilenio and the public transport reform process that it involved. They argued that 25,000 families would be badly affected and some transport companies would disappear. They felt that smaller companies and collectives would be particularly hard hit. The mayor took a pretty hard line, and said that the project was going to go ahead with or without them, and that if they resisted the project or caused any civil disobedience they would be disqualified from bidding.

Most of the power in the industry was held by a small number of large bus enterprises that controlled the licenses in the TransMilenio Phase 1 corridors. These enterprises were owned by wealthy families, and there was generational change taking place in the control of these companies. While the patriarchs of the families were resistant to change, a subgroup of the younger generation of leaders understood the potential of becoming something more. This subgroup of better informed owners of transport enterprises understood faster than the others that the tendering system might offer them some advantages in the long run. While it meant that part of their current market was at risk, it also gave them a chance to move into markets currently closed to them. They helped convince the others that competitive tendering would be fine if the tender were written in a way which heavily weighted "experience in the corridors." Under these conditions, many impacted enterprises agreed to participate in a managed tender. Those that agreed to participate were given voice in the way in which the tender was structured, and those that refused were excluded.

The chief executive of TransMilenio, Edgar Sandoval, carefully controlled the information released to the impacted owners. Information about the project was released only once the government had made clear decisions. He believed in negotiating with the industry from a position of strength, and he always tried to have more information than the industry about the operational costs. With the existing industry, he built public discontent through regular releases to the media of the many problems with the existing public transport services. He always got the backing of the mayor on key decisions, and he never wavered from the position that the industry would be forced to competitively bid and meet strict minimum qualification criteria to win the right to become a BRT operator. Though eventually TransMilenio operations came under criticism for declining performance, TransMilenio operations were for years considered the gold standard in BRT service provision.

16.4.2 Industry Engagement in Johannesburg, South Africa

Johannesburg and Cape Town were the first two South African cities to implement BRT corridors, both of them managing to incorporate existing informal operators. In South Africa these are the minibus-taxis, mainly sixteen-seaters, that began competing with the subsidized bus and passenger rail industry in the 1970s, and which presently command about 60 percent of the modal share in the country. In Cape Town, they have a 29 percent share and in Johannesburg a 72 percent share of the public transport market. They are owned by numerous individual owners, the majority owning one or two taxis only, who employ drivers that provide the owners with a target income daily or weekly. They are organized into route-based taxi associations, which play a strong role in controlling new entrants on the routes, through high joining fees, patrol vehicles, an informal sticker system controlling the right to use city-owned facilities, and at times intimidation and violence. Both cities also have formal private bus companies operating services in terms of contracts with the provincial sphere of government, while Johannesburg also has a city-owned bus company called Metrobus.

Johannesburg engaged its existing operators from the outset. It gave up on the idea of competitive bidding of the contracts fairly early on, which perhaps reduced the risk of social unrest but increased the operating cost and perhaps compromised some elements of corporate formation.

There were some thirty route-based taxi associations active on daily routes in the city (as well as numerous long-distance groupings) that belong to one of two umbrella bodies in the city—called Top Six Taxi Management and the Greater Johannesburg Regional Taxi Council (GJRTC). (These umbrella bodies are each affiliated with provincial and national structures as well.) The leaders of each of these, as well as of the two main bus companies active in the city, were initially cultivated by the BRT project team, and then invited to join the city's initial BRT study tour to South America, in August 2006, when BRT was being considered. Once Johannesburg made a decision to plan and build BRT, which it called Rea Vaya, the participants in these study tours became proponents for the project within the minibus taxi industry. The city held in-depth discussions with these "early adopters" among the minibus-taxi industry representatives on how to structure their participation in the BRT project. It settled on a business model that would make affected taxi and bus operators shareholders in the VOC that would operate the first Phase 1A of Rea Vaya. Initial discussions were held separately with the two umbrella bodies, but in February 2007 the two bodies agreed to represent the industry as one entity. They set up a steering committee, made up of the executives of Top Six and the GJRTC, chaired respectively by the two structures' leaders, Sicelo Mabaso and Eric Motshwane, respectively. These bodies each signed memoranda of understanding with the City of Johannesburg, setting out the mechanisms for cooperation and liaison (another was signed with the city's bus operators the following year). The TSC was given office space and meeting facilities alongside the BRT project offices. In addition, the city paid a full-time technical adviser chosen by the TSC, and office support staff to assist the TSC. Additionally, it paid an independent facilitator to manage the engagement process.

A long period of consultation, debate, information sharing, and discussion took place from 2007 to 2009 among city officials and industry leaders, steered by the facilitator appointed by the city. Apart from the TSC, other structures were also convened for these engagements, including a committee of four leaders each from eighteen taxi associations that would be affected by the first full phase of Rea Vaya. An even larger structure was sometimes convened made up of the executive committee members of all eighteen associations. Roadshows were embarked upon to explain the proposed rollout of BRT to individual taxi association members. The engagement included raising awareness of BRT, education about BRT, change management workshops, engagement on infrastructure rollout and taxi routing during construction, and communication about affected routes and vehicles in the various proposed phases.

This period was used highly effectively by the industry to secure reassurances that it would not be harmed by the BRT project or be left worse off by it in terms of profits. The taxi industry held several conferences and workshops where resolutions were taken to be part of the project and to support it. Additionally, they insisted on having 100 percent stake in operations, a share of other contracts, and various other measures to ensure the industry's interests were looked after (McCaul C. and Ntuli S., 2011; City of Johannesburg, 2011, pp. 29–31).

Significant reassurances were also secured by the minibus-taxi industry at the national level, which were binding on all city BRT projects in the country. In addition to local engagement, a significant amount of engagement about BRT was taking place separately at the national level, between the national taxi umbrella bodies and the national department of transport. These talks, as well as several protest actions and strikes by minibus-taxi operators across the country, resulted in public undertakings and guarantees by the minister of transport that there would be no loss of legitimate profits and jobs among operators and workers who moved into the BRT systems. He also expressed the government's willingness to explore legal options to make the long-term contracts renewable subject to good performance.

The city, for its part, made clear its proposals that, in exchange for participation as operators of the new system, existing operators would need to withdraw their vehicles from BRT routes. The Phase 1 Operational Plan detailed which routes should be "cancelled," diverted, or reduced.

After the Phase 1A service design was revised and finalized in August 2008, the process concentrated on the operators who would be directly affected by it—namely taxi operators on routes of ten taxi associations. From early 2009 the city expanded the technical support it was giving to representatives of the taxi industry, and paid for additional technical advisers of their choosing. In addition to the transportation engineer supporting them full-time, the city paid for a lawyer, a bus operations expert, and a management and business adviser. It also funded all the meetings, workshops, and breakaway sessions required in the engagements.

To ensure that all affected operators on the Phase 1A-affected routes had the opportunity to be involved, the city placed advertisements listing the Phase 1A routes and the ten associations it believed were affected, and it asked individual operators to come forward to register their interest in participation. It also wrote letters to the affected taxi associations in this regard. A process took place by which these registered operators nominated representatives in negotiations—either existing leaders in their associations or other candidates.

Despite these extensive engagement and communication efforts, the BRT project divided the industry in Johannesburg, and those opposed to the project organized themselves into a body called UTAF (United Taxi Association Forum). The planning and initial implementation periods were characterized by protests and strikes, intimidation of participants, violent attacks on participants, and violent attacks on the system itself in 2009 and 2010.

16.4.3 Industry Engagement in Cape Town, South Africa

Cape Town managed interactions with the affected minibus taxi industry somewhat differently. It held out the possibility of having a competitive bid longer, and retained the concept of having multiple operators on the Phase 1A corridor.

The operators impacted by Phase 1A of the Cape Town BRT system were of three types:

- Members of the Peninsula Taxi Association, a well-organized, sophisticated, and diverse association heavily dominant in the Cape Town city center;
- Golden Arrow, a bus company under contract to the Western Cape Province, largely under white ownership;
- Smaller associations.

The process of transitioning the existing public transport industry into a new BRT business model was sensitive and required careful planning. Several months of engagement with the industry were necessary before a formal process of transition began. During this time, a series of meetings was convened with members, at many levels, from associations directly affected by the new system as well as with members of the broader industry. Additionally, pamphlets and other forms of media were distributed as a way of disseminating as much information as possible, and as broadly as possible. In early December 2008, a study tour to South America was arranged where representatives of the taxi and scheduled bus industries and city officials visited three cities in South America where BRT systems have successfully been introduced. Many of the taxi and bus industry organizations affected by Phase 1A participated, with the intention of briefing the remaining members of these organizations regarding lessons learned. One of the major taxi associations, the National Taxi Alliance, refused to participate.

The first formal engagements between the City of Cape Town (CoCT) and the existing industry took place in November 2008. The first meetings were intended to be informational meetings geared to the directly affected industry. As such, only members of the directly affected industry—minibus taxi and bus—were invited. But, in addition to the invitees from the directly affected industry, members of the broader industry attended uninvited. The CoCT made the quick decision not to turn anyone away. But this caused friction between the directly affected industry and the broader industry and the meeting ended in a stalemate.

Meetings were also convened with the Western Cape Provincial Taxi Council (WCPTC) representing the broader minibus taxi industry. This council has been positive about the IRT. At an IRT Summit on November 27, 2008, two representatives from all minibus taxi associations in the Western Cape were invited to hear a presentation on IRT and to discuss the project. Further, the CoCT met with a wide range of interest groups within the broader transport industry, such as the Touchdown Metered Taxi Association (servicing the airport), small bus operators, and the Metered Taxi Council and taxi associations operating outside Phase 1A, or not directly affected by it. In addition, the CoCT started meetings with the affected private bus operator, Golden Arrow.

The head of the Peninsula Taxi Association (PTA) was generally supportive of the BRT system plans, and was rapidly able to convert his association into a corporate entity. Golden Arrow already existed as a corporation, and was also readily capable of providing BRT services. They were conditionally supportive.

One group of associations, however, organized in opposition to the project. A grouping split from the WCPTC in December 2008, and called itself the National Taxi Alliance (NTA). Though the opposition of the national NTA began to soften as the prospects of success in Johannesburg improved, the local associations within the

NTA-Western Cape umbrella that have been identified as part of the affected industry remained opposed to the IRT system longer. These include DuNoon Taxi Association (DTA), Ysterplaat Taxi Association (YTA), Maitland Taxi Association (MATA), and Devils Peak Vredehoek Taxi Association (DPVTA).

The NTA ran two work stoppages, one in December and another during 2009. The city met numerous times with the NTA, without being able to resolve their differences. NTA's position, however, was not that strong, as the majority of the impacted routes were under the control of the PTA, and there was always a significant threat that the city would simply turn over operations to Golden Arrow and the PTA. Finally, with the direct intervention of Mayor Zille in March 2009, there was a successful meeting with the whole minibus taxi industry where more of the industry decided to support the project.

The industry was asked to select a steering committee, and to form other committees, and from that time forward regular meetings were held between the city and the various committees, particularly with the steering committee.

Cape Town decided to write down all of the information that it was in a position to share with the impacted industry in a living document called the Vehicle Operator Prospectus. This document, drafted initially by the city's business planning consultants, was the basis of formal discussions, and negotiations and workshops resulted in significant changes to its content before the next formal release of the prospectus in August 2009. Other issues worked out in the meetings were how to handle threats on the lives of the attendees.

Eventually, due to internal cleavages within the industry, Cape Town decided to organize the services into three separate contracts: one led by PTA, one by Golden Arrow, and the third led by the smaller associations. As negotiations were not concluded in time for the 2010 World Cup, an interim operation was put into place with the company created by PTA. This company operated during the World Cup, and put pressure on the other companies to conclude their contracts.

16.4.4 Industry Engagement in Dar es Salaam, Tanzania

In Dar es Salaam, the existing minibus taxi, or *daladala*, owners that would be affected by the DART BRT system, were less well organized than in most other cities developing BRT systems. Initially, there was only one association of *daladala* owners, DARCOBOA. The de facto head of this association, Sabri Mabruki, owned a fleet of vehicles mostly concentrated on a parallel corridor, Uhuru Road, that were only indirectly affected by the BRT system. The owners association only represented part of the *daladala* industry affected by Phase 1. Sabri Mabruki was included in most of the DART visits to other BRT systems in Latin America and was in contact with the BRT operators in South Africa as well. Route licenses were reasonably well organized in Dar by a national government agency called SUMATRA. Most of the owners were not active participants in the business, and they simply leased their vehicles to drivers for a flat rate. As such, the drivers had relatively more power and the owners relatively less in Dar than in other places.

DARCOBOA's leadership, and some of its members were informed about the DART BRT project since the earliest plans for the project, and were always told that they would be given an opportunity to become the operators of the new system. Information, however, did not pass to many of the affected owners who were not well organized or easy to identify. The project was frequently delayed, and information flow between the DART agency and DARCOBOA was infrequent. Many project documents were prepared by the BRT consultants, but few of these documents were ratified formally by the government, and few of them were shared with the impacted industry. The impacted industry operated under relatively short-term contracts, and as such, had no legal rights to compensation.

The business plan developed by the original project team proposed having a competitive tender where two vehicle operating companies would be chosen to operate the BRT, both run by new consortia composed of international operators in joint venture with impacted and nonimpacted local owners. The World Bank loan, which paid for the infrastructure, stipulated that the impacted owners be given preferential treatment with respect to operating the BRT system. It also required competitive tendering of the operations.

The idea of having multiple operators was not supported by DARCOBOA, which wanted one big consortium to operate 100 percent of the BRT system in joint venture with a single international operator. The World Bank and its consultants also felt a single operator contract, more typical of the European public transport systems, would be easier to manage. The World Bank's consultants felt that the trunk BRT routes should be operated by an international operator selected through international tender. And they wanted this to happen with no involvement of the *daladala* owners, who would be given the right to operate the feeder routes and possibly other forms of compensation to exit the industry. The government of Tanzania never took a position with respect to these matters, leaving the *daladala* owners and potential investors unsure of the government's position.

Complicating matters, licensing of public transport routes was handled by SUMATRA, which is under the ministry of transport, while the DART agency is under the ministry of regional and local government, reporting to different ministries. Communication with affected industry was spotty. There was an initial meeting held with over two hundred *daladala* owners in the fall of 2013, as the infrastructure began to progress. The meeting included those with operations on the planned BRT corridor and those with operations unaffected by Phase 1. The Ministerial Advisory Board, under pressure from Darcoboa, abolished the distinction between "affected" and "unaffected" *daladala* operators.

At this meeting, the owners then organized themselves into three stakeholder groups, Darcoboa, UWADAR, and another group of otherwise unaffiliated *daladala* owners. From these, six individuals from a working group of representatives were selected with whom the regional commissioner was to continue to have more detailed discussions. There was little formal communication again until May 2014. Part of the delay was a result of cumbersome World Bank procurement rules, and by this time a "transaction adviser," the Rebel Group, had been hired, as had a local expert. At this meeting, about 35 percent of the impacted operators showed up and registered as impacted owners or drivers. About 85 percent said they wanted to have shares in the DART operating company, and only a few were looking for compensation to exit the industry.

Then, in May 2014, there was a "road show" where potential bidders were invited to visit the DART BRT infrastructure. The information given to the potential international investors was prepared by the World Bank consultants, the Rebel Group, and it indicated that one company would be selected to operate the entire BRT system, including the bus operations, the fare system, and the operational control system. There was no mention of any requirement to include impacted *daladala* owners. As a result, the representative of Darcoboa renounced the meeting, and he was supported by the mayor of Dar es Salaam, leaving many of the investors unsure of government policy.

Of the international visitors who participated, only one bus operator, Gursel from Turkey, participated, and the firm does not operate a BRT service but an intercity bus service. Some fare system operators also participated, as did some bus manufacturers and some banks. As the formal tendering process would take more than two years to complete, well after the infrastructure was to be completed and well after the national elections, DART was in a position of needing to find an interim operator.

Meanwhile, the moribund government-owned bus operator, UDA, that had the right to operate many of the routes affected by the DART BRT, but which had not operated any routes for many years, was suddenly resurrected. As the DART corridor moved toward completion, a powerful private investor purchased a majority share of UDA and immediately began operating vehicles in DART affected corridors. This company had the rights to operate given to it by the ministry of transport.

By August 2015, UWADAR, DARCOBOA, and UDA's new private owner (Shirika la Usufiri Dar es Salaam Ltd.), with the endorsement of the DART Agency, signed an agreement. This agreement stipulated that the two *daladala* owner associations would compensate impacted owners on the BRT corridor in exchange for the right to buy shares in UDA and have representatives on its board. UDA in turn promised not to sign any joint venture with an international company to operate BRT operations on the BRT corridor. Since UDA still held the legal rights to operate vehicles on the corridor, this agreement seems to have legally foreclosed vehicle operations by any foreign company.

As of October 2015, this company had procured 138 vehicles to initiate BRT operations. As of this writing the vehicles were still stuck in the port and operations had yet to commence despite the presidential elections that returned the ruling party to power in November 2015 in a relatively closely contested election.

16.4.5 Industry Engagement in Lagos, Nigeria

LAMATA, the Lagos transport authority, engaged extensively with future users, communities, and existing operators in the design of the BRT-Lite system. There was a significant publicity effort and community outreach, as well as mobilization of key community supporters and opinion-makers. Design and operational decisions were workshopped with stakeholders and the informal transport sector leadership, NURTW, became convinced to change its business model to become more efficient and sustainable. They also convinced their membership of this. Study trips to South America were undertaken in 2004 and 2006. This long process of consultation seemed to have ensured widespread buy-in.

16.5 Managing a Negotiated Operating Contract with Impacted Operators

"The most important trip you may take in life is meeting people half way."

— Henry Boyle, Anglo-Irish politician, 1669–1725

If the operating contract is to be tendered, the initial industry engagement process described in the previous section is generally sufficient to draft a successful tendering document and issue a competitive tender. In a tendered contract, the government does not then need to enter into detailed negotiations over all elements of the contract. The government can draft the proposed contracts in advance, closely based on the tender documents, which should stipulate most of the contract provisions, and only modify elements of the contract that are heavily disputed by all the winning bidders.

If the operating contract is to be negotiated with the impacted operators, however, the negotiation process becomes far more complex, as all of the areas that would otherwise have been subject to the bid or part of minimum qualification criteria become the subject of negotiation.

Before negotiations begin it is helpful to determine the following:

- Technical support;
- Remuneration of participants;
- Facilitation;
- Representation of affected operators;
- A negotiations plan.

Technical support: Both the BRT team inside the BRT agency and the impacted operators may need technical support. Most city governments are unfamiliar with negotiating a bus operating contract with impacted operators, and in many cities the impacted operators will be unsophisticated individual owners with little business savvy. The BRT team may want to be supported by consultants or advisers to engage with the existing affected operators. It may also want to pay for consultants to assist the impacted operators in meeting their legal, financial, and operational requirements under the new BRT operating contract.

A negotiated process may take a long time, and the operator representatives may require that they be remunerated for attending the meetings involved in the negotiation process and meetings with their constituencies for report-backs, mandating, and so on. The city needs to decide if it will accede to this—it may take the view that representatives of vested interests should not be remunerated for taking care of their own interests. Remuneration can also create the wrong incentives—to participate even where there is no commitment to the project, and to prolong the process. If remuneration is deemed acceptable, it needs to be decided how to structure it. One method may be to pay representatives a fixed remuneration amount upon the achievement of certain milestones in the process. Another way is to pay a fixed allowance per meeting, with a limit set to the number of meetings that will be remunerated. Another is to agree to a total “brokerage” fee paid at the end of a successful negotiation process and divided among the operators’ representatives according to the number of meetings attended by each.

In some cities, the relationship between the government and the informal impacted operators is one of mutual suspicion and mistrust. In this case, the process may have more chance of success if the talks are independently chaired and facilitated, rather than run by the city itself. This has the advantage of creating trust in and respect for the negotiation process, even if the parties do not fully trust each other. A person or team that is skilled in facilitation, negotiation, mediation and conflict resolution should be sought. A selection process that is jointly run by the city and operator representatives is ideal in choosing a person/s trusted by both parties.

A negotiation plan should be drawn up at the outset of the talks and endorsed by all parties as the first milestone in the process. This should deal with topics including:

- Parties to the negotiations;
- Objectives of the negotiations;
- Scope of the negotiations;
- Milestones;
- Timeframes;
- Representation (number of representatives per party, reporting back and mandating);
- Advisers;
- Allowances;
- Independent facilitation;
- Negotiation committees and subcommittees and roles of each;
- Decision-making process (particularly in multiparty negotiations);
- Dispute resolution and deadlock-breaking process;
- Conduct of parties and negotiation procedures and protocols;
- Media liaison;
- Secretariat.

The negotiation objectives will be likely to include reaching agreement on:

- The VOC contract;
- Compensation;
- Formation of the VOC—ownership, shareholding, structure;
- Plan for removal of competing vehicles and routes;
- Accommodation of displaced staff of affected operators;

- Company setup and operationalization.

The city, through its legal advisers, should prepare a draft VOC contract and present it to the negotiations. The city strategy will determine the content of the draft VOC contract, which is typically a gross-cost contract, where the VOC will be paid a fee per kilometer for each kind of bus.

In the negotiations with the operators, the financial negotiation is a key part of reaching agreement on the contract. The fee per kilometer specified in the contract needs to cover the fixed and variable operating costs of the services, the costs for financing the vehicles (capital and interest repayments), and company profit. There needs to be a fee per kilometer specified for each type of bus that will be used.

In the negotiation, both the city and the operators will ideally have financial advisers with models to simulate the finances of the VOC over the contract period—including preparing a balance sheet and annual financial statements—and able to determine the required fee per kilometer. The three main components for the fee per kilometer are:

- The operating cost calculation will include personnel costs, statutory levies on staff, vehicle fixed costs such as license fees and vehicle insurance, variable costs including fuel, oil, tires, maintenance and spares, overhead and administration costs, and company tax;
- The vehicle capital cost—interest and capital repayments—will be determined outside of the negotiations by the fleet financing arrangements that are settled with the financiers (either by the operators or by the city, depending on who is procuring the fleet);
- The third component is the allowance for profit.

Both operators and the city may present their financial proposal simultaneously and agree at once if they are within a narrow range of each other, say 5 percent. However, if they are far apart, a number of approaches can be followed. Each component can be subjected to a negotiation until settlement is reached. The operating costs are factual items—e.g., the price of diesel and the cost of the maintenance contract—and so spreadsheets can be compared and assumptions, e.g., about dead mileage or fuel consumption, compared and agreed.

The profit margin will be more controversial and will also be the subject of negotiation. If existing traditional or informal operators are being persuaded to take the risk of giving up their known livelihoods in return for something less certain, a commercial markup may simply not be enough of an enticement. The level of profitability may need to be sufficiently high to persuade the operators that participation in BRT will leave them better off than remaining with their existing taxi businesses.

The city strategy discussed earlier will have a negotiating position built into it about the upper limit of profit rate that its budget—or system revenues, if the system is designed to be self-funding—are able to handle.

If there is a deadlock, the dispute resolution procedures agreed in the Negotiation Plan will need to kick in. This may comprise several steps, such as nonbinding expert determination by which the city will be advised before making its final offer. If agreement cannot be reached, fallback positions may need to be exercised, such as awarding the whole contract to only those operators who are willing to accept the offer, or such as putting it out to competitive bidding of one form or another.

Other aspects of the VOC contract may also be contentious in negotiations. The city may, for example, want to limit allowable changes in ownership to a noncontrolling percentage, in that it had certain industry transition or transformation objectives in mind in including the affected operators in the first place. For them to then sell the shares to outsiders may not be acceptable in this context. Johannesburg limited this in its VOC contract to no more than 24.9 percent and no sooner than a year after the contract signature date. Bogotá also forbade the selling of shares to outside parties for five years to protect the indigenous operators' control (Hook, W. 2009).

Contract length will also be debatable and should also be covered in the city strategy. The length should be sufficient enough that the useful life of the vehicles can be used. Operators may want to make it as long as possible, and they also may want to extract guarantees that at the end of the contract it should be renegotiated with them again. The city should decide its approach in this regard and know the legal requirements in this respect.

The contract also needs to provide for requirements on the VOC to replace old vehicles if necessary in the course of the contract, and to require new vehicles to be purchased if the BRT entity deems that customer demand warrants this. The contract needs to specify adjustments to the fee per kilometer if this happens and is necessary, as well as the treatment of vehicles at the end of the contract, which still have useful life (e.g., compulsory buy-back by the city at the end of the contract, cession to the next contract holder, etc.).

Another area that becomes the subject of negotiation in a contract is maintenance. Where a company is to be formed by inexperienced operators, the city may seek a level of comfort in requiring that a maintenance contract is in place with the bus chassis and engine manufacturer, at least for the first three to five years of the contract. Experienced VOCs often prefer to carry out maintenance through in-house workshops and to achieve significant savings in input costs this way. Thus, the maintenance regimes are an important part of the negotiation.

16.6 Company Formation

> *"If you want to build a ship, don't drum up people together to collect wood and don't assign them tasks and work, but rather teach them to long for the endless immensity of the sea."*
>
> — Antoine de Saint-Exupéry, writer, 1900–1944

One of the biggest challenges is transitioning a group of informal public transport industry owner-operators into high-quality modern vehicle operating companies. Compensating impacted transit owners in the BRT corridor is not the only consideration when hiring a VOC composed primarily of impacted owners to operate the BRT services. The BRT authority should also make sure the company is successful and able to provide the best quality of service at the lowest price over the long term. There is a big difference from a management perspective between owning and managing a few individual buses or minibuses with route licenses and owning shares in a modern bus company with integrated fleet management and optimized maintenance regimens.

Successful VOCs have a few things in common. All of them have competent senior management. They also have found sufficient working capital. All of them work out of a secure depot, either provided by themselves or by the city. And all of them have integrated fleet ownership and management, meaning that the vehicle fleet is owned by the company and not its individual owners, and the maintenance of the fleet is done as a fleet and not as single vehicles owned by separate individuals. Successful VOC attributes include:

- Skilled senior management;
- Sufficient working capital;
- A secure depot;
- Integrated fleet ownership and maintenance.

Some of the most successful BRT VOC companies are joint ventures between the former impacted owners and larger international companies that brought with them the possibility of placing large bulk orders of spare parts directly with spare parts manufacturers. Some brought with them skills from trucking and logistics that have optimized the deployment of staff, the utilization of vehicles, and optimized maintenance regimens. Other larger vehicle operating companies have their own credit history with major banks that lowers their cost of credit. And some of them already have their own depots.

Not only the city and the BRT customers, but also the existing owners receiving compensation in the form of shares in the new VOC, have a big stake in the commercial success of the VOC. Shares in a poorly managed company that is not in a position to win contracts on future BRT corridors and in other cities is going to be worth less than shares in a competitive, fully professional BRT operator.

It is therefore important to explain to impacted owners that they can become shareholders of the new operating company, but that as shareholders they may not play a direct role in the management of the new company. If the impacted owners are not very sophisticated, they may not think strategically about the long-term interests of the company. It may in some instances be advisable therefore to make them "preferred" shareholders without voting rights. As shareholders they will need to hire the management team, and this management team may not necessarily be the best if it comes from within the ranks of the impacted industry.

Table 16.3. Select BRT system operators by ownership type.

BRT Operator Ownership Type					
BRT System	Former Minibus Operators Formed into Companies	Mixed Former Minibus and Private Investors	Former Private Bus Companies under New Contract form	Outside Investor, Truck or Intercity Bus Operator	Municipal Bus Company
TransMilenio, Bogotá	X	X			
GBRT, Guangzhou			X		X
Curitiba (Brazil)			X		
Guadalajara, (Mexico)	X	X			
Lima (Peru)			X		
Rio de Janeiro (Brazil)			X		
Yichang (China)					X
Belo Horizonte (Brazil)			X		
Perreira, (Colombia)	X	X			
Mio, Cali, Colombia	X	X			
Jan Marg, Ahmedabad				X	
Rea Vaya, Johannesburg	X				
Metrobús, Mexico City Lines I - II	X				
Metrobús, Line III	X			X	
Guayaquil (Ecuador)	X				
Metrobús, Mexico City, Lines IV - V		X			
TransJakarta, Jakarta	X			X	
Lanzhou, BRT					X
MiCity, Cape Town	X		X		
LiteBRT, Lagos	X				

Courtesy of Walter Hook, BRT Planning International, LLC.

In most of the Colombian BRT systems, the BRT VOCs were consortia between national and international bus operating or trucking companies and the impacted owners of the route licenses, which tended to be large bus enterprises. This pairing has worked well as it compensated the impacted owners, utilized the management skills that were already present at the bus enterprises, and brought in outside management skills from the joint venture partners where this was needed.

In some cases, it is difficult to form consortia between impacted owners and major companies. Sometimes the impacted owners are not comfortable working with larger, more established vehicle operating companies (VOCs) and vice versa. In South

Africa and Mexico, the BRT VOCs tend to be dominated entirely by the impacted owners, who in turn went out and hired the necessary management teams. Some hired individuals to fill the management positions, and others hired firms.

It is fairly typical to have the bus supplier maintain the vehicles under a medium term service contract until the new BRT VOC has mastered the skill of bus maintenance. This is very expensive in the long run so the sooner the VOC is competent to take over the maintenance the more quickly the firm is likely to be profitable.

In cities where there are already established vehicle operating companies with integrated fleet management, or in cases where there were no impacted owners, the issue of management skill is less critical. In Brazil, most of the BRT systems are operated by the same big private bus companies operating under zone-based gross cost contracts that emerged in Curitiba in the 1960s and in most other cities of Brazil by the 1990s. Most of them have competent management. In China, and parts of India, the BRT systems are operated by municipal public bus companies. Although these municipal operators can be obstacles to improvement service provision, they generally have the basic skill to provide the service. Ahmedabad and Guangzhou are exceptions. Bus operations in Guangzhou were put on a commercial footing already in the 1990s and the BRT is operated by three consortia, all of them a mix of public and private ownership but operating as commercial companies. Ahmedabad's BRT was built where there were no competing bus operations, and a private firm out of the trucking industry was hired.

A VOC typically has several key senior management positions that need to be filled with qualified staff:

- A managing director/chief executive officer/general manager;
- Financial manager;
- Operations manager, in charge of bus and driver dispatch, coordination with the BRT entity on bus schedules, monitoring bus arrivals and departures and driver performance, optimizing operations and control, etc.;
- Technical manager, in charge of the depot, workshops, and maintenance systems;
- HR manager.

Typically, whether the operating contract with the VOC is tendered or turned over to the impacted operators, the BRT project team on behalf of the city needs to require that the company demonstrate that it has a competent management team in place.

If the contract is tendered, if the city is allowed to have the tender competed on both quality and price, then the qualifications of the management team were a critical part of the evaluation of the quality score of the tender. If the tender can only be done based on cost, or if the contract is to be negotiated with the impacted owners, then demonstrating that a competent management team has been selected should be part of the minimum qualification requirements. The board of directors has to present a management plan indicating how the company will be staffed and resourced, and to demonstrate that sufficient skills, expertise, and experience have been brought on board to fulfill the conditions of the contract.

There are three basic ways to attract qualified management:

- Find qualified management from within the VOC's own ranks;
- Have the VOC partner with an experienced BRT operator in a consortium;
- Have the VOC partner subcontract the management to a qualified BRT operator.

If the impacted owners are already reasonably sized corporate entities with business skills, it is possible that they can draw many management positions from within their own ranks. For instance, in Brazil, where the bus industry has been largely private since the 1990s and the big bus operating companies are corporate entities with existing management structures, finding qualified management from within the bus industry should be relatively easy.

If the industry is not yet corporatized and is controlled mostly by individual owner operators, getting skilled corporate management will be a bigger challenge. The safest strategy is to require joint ventures between the impacted owners and formal bus operators to form the new VOC. This has the advantage of allowing experience to be shared. Ideally the operator will have experience operating BRT companies, but often an intercity bus company or trucking company can learn how to manage a BRT operation. It is possible, however, to have the impacted owners sign a management contract with a qualified firm to manage the company, or to hire talented individuals to manage the company on behalf of the shareholders.

16.6.1 VOC Formation in Bogotá

The discussion of BRT VOC formation begins with Bogotá, because the companies that emerged out of TransMilenio went on to successfully operate BRT systems in a number of other cities, not only in Colombia but also in Peru and other Latin American countries.

Bogotá did not make a political commitment that no adversely impacted license owner, bus owner, or driver would be worse off, but it did give impacted owners competitive advantage in the tender. In Bogotá, bus "enterprises" owned the licenses and small individuals owned the vehicles. Thus, the bus enterprises had more management experience, the capital needed to procure the new vehicles, and the political power to block the entire project. As such, the bus enterprises became the natural basis for the new BRT VOC companies.

To ensure that both the bus enterprises and the bus owners became owners of the new BRT operating companies, the tender required that the company have "experience operating buses" in the affected corridors. This was basically a way of ensuring that all of the bus "enterprises" would win part of the new contract. The contract also required that at least 15 percent of the shares of the new company be owned by affected bus owners whose names were on the city's list of impacted owners. They had to demonstrate experience operating public transport in the *specific BRT corridor (meaning specifically the affected owners)*. Operating public transport elsewhere in Bogotá also gave points, though somewhat fewer.

Of this 15 percent of the shares, the maximum number of shares that could be given to any one person was only 0.15 percent in order to ensure that most of the affected owners would be able to get at least some small share. If a person wanted more than this 0.15 percent of the shares in the new company, he or she could buy more, but then these shares did not count toward the 15 percent of shares from affected owners.

The contract also required that three vehicles be turned over to the government for scrap for every one bus that needed to be bought. The company was required to scrap a minimum number of old vehicles per each new vehicle procured. This requirement meant that those adversely affected bus owners would be able to sell their old vehicles to the new company and get some compensation either in the form of cash payment or in the form of stock in the new company. The contract also forbade the selling of stock to outside parties for five years to protect the indigenous operators' control.

These affiliated enterprises and cooperatives were not modern bus companies. They did not own most of the vehicles under their control, so there was no collective fleet management. The bus operators were also not generally their employees, so there was no collective staff management, no standardized maintenance regime for the vehicles, nor any of the other critical attributes of a modern bus company.

The tendering documents were created in such a way that they guaranteed that the winning Phase 1 companies would be owned mainly by the existing affected bus enterprises. As of the completion of Phase 2, 98 percent of the transport companies in the city owned shares in one of the seven operating companies.

Each company also had to demonstrate that it had the minimum required equity. The minimum equity requirement was 15 percent of the value of each bus being offered in the tender (each bid offered a total number of vehicles within a given range). They also had to demonstrate that they had financing for the remainder of the vehicle procurement cost. If the company could find a financial institution willing to lend money for 95 percent, then the equity share could be lowered to 5 percent.

The operating companies also had to demonstrate that they had a qualified management team with experience operating large fleet bus companies. Forming a joint venture with an experienced international partner won extra points in the bid.

These bidding criteria, which were informally negotiated with the bus industry during the engagement period, gave the existing bus enterprises a significant advantage in winning the tenders. As a result, virtually all the bidders were companies dominated either by existing bus enterprises or outside investors who found partners among the existing bus enterprises.

Beyond the terms of the tender, the share structure of the new vehicle operating companies was not dictated by the government, but rather was sorted out within the new companies internally. Shares were awarded based on paid-in capital, on the number of vehicles turned over to the parent company to meet the scrapping requirement, and on the public transportation management experience the company could bring to the new entity.

Raising the necessary capital for the minimum equity requirement and the cost of the vehicle procurement forced most of the bidding companies to forge partnerships. The City of Bogotá never offered any municipal guarantees for bank loans for vehicle procurement, so securing the necessary financing was a big concern of the transporter companies. The only thing that Bogotá offered the banks was a letter stipulating that if the municipality did not allow the fare to rise with the formula agreed to in the operating contract, the municipality would pay compensation into TransMilenio's trust fund.

While some of the operators had relationships with banks from Brazil because they had bought Brazilian vehicles before, others were forced to look for partners with formal sector companies that had credit histories and relationships with the banks. In a couple of cases, outside investors approached affected owners and agreed to form a company together, and the outside investors had connections with banks. However, in Phase 1, it was actually not that easy to find investors from outside the bus industry willing to jump into the Bogotá bus business. Most vehicle operating companies that did so were from related industries (vehicle suppliers, trucking, etc.). Those that expressed interest wanted to find local bus operator partners not only to meet the tender requirements but also to run the business effectively.

The city worked with these consortia in approaching private banks. The banks were very reluctant to lend money to these transporters because the transporters were an informal economic group without a financial history. In the end, some of the final operating companies did secure financial support from private Colombian banks, and others from Brazilian banks such as BNDES, the Brazilian development bank and export credit agency, since the Brazilian banks were more familiar with BRT systems.

The problem of securing loans was also partially solved by the creation of a trust fund to collect the fare revenue. Banks have primary access to the fare revenue to repay the loan. Once this was established, it was a lot easier to convince banks to provide financing.

In Phase 1, fifty-eight of the sixty-four preexisting bus enterprises or collectives participated in the bidding process, and three of the four trunk operating companies were majority-owned and operated by former affiliated bus enterprises. The trunk companies were Si 99, Connexion Movil, Metrobus, and Expresso del Futuro.

Si 99 was formed from the largest independent affiliated bus enterprise. Its shareholding was 40 percent from one family, 15 percent from five other affiliated individuals who were friends of the family, 44 percent came from small individual owners, and a very small share went to RATP (1 percent), the French public transport operator. The main reason for the inclusion of RATP (the French commuter rail provider) was to secure from it some critical software used for scheduling, and to secure the additional points in the tender from having an international partner.

Together, this included twenty-four of the separate integrated bus enterprises and three cooperatives, as well as over six thousand individual small bus owners. In Phase 1 there was no restriction in the contract that prohibited the resale of shares, so the cooperatives sold their shares after only two years at a very high price.

Another Phase 1 operator was Ciudad Movil. Ciudad Movil is a subsidiary of Connexion Movil, which also owns a Phase 2 operating company also called Connexion Movil. Because Ciudad Movil decided to tender operations, the possibility of one company owning operators in different phases emerged, naturally to the benefit of the early adopters.

Some 40 percent of Connexion Movil's shares were bought by a Colombian industrial conglomerate called Fanalca that also owns "Superpolo." Superpolo is a bus body manufacturer that is a consortium between Marco Polo (Brazil) and Superior (Colombia) that has joint ventures now with Tata in India, with a bus factory in Changzhou, China, and in Monterrey, Mexico. Another 20 percent was owned by Connex, the French transport company that was later bought by Veolia Transport, a large international transport conglomerate. The remaining 40 percent was owned by the largest affiliated bus enterprises in Bogotá. As there was no restriction in Phase 1 on the resale of shares, Veolia has since bought some of the shares from the Colombian affiliated enterprises. Connexion Movil now owns not only Ciudad Movil, but also Connexcion Movil (the Phase 2 trunk operator), City Movil (a feeder operator), Transantiago in Santiago, and a bus operation in Cartagena. The link with the international company no doubt has played a role in the rapid expansion of this company's international operations. It is this company that has an operating agreement with the Rea Vaya Phase 1A operator, as discussed later.

Express del Futuro, another Phase 1 trunk operator, was initially formed 100 percent from thirty-four traditional affiliated bus enterprises. Over time the company has achieved ISO 9001 (quality certification), ISO 14001 (environmental certification), and OHSAS 180001 (industrial safety certification). One of these was a contractually required target, but the others the company did on its own initiative. It bought over twenty vehicles initially purely with equity because the company could not initially get bank financing. As the company needed more capital, over the course of the first year it called for an open expression of interest and found private investors who negotiated a 33 percent stake in the ownership of the company. The outside investor was put in charge of managing negotiations with bus suppliers and the banks. In the end, a bank finally closed the loan on the basis of individual guarantees of the outside investors, and the bank also required primary access to the trust fund (where the fare revenue is deposited), in addition to requiring the contract with TransMilenio that ensured a basic income to the company. This eventually led to a 30 percent/70 percent debt to equity ratio, which left a good profit margin. By Phase 2 the company had no problem at all securing a loan for US$350 million from HSBC. It now also owns Tao, a Phase 2 feeder service provider.

The last Phase 1 trunk operator was Metrobus. Some 20 percent of the company was initially owned by the affiliated enterprises, and the remaining 80 percent came from a single outside investor that managed a big trucking company. Since there was no restriction in Phase 1 on the resale of stocks, over time the trucking company eventually bought out all but about 1 percent of the remaining shares.

All six of the Phase 1 feeder bus companies were composed entirely of former affiliated bus enterprises. As such, fifty-nine of the sixty-six affiliated bus enterprises bought into TransMilenio after Phase 1.

Three problems became apparent during Phase 1:

- The mayor (by this time, Mayor Antanas Mockus) was concerned that Phase 1 had not sufficiently encouraged shareholder participation by individual bus owners;
- The scrapping requirement was too low, so many vehicles relocated to parallel arterials, badly congesting and polluting these parallel roads and competing with TransMilenio services;
- The mayor had also become concerned about the equity ramifications of the consolidation of stocks after the companies began operations. Mockus did not want a situation where a company formerly composed of bus owners would be taken over by an international conglomerate.

These issues were addressed in Phase 2 as follows:

Having 25 percent or more of the shares owned by small individual bus owners gave the bidder more points in the tender. In Phase 2, the shares owned by the small bus owners could not be resold for the first five years in order to avoid a takeover by an international conglomerate.

Because of these requirements, the stock composition of the companies turned out as follows:

- Si 02: 25 percent small individual bus owners, 75 percent affiliated bus enterprises (largely the same people as Si 99);
- Transmasivo: 25 percent small individual bus owners, 75 percent from 20 traditional affiliated bus enterprises. So far it has not secured any contracts outside of Bogotá;
- Connexion Movil: 25 percent small individual bus owners, 10 percent the biggest affiliated bus enterprises, 40 percent Fanalca, and 25 percent Connex (Veolia).

Finding a management team was another reason that some companies, but not all, opened up the company to outside investors. Most vehicle operating companies recruited management mainly through the use of an employment agency. In other cases the bus companies were owned by large companies established a long time ago and they had management skills among their own companies. Si 99's general manager, for instance, was the son of one of the largest bus enterprise owners in Colombia, previously working as a manager in the state oil company, and came back to run the family business. Other management people were hired from the trucking industry.

Most of the people involved in the process now feel that it might have been better if the small owners and collective bus drivers would have been given “preferred” stock. This would have given them priority in terms of the payout of dividends and liquidation, and it would have inhibited the buyout of their shares, but removed their voting rights. The membership of the board should be constituted of transport professionals rather than ownership-based. Shareholders would be welcome in the general assembly but should not be part of the board.

The City of Bogotá also financed the construction of depots and offices for the operators, one for each of the trunk bus operators. Since the depots were owned by the city, this gave the city some control over the operator, as the BRT authority could have its employees in the depot monitoring vehicle departures, maintenance, and so on.

16.6.2 VOC Formation in Mexico City

In the case of Mexico City, the city dictated both the stock ownership structure of the new company and the management structure of the new company. Both turned out to be imperfect and had to be modified later.

In order to avoid disputes among the members of the Ruta 2 Insurgentes association, the city decided, in dialogue with Ruta 2 Insurgentes, on the stock ownership structure of the new company. Not 100 percent of all the Ruta 2 drivers were impacted even on Insurgentes, so the Mexico City administration first determined which buses were impacted. If the bus route only overlapped the corridor for less than 50 percent of the route, it was not pulled out of operation and the operator was unaffected.

Secondly, as a condition for signing the operating contract with the newly constituted company, CISA (see "Company formation" below) required that the current operators turn over all of the affected vehicles for scrapping by the city. This scrapping requirement was directly related to the capital composition of the new company.

The city required some starting capital, approximately 15 percent of the cost of the vehicles. This worked out to be about US$10,000 per vehicle in cash that the operators needed to raise. In addition, they had to turn over their vehicles for scrap. They received US$7,500 for each vehicle scrapped as a scrapping allowance from the city. This, together with the US$10,000 per vehicle of cash investment, constituted roughly the 15 percent starting capital they were required to raise. This did not include any working capital, so they later regretted this decision and wished that they had required more starting capital. This company strongly recommended that in the future phases the starting capital be set at a level sufficient to cover all start-up costs or there will be serious financial instability in the opening period of the company. The company was profitable with this number of shareholders.

The government initially secured a loan from HSBC to cover the remainder of the vehicle procurement cost, and CISA had to accept this loan, as it was guaranteed by preferential access to the trust fund where the fare box revenue is deposited. The interest, at 14.5 percent, was pretty high. CISA eventually found a local bank willing to refinance at 11.5 percent, which significantly lowered its operating costs and increased its profits.

The municipal government of Mexico City dictated to Ruta 2 Insurgentes that the stock composition of the new company was going to be one share of stock for one vehicle turned over to the city for scrap. There were 262 buses that operated in the corridor that needed to be removed, and these were owned by 180 shareholders. There was a law in Mexico City that a bus owner could only own five vehicles, so the number of shares per owner ranged from one to five. Thus, the total number of shares was 262, divided proportionally among 180 shareholders.

The selection of the management team of the company was fairly straightforward. The general manager of the Ruta 2 Insurgentes association was considered to be a good manager and was therefore unanimously elected to be the new general manager. He knew he would not be able to manage all the functions of a modern bus company, however, so he quickly hired an outside expert, a transport professional and university professor, who became the operations manager. The operations manager in turn brought in several other people capable of optimizing maintenance regimens for big fleets, managing large numbers of personnel, training, and other management needs.

CISA took about two years to establish good maintenance regimens, scheduling, and labor practices. The company believes that an international partner might have reduced this learning curve substantially. However, now it is providing consulting services to Phase 2 BRT companies, non-BRT bus operations in Mexico City, and bus operating companies in other cities in Mexico.

In Phase 3 Metrobús, an intercity bus operator, offered to give shares in the parent company to all the affected owners in exchange for allowing them to take over the operating contract. In this way, the bus owners got shares in a more powerful national company and not just shares in a specially created entity. This is a model that could be further explored in other venues.

16.6.3 VOC Formation in Jakarta, Indonesia

In Jakarta, there were four major bus leasing companies operating on the Phase 1 corridor. One of these was a national government owned bus company, PPD. Three of them were bus leasing companies. These companies were not fully transparent corporations meeting ISO corporate governance standards, but they did have bylaws, corporate identities, stockholders, and working capital. These bus companies owned fleets of vehicles and they controlled all the route licenses. These route licenses were not very cleanly registered but most had some sort of route license.

The governor of Jakarta decided to create a BRT company mostly out of the impacted operators. He had been to Bogotá and understood the process there. The company he created was called PT Jet. It had only one month prior to the start of operations. The governor forced these four impacted companies to join with a fifth company that operated taxis in the corridor. The reasoning behind adding the automobile taxi company to the consortium was that the governor believed the taxi company was well managed and also somewhat affected by the new service. These five companies were forced by the governor to become a consortium. The shares of the new consortium were divided roughly based on the number of vehicles operating on routes that overlapped more than 50 percent with the Phase 1 corridor, and the share of the new company, Ratax, was negotiated from this. The share structure is not very transparent. Jakarta did not require the old vehicles to be scrapped. Because these parent companies already had working capital, and were already corporations, they simply divided up the shares among the parent companies based roughly on the share of affected routes, and these parent companies remained the owner of PT Jet, the new consortium. The negotiations were quite easy because they were headed by the heads of the impacted companies.

PT Jet was not undercapitalized, but the company had numerous problems in the beginning because it had no experience operating an integrated bus company, as it was leasing companies and not operating companies. International technical advisers were donated to the companies to develop scheduling protocols and personnel protocols but much of this type of information is proprietary so the technical support was not entirely successful. The company did not operate particularly well, though the problems were mostly sorted out over the first several years of operation. Jakarta also did not supply the operator with a fully equipped depot, which may have contributed to poor vehicle maintenance.

In Phase 3, TransJakarta tendered out operations for some 40 percent of the service. The company formed of the 60 percent was a former affected collective with weak corporate governance and high operating costs. The quality of service was quite low and the cost per kilometer was high. The tendered part of the service was contracted out to a private intercity bus operator that was a modern bus company with no ownership from affected owners. The government argued that as the government paid 40 percent of the total capital investment (inclusive of vehicle procurement) it had the right to tender out 40 percent of the market. The service provided by the outside operator tended to be better than the service provided by the impacted bus owners.

16.6.4 VOC Formation in Johannesburg

In Johannesburg, the creation of the vehicle operating companies from affected minibus taxi operators was done through negotiation with affected owners without any element of competitive tendering, which in turn required a more interventionist approach to company formation on the part of the CoJ.

Because the negotiations with impacted owners had not concluded by the time operations needed to start (to provide service for the 2010 World Cup), the city needed to buy the vehicles on behalf of the future VOC, and find an interim operator. The financial adviser hired to finance the vehicle procurement (HSBC) set up a temporary company that owned the vehicles and was responsible for repaying the loan. This "paper" company service was essentially run by the department of transportation of the CoJ. The loan by HSBC to the paper company was guaranteed by the CoJ. This temporary company created by the CoJ started using many of the impacted drivers, but it supplemented this with former and current Metrobus (the Johannesburg municipal bus operator) management. This company operated the Rea Vaya BRT system until the negotiations with the affected taxi owners could be concluded.

Because the impacted owners in Johannesburg were being formed into one company from nine often competitive separate minibus taxi associations, and it was difficult for these associations to come to agreement on a shareholding structure for the new operating company, the CoJ ultimately had to dictate the basis of stock ownership in the new company. The taxi negotiating committee itself, after many months, had made little progress on its own and did not object to the CoJ dictating the shareholding structure, largely as a way of avoiding internal acrimony.

The CoJ decided on the following process to becoming a shareholder. First, it decided that the total number of shares in the new company would be 575, representing one share for each minibus taxi that needed to be withdrawn from service and turned over for scrap or resale to a CoJ-appointed leasing company. Shares could not be based on route licenses because the route licensing was so poorly organized.

The CoJ, based on impact area, determined the allocation of vehicles that needed to be removed per association, and shares per association as in the table below. In this way, shares would be divided up among the associations in proportion to the number of routes that were affected. The associations were not, however, formally recognized as parties to the negotiation.

Table 16.4. Distribution of Shares in the Vehicle Operating Company by Taxi Association Affiliation

Taxi Owners Belonging to the Following Taxi Associations	Distribution of shares in the VOC
Soweto Taxi Services (STS)	180
Witwatersrand African Taxi Association/Johannesburg Taxi Association (WATA/JTA)	129
Nancefield-Dube-West Street Taxi Association (Nanduwe)	77
Meadowlands Dube Noord Street Taxi Association (MDN)	90
Diepmeadow City Taxi Owners Association	59
Bara City Taxi Association	13
Noordgesig Taxi Association	9
Dobsonville Roodepoort Leratong Johannesburg Taxi Association (Dorljota)	7
Faraday Taxi Association	6
Johannesburg Southern Suburbs Taxi Association (JSSTA)	5
Total	**575**

When the owner registered as an affected owner (described above) the operator was given a verification document authorizing them to do one of two things:

They can opt to become a shareholder in the new VOC, in exchange for which, they have to turn over to the CoJ this verification document along with at least one valid operating license and all the vehicles they wish to turn in. They would be given one share per vehicle turned in.

Alternatively, parties may opt out of the BRT system. The initial thought was that those choosing not to be part of the BRT company for whatever reason would be able to use the verification document to receive a new, enforceable route license under a new regulatory regime established under the CoJ. In the end, while the CoJ closed the most important taxi ranks (*daladala* parks) and scrapped 575 vehicles, some taxi operators who chose to opt out continue to operate along all or part of the BRT corridor, eroding the customer base of Rea Vaya. Previously, route licensing was under the provincial government, where it was poorly managed. New legislation gave the power to the city, but this power was only gradually taken over by the city. As a result, the CoJ had yet to develop the power to regulate the competing routes other than through the closing of taxi ranks.

With the help of technical advisers of their choosing, paid for by the city, impacted owners wishing to become shareholders in the Rea Vaya operating company formed "taxi operator investment companies," or TOICs, one for each of the nine taxi associations to which the owners belonged. Owners were entitled to buy one share in a TOIC for each taxi they took off the Phase 1A routes. They also had to cancel its operating license. Each had to invest US$5,157 per share (converted from R54,000 with a January 2014 rate on XE.com) held into the company equity, which is the amount of money the government pays for the scrapping of old taxis. More valuable vehicles were sold by the company hired by the city to handle the turnover of vehicles.

After the negotiations were concluded with the impacted operators, the temporary company set up by the city to run the services was then sold to the nine TOICs, who designated thirteen nonexecutive directors to the company's board, appointed one of the taxi leaders in the negotiations, Sicelo Mabaso, as chairperson, and renamed it "Piotrans." This was to reflect, in their words, "the pioneering steps of the taxi operators who have decided to transform and grow into the fully fledged public transport operator as part of the public transport transformation process in the city and South Africa."

In other words, the company inherited by the taxi owners was already a going concern with seventeen months of operations before the affected minibus taxi owners took over the ownership. Staff were already employed, including a full complement of drivers drawn from the taxi industry and trained by Scania to drive the vehicles. A three-year maintenance agreement for the vehicles was in place with Scania. A depot built and owned by the city was in operation with a fuel-supply contract. The 143 vehicles had been procured by the city on behalf of the company, the financing had been arranged, and while the company was responsible for repaying the loans to the Brazilian ECA, the City of Johannesburg stood ultimately as responsible for their repayment.

There was a six-month period during which handover from the management of the temporary company to the new board and management occurred. In this time, the city provided an in-depth orientation and capacitation program for the new board of directors and mentoring for the new management team. Penalties for nonperformance in the operating contract were only introduced after an initial grace period.

The CoJ required, as a contract condition, that the new company enter into a management contract with "a suitably experienced bus operating contractor and/or key management personnel." Fanalca, the large Colombian industrial group, was announced in early 2010 by the taxi leadership as its choice of experienced bus operating contractor. Fanalca, among other operations, has BRT operating companies running 5,000 vehicles in South America. It operates BRT as part of TransMilenio (Bogotá), Transantiago (Chile), Metrobus (Panamá), MIO (Cali), MetroSinú (Montería), and SITP (Bogotá). It subsequently established Fanalca South Africa as a local subsidiary.

The understanding from the outset was that it would be both a management and an equity partner. The city thus agreed to amend the bus contract to allow the shareholders (TOICs) to sell a maximum of 24.9 percent of the shares to a suitably experienced BRT operator approved by the city, no sooner than a year after the signature date. The proceeds from selling the shares could only be used for the purpose of capital expenditure and/or working capital for the bus company. The nine TOICs and Fanalca entered into a heads of agreement, outlining the management and operational support which Fanalca would provide to Piotrans, and that discussions leading to Fanalca acquiring the allotted shares in the company and becoming a co-owner with the TOICs would take place a year from inception of operations.

Sicelo Mabaso, the chairman of the Piotrans board, said the decision to partner with Fanalca was done to ensure the success of the company. He said, "This is a totally new project, and we need to deliver a professional service. We looked locally and found no one, so we had to look at successful BRT systems." Regarding the proposed sale of shares to Fanalca, he added: "We are looking for sustainability and we felt the best way of ensuring success was by providing them with an interest and stake in the company."

The management team announced by the new directors on February 1, 2011, named Victor Cordoba of Fanalca South Africa as the inaugural CEO. Taxi leaders from the negotiations were placed in the roles of deputy CEO and corporate affairs director. The chief financial officer from the temporary company stayed on, as did the majority of incumbent staff, and roles such as human resources and company secretary were filled by South Africans. However, Fanalca supplied a significant number of full-time and part-time personnel to the operation. Fanalca estimated that at any one time, it had up to ten of its staff in Johannesburg working with Piotrans. This included its engineers in the minimum three positions in terms of the heads of agreement, namely the CEO, technical manager, and operations manager, supplemented with three other full-time engineers in the roles of a second operations manager, deputy chief financial officer, and driver trainer. Only costs for the three full-time positions were covered by Piotrans, and Fanalca did not charge any management fee or the costs of other personnel seconded to the operation, nor share in any profits.

Over the fifteen months from takeover, Piotrans has improved on many aspects of the service compared to the performance of the temporary company. For example, by May 2012, levels of absenteeism, breakdowns, accidents, maintenance costs, and dead kilometers were all significantly reduced. The number of vehicles washed per day doubled and 99.86 percent of scheduled kilometers were being operated.

In February 2012, a year had elapsed from the launch of Piotrans, opening the way for the sale of shares to Fanalca. However, it began to emerge that there was dissension within the Piotrans board. Various TOIC directors were by many accounts reluctant to sell shares to Fanalca, preferring that ownership of Piotrans should remain with the original shareholders. Others were in favor of honoring the heads of agreement, and selling the allotted 24.9 percent shareholding to Fanalca. The board agreed to follow a negotiation process with timeframes and appointed a negotiation team, but little happened. In Fanalca's perception, there were continuous failures by the board to move forward with this process, or to make progress with producing the proposed transaction document. By mid-May, this had created serious doubt for

Fanalca about whether its huge commitment was reciprocated, and whether a long-term relationship with the TOICs was feasible. It took the view that it had no interest or intention of forcing its participation in Piotrans if the TOICs did not wish to pursue a partnership. In their view, this would create instability, which would be bad for the company, the system, and the customers.

On June 7, Fanalca formally withdrew from any further participation in Piotrans, at both a management and potential partnership level, and terminated its staff services formally from June 13. To avoid a negative impact on customers, Fanalca developed a transition plan and made its technical team available for eight further weeks to hand over the full operation of Piotrans to the TOICS and local staff.

The chair of the board, M. K. Mohlala, who replaced the late Sicelo Mabaso, says that Fanalca decided to withdraw before matters were resolved. He says the talks did not get off the ground because Fanalca pulled out.

Restructuring then took place. A new key position of chief operating officer has been created to oversee the operations and technical functions, and lightening the concerns of many is the news that this will be filled by Javier Cajiao, the former technical manager supplied by Fanalca who has signed a five-year contract with Piotrans from September 1. The technical manager position—for fleet maintenance and in charge of the workshops—has been advertised, while the operations manager position will be taken by Eric Motshwane, the former corporate affairs director and key taxi leader in the negotiations. He was specifically trained and mentored by Fanalca over the past year to assume this role. Mohlala, the chairperson of the board, who will act as CEO for the time being, is confident that service levels will not be compromised. He says, "The skills are replaceable," and adds that a great deal of skills transfer to local staff, reinforced in the two-month handover period, took place. The plan was always for Fanalca to hand over to local management and staff, he adds. He says that Fanalca's technical and operational expertise, the people they sent, and their attention to detail had "overjoyed" him, and that they had transferred a lot of skills to the people they worked with closely.

Among the difficult gaps to fill may be the plan to replace the outsourced maintenance contract with full in-house maintenance. Fanalca had projected to cut overall maintenance costs by 26 percent by doing this. Another is the crew scheduling function where the company will need to purchase software to replace that previously supplied by Fanalca and train staff to use it. In the meantime, the city's Rea Vaya staff will assist Piotrans with this function and the software.

16.6.5 VOC Formation in Lagos

In the case of the Lagos busway system, the new franchise company, FBC, formed by officials and operators from the informal minibus sector, put in place a management team, with some outsourced functions, and recruited drivers (called "pilots") from their informal operations. However, its inexperienced team proved inadequate to the task of managing a controlled and scheduled operation, particularly when the fleet grew rapidly from 100 to 260. The Lagos Metropolitan Area Transport Authority (LAMATA) stepped in and provided relevant expertise to the inexperienced company in the form of a specialist from one of the major private sector bus and coach operators in Nigeria. It also required the outsourcing of vehicle maintenance, financial management, and operational management, including all human resource issues. LAMATA also stepped in and divided the fleet and drivers into four units of fifty-five vehicles, each with its own operational manager recruited by LAMATA, and a fifth carrying out scheduling. FBC plans to understudy and replace the functions provided by LAMATA recruits or outsourced contractor, but this will take a considerable time (Integrated Transport Planning Ltd., 2009; and Mobereola, D., 2009).

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17. Funding and Financing

"Money never starts an idea; it is the idea that starts the money."

— W. J. Cameron, journalist, 1878–1955

This chapter reviews how the capital costs of many of the best BRT systems around the world were both funded and financed. Any BRT project must be funded in order to get built. Sometimes, if the funds are not available up front, debt financing can help ensure that a BRT project gets built, or gets built faster. Funding and debt financing, however, are different and will be discussed separately. While debt financing and private investment can often provide crucial investment capital for a BRT project, a private investment has to yield a return, and a loan has to be repaid, so the ultimate source of funding has to be either the system's own revenue, primarily fare revenue, or some form of government funding. This chapter reviews how many of the world's better BRT systems have secured the necessary funding and financing needed to become operational.

A BRT system should be designed to cover at least its basic operating costs from its own fare revenue. In lower-income economies where most people depend on public transport, this is usually possible. In higher-income economies, while public transit rarely covers its operating costs, the introduction of BRT should generally be profit-neutral or better. In other words, it should not impose significant additional operating costs that need to be funded, and in the best cases it can significantly reduce ongoing operating losses from traditional bus services. As such, the best way to fund operations is by designing the system to cover its operational costs from fare revenue. Other chapters provide guidance on how this can be done.

If a new BRT system is developed that will face ongoing operational losses, as has occurred in a few countries such as South Africa, it is best to have a sense of the scale of these losses in advance and to plan accordingly. This chapter provides limited guidance with respect to how to fund and finance the operating losses of a BRT system other than to say that they should not be debt financed, and the source of public revenue should be recurring (i.e., general taxation) rather than a onetime source of revenue (such as the proceeds from the privatization of a power plant or sale of public land).

17.1 A Strategic Overview of Funding and Financing

"Usually with things, you go where you can find the financing to do it."

— Don Bluth, animator, 1937–

In order to secure the necessary funding and financing for a BRT system, it is necessary to first have an idea about how much the system is going to cost to plan and construct, and then how profitable or loss making the operations are likely to be. Normally, the engineers designing the infrastructure have the best idea about the projected cost of the infrastructure, while the fleet size, fare collection system equipment, and other capital costs necessary for operations are better projected by the team that developed the specific service plan and the team that is doing the business planning. The service plan provides the basis for the fleet projections, which are the most significant capital cost after the infrastructure. The service planning team should also be asked to provide a reasonable estimate of the potential profitability of the system.

17.1.1 Summarizing the Costs

The costs of a BRT system can be divided into the costs of planning and engineering, the capital costs incurred in creating and building the system, and the operating costs incurred in running it and maintaining it. While this chapter focuses primarily on funding and financing the capital costs, it is a good idea to know how much the system will cost to plan and design. It is also good to have an idea of how profitable the operations are likely to be. If there are no funds available for planning, they can perhaps be covered as part of the capital program's funding and financing. If the operations are not going to be profitable, more of the costs of operating the system can be treated as a capital investment, hopefully reducing operating losses to zero. In other words, there is a category of costs that can either be treated as an operating cost or as a capital cost. For example, if the system being planned is potentially very profitable, the cost of buying the vehicles, the fare collection equipment, and the operational control system can all be treated as operating costs and paid for out of operating revenue. If the system is less profitable, these will need to be treated as capital costs—and funds to cover them will need to be found elsewhere.

Funding Planning and Design

The costs of planning and designing a BRT system are not generally a significant part of the overall project cost. Proper planning, however, can make the difference between a system that fully recovers its operating costs and one that loses money year after year. As such, it would be foolish to fail to invest in proper planning and design, only to encumber the system with permanent liabilities. Total planning and engineering costs for a BRT project normally run in the US$5 million range, though this could be done for much less if the project team is very talented and can do much of the work in-house, or it could cost more if the detailed engineering is included and the project involves complicated engineering. Quito's BRT was done largely in-house. Bogotá's TransMilenio spent just over US$5 million for planning, basic engineering, and business consulting.

In higher-income economies, there are generally funds available from the operating budget of the transit authority or department of transportation to contract outside experts to design and engineer a BRT system, though some have been done in-house as part of the normal operating budget. Sometimes this has led to an over-reliance on local contractors familiar with the local government but not necessarily familiar with international best practices in BRT system design. Ideally, projects are designed by consortia with both local and international best practice knowledge. Normally, it is somewhat better to contract out the planning and design of the system rather than doing it in-house, so that the design team can focus fully on the BRT project and not be distracted by other responsibilities. It is also better this way so that the design team can benefit from the broader expertise of specialists.

In lower-income economies, there are many sources of technical assistance available for designing BRT systems. Normally the funds required are not so high that the government planning the project cannot fund it. However, local governments sometimes have a hard time contracting foreign experts, and they are less likely to be familiar with the appropriate experts. As such, international funding for BRT project planning has been fairly common. If the project is likely to be funded by one of the development banks, it is generally possible to use project preparation funds or an ongoing larger infrastructure loan to also finance the necessary technical assistance, and most development banks also have funds for project preparation. Almost all of the development banks, UNDP, UN Habitat, UNEP, GIZ, the Global Environmental Facility, and many private foundations have all played a role in BRT project preparation. Once the system is operational, planning should be a function of the BRT authority and included as part of its operational budget.

Capital Costs

The capital costs of a BRT system are those for which capital investment funds need to be found. These investments should result in a long-term sustainable reduction in operating costs for the public transit system as a whole, so long as the investment is properly maintained. The capital costs of a BRT system primarily include the BRT infrastructure, such as:

- Stations and station maintenance;
- Depots and depot maintenance;
- Transfer terminals and their maintenance (if necessary);
- Dedicated running ways and their maintenance.

Normally, the costs of infrastructure construction and maintenance are paid by the government, and there should be no expectation that these costs will ever be recovered from fare revenue. There is no evidence that a BRT system can cover these costs from fare revenue even in the best of circumstances.

Capital costs also generally include the following:

- BRT vehicles and their replacement;
- Fare collection equipment and its modernization;
- Operational control system and its modernization.

Whether these capital costs can be made by private investors and fully covered by fare revenues (and hence be treated as part of operating costs covered by ongoing operating revenues) or whether they should be treated as capital investments and funded by outside, generally public funds, will vary on a case by case basis depending on the profitability of the system overall. Empirical evidence suggests that the most profitable systems are able to cover all of these costs, while the less profitable systems will not be able to cover all or perhaps any of these costs out of fare revenue.

Operations

Operating costs normally include the following:

- The cost of managing the system (system administration costs), normally the cost of running the BRT authority;
- Vehicle operations, including the cost of operating and maintaining the vehicles, station operation and maintenance;
- Fare collection system operations and equipment maintenance;
- Operational control system operations and maintenance;
- Ancillary services such as cleansing and security.

How much of these operating costs, if any at all, can be covered from fare revenue depends on the overall profitability of the system. The most profitable systems cover the system administration costs from fare revenue, which helps insulate the system's administration from political interference, but the less profitable systems generally cover system administration costs out of general budget revenue. Vehicle operations are generally recovered primarily from fare revenue, but some BRT systems require operating subsidies. These are generally covered by tax revenues. The fewer tax revenues are needed to cover operating losses, the more public funds that are available for capital investments.

In principle, ongoing recurrent costs such as operating losses to a BRT system, should not be debt financed, nor should they be funded from one-off revenue sources. For example, additional tax receipts resulting from "value capture," or the increase in property values arising directly from the implementation of the new BRT system, could be used to fund capital costs but should not be used to fund ongoing operating losses. Longer term increases in property or sales tax receipts, however, would be a reasonable source of funds to cover operating losses.

17.1.2 Designing for Financial Sustainability

The BRT project team will need to identify sources of funding and financing for all of those capital costs that cannot be covered out of the fare revenue. Advertising revenue, while it sometimes helps to supplement fare box revenue, is rarely sufficient to significantly change the equation. Therefore, estimating what capital costs above and beyond operating costs can be covered from the fare box revenue is a critical first step.

No BRT systems fund more than a small portion of their infrastructure capital costs out of fare revenue, and only a few are able to cover the capital investment into their vehicles, their fare collection system, and their operational control system. The extent to which these costs can be covered from fare revenue depends on a variety of factors—and they can vary widely among cities. Crucial factors include not only the number of customers carried by the system, but especially the differential between peak and off-peak demand and whether demand is tidal in nature. Where a system has high peak demand all in the same direction and low off-peak demand, its financial viability is likely to be low even if it carries large numbers of customers. This is because the system has to be sized to service the peak but has very low utilization levels at all other times. Even in peaks vehicles are largely empty on their return journey to take their next peak load.

Indeed, once a basic demand threshold is reached that justifies investment in the system the viability of the system is much more dependent on an even customer demand flow in all directions throughout the day than on total customer volumes.

Other important factors include average trip length and user income levels. Short trips are more affordable and can be charged at a higher rate. Where there is substantial seat renewal along a single bus route a vehicle can earn far more than if it carries customers for long distances between route end points.

Gaining an understanding of the extent to which vehicle procurement, fare collection equipment, and operational control system equipment can be covered by operating revenue, thereby to be treated as an operating cost, should be determined as early as possible. It must be based on a sound understanding of the demand profile including not only the estimated number of customers carried but also the peak to off-peak differential and realistic fare levels. And it must be based on realistic cost projections. Unfortunately, when BRT is new to a city or country or where good demand modelling is not available, achieving accuracy can be difficult, but doing so must be treated as an absolute priority as part of the initial planning process.

The financial challenge is to first design a system where as many of the capital costs as are feasible can be covered out of fare revenue. Secondly, it is to raise the remaining capital funds, turning to debt financing where the capital funds are likely to accrue gradually over time while the need for the funds is immediate. Thirdly, if operating revenues are insufficient to cover projected operating losses, other stable long-term revenue sources will need to be found to cover these projected deficits. If the system is likely to operate at a deficit, then financing the capital program is likely to require that the project team can prove it has access to an ongoing revenue stream large enough and reliable enough to cover the operating losses and still service the debt.

17.1.3 Approaching the Funding and Financing Plan

A logical starting point for any funding and financing plan is to examine existing capital budgets for public transport and roadway development. If financing is needed, the first source of financing to turn to should be the typical source of financing for any similar public works project sponsored by the same client, whether it is a municipal, state, or national government building the BRT system. Financial institutions are always more comfortable lending to established clients for projects similar to other projects they have financed. Often the price of two or three highway flyovers or one or two links in a new metro system is equivalent to the cost of building the first operational phase of a BRT system. Unorthodox sources of funding and financing should only be approached as a last resort as they are likely to significantly delay a project.

Ideally, an effort to identify the necessary funding should begin at the earliest stages of the planning process. The funding and financing plans should be developed on an iterative basis with the operational and infrastructure design process since the available funding and financing will be a determining factor in the final design.

If the estimated needed funding and financing is based on tenuous assumptions about certain future revenues, then the long-term viability of the system will be placed in doubt. In such cases, the quality of all public services can be compromised if future administrations and future generations are burdened with an unrealistic debt level. For this reason, as far as is practicable, the funding and financing process and the assignment of long-term financial responsibility to specific institutions or levels of government should be discussed in a wholly transparent manner to allow all parties (including civil society) to provide input. The total financing package must be cost-effective, achieving an optimum interest rate and a reasonable debt level.

Financing also needs to be timely. Generally, the political leadership of a BRT project will require project implementation to be achieved within a particular time frame, and sometimes higher interest rates or fees may be required in order to secure financing in time to meet a specific political timetable.

The long-term vision of the funding and financing strategy will likely vary from the financing applied to the system's initial corridors. Before a country is familiar with BRT it is likely that more of a project will need to be funded on a cash basis from government grants, or with loans with the full faith and credit of the government behind them. If BRT becomes proven and viable in a city, alternative, lower-cost forms of financing generally become available. Many BRT projects have been started with relatively expensive financing, only to be later refinanced once the viability of the project and the credit-worthiness of the borrowers have been better established.

17.1.4 Strategic Recommendations

While there are exceptions, the general funding strategy for a BRT system will often focus on the following principles:

- Initial BRT planning should be funded by the government and donor agencies with a combination of municipal funding and international funding when possible. Once the system becomes operational, it is usually possible to fund future phase planning of the same revenue source as the BRT system's other administrative costs. More profitable systems can usually cover planning from fare revenue, and less profitable systems usually rely on government funding. Typically, international technical assistance grants fund the first phase of a BRT project, while national technical assistance is usually funded as part of normal government budgeting. If the infrastructure for the project is being debt financed, particularly by a development bank, it is common for the infrastructure loan to also cover the technical assistance and the planning and engineering costs.

- Construction of BRT infrastructure and its maintenance should be paid for by the government from a stable source of tax revenues, ideally with taxes on private motor vehicle users.
- Debt financing of up to 70 percent of the infrastructure cost should be pursued if: (1) The project sponsor does not have the cash on hand to implement the first operational phase; (2) The project sponsor is not already deeply in debt; or (3) The project has passed a reasonable cost benefit appraisal.
- The system should be designed so that revenue from fares will be sufficient to cover the cost of the system's operations.
- "Operational costs" should be defined to include all the operating costs, plus any capital costs that fare revenue can reasonably be expected to cover on a sustainable basis. This includes the vehicle procurement, financing, maintenance, fare collection equipment, and operational control system equipment where possible. System administration costs should also be considered operational costs.
- Where fare revenue is not projected to be able to cover even basic operations, projected operational losses should be covered by preidentified stable sources of government funding. This includes sources such as specified earmarked or hypothecated government tax revenues or road and bridge surplus revenues. Stable government funding streams such as these are preferable to annual budget appropriations or one-off sources of government funding from the sale of government assets. Debt financing should not be used to cover operational losses.

17.2 Funding BRT's Capital Costs

"Money often costs too much."

— Ralph Waldo Emerson, author, poet, and philosopher, 1803–1882

The capital costs of BRT systems are generally funded in a manner similar to other medium- to large-scale capital projects of the same implementing agency, which is usually a level of government (municipality, state, or national) or a government-owned enterprise established under one of these levels of government.

17.2.1 Sources of Funding by Level of Government

Funding the capital costs of a BRT system depends on which level of government is leading the BRT project, and its track record at managing projects on a similar scale.

In the chart below, a large sample of BRT systems was broken down by the source of the capital funding.

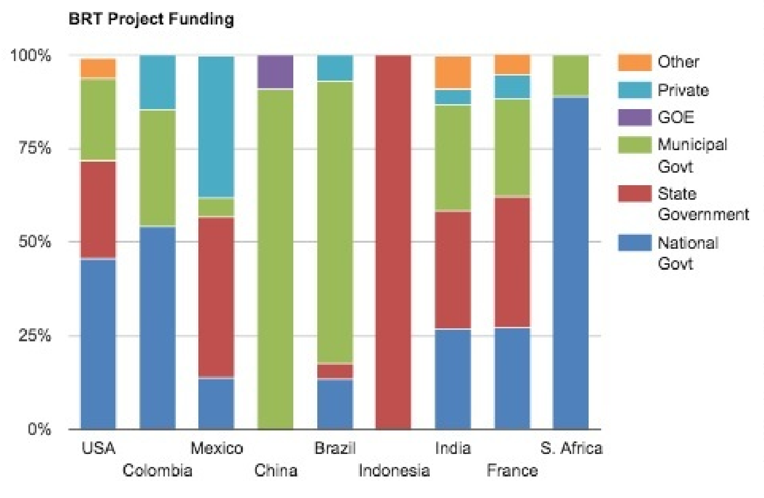

Figure 17.1. BRT projects in different countries broken down by their main sources of funding. *ITDP*

The funding details of forty-eight BRT projects in nine countries were analyzed in the report *Best Practice in National Support for Urban Transportation, Part 2: Growing Rapid Transit Infrastructure—Funding, Financing, and Capacity* (2015), and the source of funding was broken down into the following five main sources of funding: +

1. National government; +
2. State government; +
3. City/metropolitan governments or transport authorities; +
4. Government-owned entities; +
5. Private sector backed primarily by user fees.

Funding sources in this case refers to the level of government that has ultimate spending discretion to choose a project and takes ultimate responsibility for paying for the project, either directly or indirectly by agreeing to service the debt. If taxes are collected by a national government and the revenue is passed on to a city or metropolitan government to use at the discretion of the city, then the funding source is considered "city." If the funds are invested by a private company or a government-owned enterprise (GOE), they are marked as such. Such investments of private companies or GOEs are usually made by borrowing money against the expectation of future public funds in the form of user fees and/or fees from concession contracts paid by the government.

Normally, infrastructure accounts for 85 to 90 percent of total capital costs, while the vehicle procurement and other equipment makes up only around 10 to 15 percent of the total initial capital cost. In the cases listed below where "private" investment has been used to fund the capital costs, as in the case of Mexico, Colombia, and India, this normally covered the vehicle fleet procurement. Generally, where the source of capital was "private," there was the expectation that fare revenues would be sufficient to cover the initial private investment in the vehicle fleet. Only in Mexico was there an attempt to get fare revenues to cover part of the original infrastructure investment, and these systems are proving to not be financially viable. As such, BRT project teams should assume that infrastructure costs will ultimately be paid by the government in some form, and user fees will hopefully be sufficient to cover all or most of the operating costs.

Generally, where possible, municipalities take the lead. When municipalities are weak, or where a capital city area is designated as a state or provincial level of government (as is the case for Jakarta, Delhi, and Mexico City), state or provincial authorities carry the primary funding responsibility. Normally, government-owned enterprises are controlled by one of these levels of government. Where both municipalities and states are too weak to raise the necessary revenue, or where accelerating a national urban mass transit program is a national priority, national authorities have stepped in to meet the funding gap.

Countries can be broken up into the following categorizations: those where the municipal government provide the majority of funding (China, Brazil); those where state governments or national capital areas play the key role (Indonesia); those where the state government, state-owned enterprises, and the private sector play the key roles (Mexico, India); those where the national government and the city play the key role (Colombia); and those with a fairly even mix of funding sources (United States, France). The ultimate source of government revenue used to pay for the BRT capital costs tends to follow the general sources of government revenue for the level of government that takes the lead in funding the BRT project.

17.2.2 Sources and Reliability of BRT Capital Funding

The best sources of capital funding are those that sustainably and predictably raise sufficient revenues to fund system construction, rolling stock procurement (if necessary), system expansion, and ongoing maintenance. Developing a new and untried source of funding is generally a long and cumbersome process, so a BRT project team should always first try to fund its project with well-established mechanisms for funding municipal public works.

To the extent that everyone has a stake in a vibrant economy, a healthy environment, and desirable public spaces, public transit infrastructure investment is often considered a reasonable use of general taxpayer funds. Thus, the forms of taxation that have generally proved to be the most reliable sources of capital investment funds in a particular country are usually the most secure source of BRT infrastructure funding.

In addition, sources of funding that increase the costs of motor vehicle ownership and use to something closer to its real social cost have the simultaneous benefit of encouraging people to use transit. Historically, private motorists have not been required to pay for the full social cost of their choice of travel. Motorists also tend to be among the wealthier members of society. As such, many societies find it reasonable to tax or charge motorists, and use these revenues to finance transit infrastructure investment. This may take the form of fuel taxation, road user fees, parking charges, or registration and licensing fees.

While it is generally best to have the direct beneficiaries pay the capital costs, and since fare revenues and advertising revenues are never sufficient to cover the necessary capital costs of a BRT, many have argued that property owners along a new BRT corridor should also pay for part of the BRT capital costs since they may benefit from the new BRT. Sometimes new real estate development will occur along a new BRT corridor, attracting additional property tax revenues, and existing property owners will benefit from increased rent revenues and property values as a result of the BRT investment. In theory, these increased property values can be taxed and earmarked to a transit investment. This can be done indirectly by using city property tax revenues in general to pay for new BRT infrastructure, or more directly through special tax assessment districts in the area served by the new transit link, or tax increment financing mechanisms, where increases in property tax revenues (but not of the rates) are earmarked to a specific transit investment. In practice, however, the uncertainty of such funds in higher-income economies, and the underdeveloped property tax regimens in lower-income economies, have limited the application of this type of funding for BRT systems to date.

Many have seen the growth of metro systems funded by private consortia in exchange for development rights on public land, and considered the possibility of similar funding and financing mechanisms for BRT systems. To date, however, while there are public-private partnerships (PPPs) funding BRT systems, such a PPP funding mechanism linked to a public land development deal has only been applied to BRT projects in a limited way. While this may evolve, as this would be a financial innovation in most countries, it should only be considered as a last resort.

BRT Capital Funding from General Tax Revenues

By far the most common source of funding for BRT capital costs not covered by fare revenue is general budget revenues, sometimes specifically earmarked for transit. Most typically, these are value added taxes, or sales taxes, though in a few cases they are a form of payroll tax.

Earmarked taxes are largely a higher-income economy phenomenon. In Europe and increasingly in the United States as well, it is often accepted that mass transit is a social good for a state or metropolitan area. In this way, earmarked taxes of various sorts, or public-transport-specific levies, at both the state and municipal levels, are being used to support not only capital costs but also operating losses of transit systems.

In a survey of multiple countries, funding for mass transit was the stablest in France. There, the national government collects an urban mobility tax on employers as part of a payroll tax, and channels it to departments and cities for them to use on transport largely at their own discretion. France's BRT systems as well as its LRT systems are largely funded in this way, and France has outperformed most other countries in terms of the expansion of its rapid transit networks.

In higher-income economies, as BRT services are generally part of a larger package of transit services, which are loss making as a whole, fare revenues rarely cover operational costs. Thus, these same public funds are used not only to cover infrastructure but also to cover vehicle procurement, fare collection systems, operational control systems, and other forms of capital investment that in lower-income economies would more likely be covered by the fare revenue.

In the United States, the main source of capital investment in new mass transit infrastructure for many years was the national government, either in the form of congressional earmarks (one-off capital grants) or as New Starts/Small Starts grants from the Federal Transit Administration. In recent years, however, the metropolitan areas most rapidly expanding their transit systems are almost all doing so with a large contribution from state government-level earmarked funds, generally approved by voters through referenda. A few cities are also passing referenda for transit-specific spending. The source of these funds varies. In most of the United States, bonds approved by taxpayers are backed either by general tax revenues, or by earmarked additional sales taxation (relatively regressive). The State of North Carolina, for instance, funded LRT in Charlotte, with one-half of 1 percent of the state sales tax set aside for municipal public transport projects. Similar measures are in place in Washington State, Colorado, and elsewhere. New York State has a whole host of special taxes that are earmarked to finance public transport capital investments, including mortgage transfer taxes, and a percentage of the sales tax. There are proposals in a few states (Massachusetts, for instance) to fund new transit investments from an additional state income tax on the wealthy. As BRT services are all operated as part of transit authorities that are on the whole loss making, these same sources of public funds are generally used to finance vehicle procurement, fare collection system equipment, and any operational control technology that may be in place. The funding structures are similar to those for new urban rail projects.

After France, China has been rolling out new mass transit infrastructure at the fastest rate of those countries studied. China's municipal finances are unique, and extremely strong. Its BRT systems have been funded by municipal governments virtually unaided by other levels of government. The boundaries in most Chinese municipalities extend far into peripheral urbanizing areas, and urbanizing land is often annexed to the municipality. Land is all officially municipally owned and then leased to private investors. Thus, when the land is rezoned from rural to urban use, there is an enormous increase in its value, and this value is captured by the municipal government. More than half of urban infrastructure in China is funded by this form of value capture. Otherwise, transit infrastructure investments are funded primarily by corporate income taxes. For the near term at least, and barring any crash in urban land value, these have proved reliable sources of revenue for rapid transit development in Chinese cities. Most of the vehicle procurement in the BRT systems was done by the municipal bus company, which tends to receive operating subsidies and subsidies to buy new vehicles from the municipal government, funded from the same sources. In Guanghzou, the vehicle operators are semiprivate, and vehicle operations are profitable. Many of the vehicles were ordinary, but some new special BRT vehicles were purchased out of the company's profits. Funding and financing for urban rail in China follows similar lines.

In Brazil, BRT infrastructure is largely funded by municipal governments, and municipal government budgets are heavily dependent on value-added taxes on businesses. The vehicles and fare collection equipment are generally funded fully from private investment backed by the fare revenue, with the exception of in São Paulo where the private investment is in part backed by operating subsidies. This contrasts with urban rail projects, which tend to be financed by state governments in Brazil, but state governments have a similar dependence on value-added taxation.

In Mexico, Mexico City is a federal district with powers similar to that of a state, and since the country's economic activity is concentrated there, the state VAT tax receipts are sufficient to pay for a significant share of the city's BRT infrastructure needs. Outside of Mexico City, BRT projects depend more on state and national funding. BRT vehicles tend to be paid for by private operators, though these same sources of government tax revenue subsidize part of the BRT vehicle procurement cost.

In India, BRT capital investments are largely funded with a combination of national government JNNURM (Jamal Nehru National Urban Redevelopment Mission) grants, and from the same state-level value-added-tax revenues that fund most large public works projects. In some cities like Ahmedabad, the municipality also pays for a significant part of the BRT infrastructure. This is quite different from urban rail projects in India, where the source of funding is unlikely to include any funding from the municipality. In some Indian cities, the vehicle procurement is covered by private investment, while in other cities like Pune BRT vehicle procurement is covered by a grant of new vehicles from the national government through the JNNURM program.

In Indonesia, the government of DKI Jakarta (Daerah Khusus Ibukota Jakarta) is a state-level government. Jakarta pays for all of its BRT corridors out of general budget revenue. For most phases DKI Jakarta also funds the vehicle procurement and ticketing equipment using the same general tax revenue of the city. This differs markedly from urban rail, most notably with the Jakarta metro, where the national government funds more than half of the total capital costs.

BRT Capital Funding from Fuel Levies and Other Motor-Vehicle-Related Sources

There are obvious merits in raising revenues from motorists to fund BRT capital costs. The higher costs imposed on motorists incentivizes a shift to public transport, which generally results in overall economic benefit as the negative externalities arising from motoring are reduced.

Dedicated revenue streams from petrol taxes are potentially a very good ongoing source of funds and can help establish a long-term sustainable basis for financing BRT development and expansion. Fuel taxation is both a lucrative revenue source as well as an effective mechanism to help discourage car usage. For those municipalities that can gain access to fuel tax revenues, the possibility of funding much of the BRT system through such a tax is quite good.

In lower-income economies, the use of fuel taxes to fund urban rapid transit is common, though earmarking of the funds is relatively rare. In Colombia, municipalities are allowed to levy local fuel taxes up to 30 percent of the retail price of gasoline, and these fuel tax levies provide much of the municipal counterpart funding for most of Colombia's BRT systems. Bogotá's TransMilenio has benefited greatly from the proceeds of a petrol tax that is partly dedicated to public transport. Approximately one-quarter of the first phase of TransMilenio was funded through the local petrol tax revenue, and most of the BRTs outside of Bogotá use local gasoline tax revenues for the 30 percent of municipal matching funds necessary to receive national funds.

About one-third of the fuel taxes collected annually by the national government of South Africa goes to subsidize the national highway program's deficits, and the remaining two-thirds are spent on urban transit (Van Ryneveld, 2010). These amounts are not earmarked for urban transit or urban transport, but it works in a similar way.

In Mexico, outside of Mexico City, states depend heavily on the formula-based distribution of national government funds, many of which come from the sale of oil by Pemex, the former state oil company. As such, though the BRT systems outside of Mexico City are largely funded by state government general revenue, the ultimate source of many of these revenues is from profits from the national oil industry.

In Indonesia, funding for urban transport comes from provincial-level VAT, and national government-collected VAT, but as in Mexico much of this comes from oil and other extractive industries. The recent decision of Indonesia to remove oil subsidies could make more national funding available for urban transit investment, though to date the national government has only been willing to fund rail projects or the vehicle procurement side of projects labelled "BRT" but which did not reach the minimum definition of BRT.

In higher-income economies, the use of fuel tax revenues for rapid transit capital investments is also common. In the United States, a significant portion of the BRT projects have been funded by the Federal Transit Administration out of New Starts/Small Starts, which has received a dedicated portion of the national gasoline tax since 1970. A fixed percentage of this is earmarked for transit, creating a reasonably stable funding stream. The federal funding is available for infrastructure, rolling stock, and fare collection equipment. However, the gas tax was never pegged to inflation and faces declining revenues, forcing city and state governments to increasingly turn to earmarked taxes collected at the state level to fund urban transit.

In the United States, some states also have gasoline taxes that are used to fund infrastructure, ranging from simple gasoline taxes to indirect fuel taxes imposed on oil companies called "Petroleum Business Taxes." Using surpluses from toll revenues is also common. In the New York City metropolitan area, the MTA funds its capital program in part from the surpluses collected on bridges and tunnels by the Triborough Bridge and Tunnel Authority.

In Mexico, outside of Mexico City, the other main source of funding for BRT systems has been grants from PROTRAM, a national government funding program that is funded in part from surpluses (above the cost of maintaining the road) collected on intercity toll roads controlled by the national government.

A few countries also fund infrastructure from vehicle licensing and registration fees. Vehicle ownership may not seem directly related to usage, but there is some evidence to suggest a relationship. Once a motorized vehicle is purchased, the convenience of use often induces additional trips (Gilbert, 2000). Further, once an individual makes a financial commitment to a vehicle, there is a psychological preference to maximize the vehicle's use. Thus, discouraging vehicle ownership can help shift patronage to public transport. The financial disincentives to vehicle ownership also can produce revenues for public transport development. Vehicle licensing fees are a part of urban transit infrastructure financing in China and a few other countries, but a relatively modest one.

A number of different forms of motor vehicle charging are used to fund mass transit in other cities, but not specifically for BRT projects. Congestion charging and electronic road pricing has served as an effective mechanism to raise revenue for urban mass transit. In London, as the fees stopped increasing under Mayor Boris Johnson, the effectiveness of the measure for limiting congestion receded, but it continues to raise revenue for Transport for London. In Singapore, where charges have better kept pace with congestion levels, it also helps fund Singapore's extensive urban rail network. Though there have been advanced discussions in a number of cities in lower-income economies about adopting either congestion charging or eco-charging (São Paulo, Mexico City, and Jakarta have all developed reasonably detailed plans), to date it has not caught on in lower-income economies.

In the United States, "HOT" lanes, or "high-occupancy + toll" lanes, are increasingly popular on congested urban highways. Seattle is currently developing a highway-based BRT system that will in part be financed by toll revenues on HOT lanes that are intended to roughly vary with congestion levels. While it is too early to tell whether this will mature into a full BRT system and whether HOT lane toll revenues will be an important element in the system's financing remains to be seen, this looks to be part of an emerging trend. As electronic toll payment systems, such as E-ZPass, become ubiquitous, it is likely that road user fees of various forms will become a growing source of mass transit revenue.

Parking fees could be another source of BRT infrastructure funding. Some recent successes in increasing charging for parking have only in rare instances raised funds sufficient to play a significant role in BRT financing. Chicago auctioned off the right to collect all of its on-street parking levies for seventy years for about US$1 billion. The funds were not specifically earmarked for transit. Chicago negotiated a relatively poor deal (twenty years would have yielded roughly similar funds). Recent successes in Mexico City with on-street parking charging have raised revenue only sufficient for streetscape improvements. Cities could theoretically consider earmarking street parking levies for rapid transit, but the sums involved are in most cases more likely to make them useful for covering any projected operating losses.

A "parking space levy" is a technique that could hold advantages as a financial source for a BRT project. A parking space levy imposes a tax on all nonresidential parking spaces, regardless of whether the space is utilized or not. Examples are to be found in Australia and Singapore. In 1992, Sydney initiated a parking space levy for nonresidential parking spaces in the central and northern parts of the city. An annual levy of A$200 (US$150) was applied to each parking space (Enoch and Ison, 2006). This has now risen to A$800 (US$615) in the central business district and A$400 (US$308) in other business districts. The parking levy is currently returning approximately A$40 million (US$31 million) per year to the city (Litman, 2006a). Landowners must pay the fee on all parking spaces, whether the spaces are actually being utilized. If an unmarked lot is utilized for parking, the Sydney municipality determines the number of space by "dividing the total area by 25.2 square meters, which takes into account parking spaces and access lanes" (Litman, 2006a, p. 6).

Perth, Australia, also successfully adopted a "parking license fee" in 1999, which was applied to all on- and off-street nonresidential parking spaces. All revenues from the Perth program go to supporting the local bus system (Enoch and Ison, 2006).

Beginning in 1975, Singapore assessed a US$35 monthly fee on nonresidential parking spaces. This fee provided approximately US$25 million in annual revenues. The cost to administer the program was relatively low at approximately US$30,000 (US$18,000) per month (Enoch and Ison, 2006). When the Electronic Road Pricing (ERP) was introduced in 1998, the authorities decided to phase out the parking levy.

It should, in principle, be possible to utilize the property tax administrative system to implement parking levies, where such a system exists, in which case additional administration costs are potentially containable.

Property Development as a Source of BRT Station and Terminal Funding

Some BRT systems have leased or sold development rights at key stations or transfer terminals to developers in exchange for the developer paying all or part of the station or terminal development cost. This practice is more established for metro projects, but is catching on in BRT systems. In metro projects, many metro companies will often take a large parcel of land to build the station, in order to build the station using cut-and-cover. Once the station is built, or as part of the construction of the station, the land above the station then becomes developable. Because the large parcel was necessary for the metro construction, most legal systems will allow the land to be taken by eminent domain for this public purpose. In a few cases, such as the Tehran Metro, some US$400 million was raised in investment funds that were then put back into metro construction. Hong Kong's MRT famously uses the proceeds of property development to raise investment capital for infrastructure.

Though less used in BRT systems, there are a few examples of similar funding mechanisms emerging. Because the amount of land needed at most BRT stations is fairly modest, and most legal systems do not allow the excessive condemnation of land by transit authorities purely for development purposes, the development potential is generally lower than for metro rail systems, but some precedent does exist.

Property can sometimes be developed above or under BRT stations. Perhaps the best-known example of aerial property development is Brisbane's Mater Hill station. Shops and a hospital have been constructed over the exclusive lanes of the Brisbane busway (figure 17.2). Proceeds from this property development have been utilized to build the BRT system's infrastructure.

Figure 17.2. The development of a hospital complex over the Mater Hill station in Brisbane generated important infrastructure revenues for the BRT system. *Queensland Transport.*

In China, in the Lanzhou BRT system, shopping malls were built underground directly under the BRT corridor. As this did not require any new land acquisition, it could be done by the municipality's construction companies, and the proceeds used to defray project costs.

Figure 17.3. Shopping mall under the Lanzhou BRT corridor. *Karl Fjellstrom.*

Transfer terminals in trunk-and-feeder BRT systems are sometimes large enough to anchor a real estate development, and some or all of the cost of the transfer station can be covered by a private developer. For example, a new transfer station between a busway trunk line and its feeder buses in Belo Horizonte was financed by a private developer in exchange for the right to build a shopping mall adjacent to the station. Belo Horizonte built a second transfer station on the same model in time for the FIFA World Cup in 2014. Mexico City built several new bus stations, one of the terminals for a BRT to the State of Mexico, at the terminals of the metro system. Called Cetrams, one at Ciudad Aztecas links to the Mexibus BRT line in the State of Mexico. The developer paid for the development of the BRT terminal station in exchange for development rights for a shopping mall over the new terminal on the site of the old bus terminal. Others are moving forward under a similar model.

Financing BRT infrastructure through land banking has not yet been done, largely because land banking is not legal in most countries that have BRT systems. Land banking is the purchase of properties adjacent to the stations of a future mass transit system by the system developer, only to be sold at a later date once the land has appreciated in value due to the completion of the new mass transit system. This was a common practice in Singapore and Hong Kong for their rail systems.

Figure 17.4. In the State of Mexico, a mall was built over the top of the station of the Mexibus BRT. *Wikimedia Commons.*

Air Rights, Special Transit Area Property Tax Assessment Districts, Tax Increment Financing

In theory, taxing the gains to property owners from land rents resulting from a government improvement in rapid transit infrastructure serving the properties would be one of the fairest methods of financing BRT infrastructure. In practice, however, there are a number of reasons why this is rarely done.

In lower-income economies, it is rarely done because even basic property taxation is still only emerging as a source of government revenue. The ability of the government to capture any positive land value impacts of a BRT system requires that the municipality has the means to collect basic property or land taxes. In many lower-income economies, site ownership rights, particularly in poor neighborhoods, are not that clearly defined (figure 17.5). Establishing basic property tax collection remains the next priority in many municipalities in lower-income economies.

Figure 17.5. Lower-income governments often do not have a formal land or property taxation system in place for informal settlements. *Lloyd Wright.*

In higher-income economies, Europe has relatively high income and fuel taxation, much of it collected nationally and transferred to local levels of government. There is property tax collection but it generally makes up a relatively modest share of municipal revenue. U.S. cities rely heavily on property taxation, but there are many competing urban demands on these funds. In general, cities in the United States are relatively poor because many of the middle- and upper-class residents of a metropolitan area live in suburban areas beyond the city's tax authority.

Additional property taxes applied only to special tax districts in an area where a new BRT is being built, or earmarking of increases in property tax revenues in a zone where a new BRT is being built (tax increment financing, or TIF) has been used to fund some urban rail projects in the United States. They have been used on the Central Loop BRT stations in Chicago for a few stations, but TIF is more typically used for urban development.

In lower-income economies, municipalities lack the administrative capacity to handle such a tax, and in higher-income economies, governments are moving away from these instruments because they are unreliable. Property impacts of a new project are unpredictable and subject to business cycles in the property market. The study More Development for Your Transit Dollar (2013) indicates that the quality of the transit investment is a relatively weak predictor of whether land will develop around it. Far more important is the inherent market potential of the land and the degree to which the municipal government uses other tools at its disposal to channel new development to station areas along the BRT corridor, such as zoning, land assembly, site preparation, other infrastructure improvements, and other actions. To make transit-oriented development successful, other government investment is also generally required, and these other urban redevelopment investments may be a better use for TIF funds. However, BRT stations and terminals with architectural merit can increase commercial land values nearby as BRT becomes an urban amenity. Also, the transit-only benefits of very nice BRT stations can sometimes not be justified on purely transit benefit grounds, and using property-tax-tied funding to enhance the aesthetics of BRT stations is worth considering.

In many cities, the right to develop a site in a particular manner must be formally approved by the local government. Zoning ordinances may also restrict a site to a particular type of development. The auctioning of the right to develop a site can be a significant revenue source for a new public transport system.

The commercial opportunities around new public transport stations can make the auctioning of development rights a financing option to consider. The selling of development rights is not mutually exclusive of other property taxation sources.

São Paulo has been at the forefront of lower-income-economy efforts to raise urban development funds from the sale of air rights. Certificates of Potential Additional Construction (CEPACs), or tradable air rights, allow developers who wish to increase the density of a planned development on their property to purchase the right to add density if the property is in a strategic urban growth area. The revenue raised from the sale of CEPACs has to be used for urban investments into the strategic urban growth area. Thus far, CEPACs have yet to be used for BRT projects, but they have been discussed as a possible source of financing for the proposed BRT corridors on Celso Garcia and Radial Oeste (Murakami, 2015).

17.3 Financing BRT Capital Costs

> *"A promise made is a debt unpaid."*
>
> — Robert W. Service from the poem, "The Cremation of Sam McGee," poet, 1874–1958

Whatever the ultimate source of funding for a BRT project, in many circumstances it is advisable to debt finance a BRT's capital costs. BRT infrastructure, in particular, requires large, up-front capital investments, and many governments do not have the cash on hand to bring a minimum operable BRT link on line in a reasonable time frame. If the project is well designed, with an economic rate of return above the cost of capital, it is advisable to borrow any extra money needed to complete the BRT project as soon as possible. The sooner the minimum operable link is completed, the sooner the economic benefits can be enjoyed. With debt financing, much more can be built much faster, so the economic benefits can begin to accrue faster, yielding a greater overall benefit. Also, as the benefits will be enjoyed not only by today's taxpayers but also by tomorrow's taxpayers, it is reasonable to pass on some of the cost to the taxpayers of the future. As such, BRT infrastructure is a classic case for debt financing.

Additionally, the rigor of project evaluation often required by debt financing often helps ensure a better planned project. Lenders, as a third party, may have a stronger incentive to critically evaluate a project's long-term prospects, as the loan is likely to still be due long after the politicians initiating the project have left office.

Building a BRT system is a major investment. As noted in Chapter 2: Why BRT, BRT systems will generally cost in the range of US$5 million per kilometer to US$20 million per kilometer. The actual cost will depend on a range of factors including the complexity of the infrastructure, the capacity level required, the desired quality of the stations, the road surfaces and terminals, the necessity for property acquisition, the need for flyovers or tunnels at rivers, railway crossings or problematic intersections, the amount of general infrastructure improvements included in the corridor reconstruction (sewage, drainage, and electrical improvements), and the level and quality of corresponding public space improvements in the corridor (landscaping, cycling and pedestrian facilities, street furniture, etc.). Since a Phase I project will generally involve anywhere from 10 to 50 kilometers of infrastructure, anywhere from US$50 million to US$1 billion may be required for a project's initial phase. Many governments have a hard time mobilizing this level of resources in a single year or even in a few years.

Debt financing is also common for the procurement of the BRT vehicle fleet. Not all BRT systems require the procurement of new vehicles, but most of the better-rated BRT systems require the procurement of new vehicles compatible with special BRT infrastructure. The cost of BRT vehicles varies from as low as US$75,000 (for a standard 12-meter diesel vehicle in India) to US$750,000 or more for a bi-articulated vehicle, or articulated hybrid diesel-electric vehicle. Total vehicle procurement costs are thus likely to run into the tens of millions of dollars. The expected economic life of a BRT vehicle tends to be from about seven years (in the case of Indian or Chinese vehicles) to about ten to twelve years (European vehicle). Existing operators rarely have the up-front capital required to finance the entire fleet of new vehicles. Most BRT systems have therefore turned to debt financing for vehicle procurement.

17.3.1 How Much to Debt Finance

All other things being equal, a well-designed BRT project, backed by reliable revenue sources and with a reasonable projected rate of return, should qualify for a debt to equity ratio of about 70:30 (Izaguirre, A. K. and Kulkarni, S. P., 2011). For example, if a total investment needed is US$100 million, only US$30 million would be needed in cash from the funder (general tax revenues over a year or two), while the other US$70 million can be financed by debt, and only repaid gradually, usually also from tax revenues.

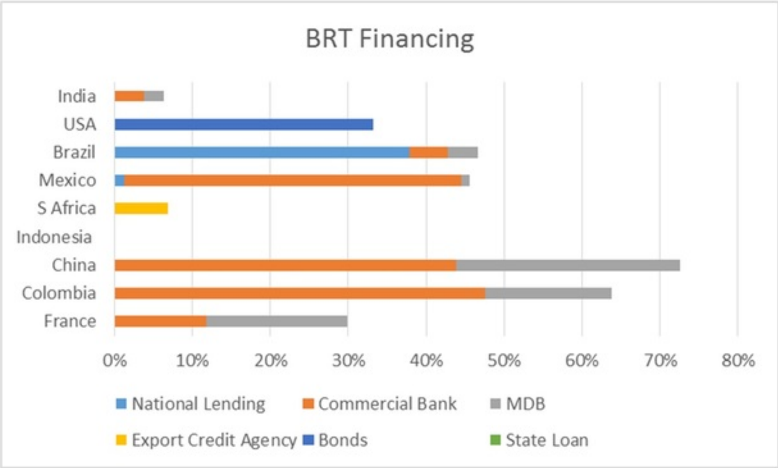

Figure 17.6. BRT debt financing in selected countries as broken down by type of source. *ITDP*

A recent study of the financing for some forty-eight BRT projects in nine countries, *Best Practice in National Support for Urban Transportation, Part 2: Growing Rapid Transit Infrastructure—Funding, Financing, and Capacity* (2015), indicates that only China and Colombia were debt financing more than 50 percent of the total capital cost of their BRT projects. This lower than expected average results from different causes in different countries. It indicates that many BRT systems could borrow more, so more could be built faster.

China and Colombia have both produced impressive levels of new BRT infrastructure in the past decade, and they also had the highest level of debt finance for their BRT projects, at 73 percent and 65 percent, respectively. In the case of China, municipal governments have historically found it quite easy to borrow from local commercial banks for mass transit projects, as the municipal governments are generally quite wealthy due to profits on the appreciation of urban land values. Further, some of the banks lending for BRTs are owned directly by the municipality. Several of the high-profile BRT projects included in the China sample were also financed by multilateral development banks (MDBs).

In Colombia, the national government borrowed money from several MDBs (World Bank, IDB, CAF) to build BRTs across the country. This money was dispensed to municipal governments over time (generally in five-year periods). As the funding only came over five years, the construction companies would front the money, borrowing much of it from commercial banks with whom they had long-standing relationships. This debt financing helped accelerate Colombia's rollout of BRTs.

Brazil, which built hundreds of kilometers of new BRT systems in the lead-up to the 2014 World Cup, also did this largely with debt financing. In this case, the financing came almost entirely from two national development banks: the National Bank for Economic and Social Development (BNDES) and the Caixa Economica. While this low-cost financing accelerated Brazil's BRT rollout, there is growing evidence that it has done so without the funding to back it up, and Brazil now faces a significant debt problem.

In higher-income economies, such as France and the United States, most of the higher-income cities with aging rail properties have transit authorities facing a backlog of unmet maintenance needs. These capital requirements tend to be met through debt, usually municipal, state, or transit authority bond financing. New projects, however, are eligible for national government grants. On new BRT projects, state or local governments will often use debt finance for only 70 percent or so of the non-federal portion of the infrastructure cost (Lefevre, Leipziger, and Raifman, 2014). For this reason, the debt-financed share of new BRT projects in both the United States and France is only between 30 and 40 percent. Most transit properties are not, however, in a position to greatly increase their debt financing unless new revenue streams to back this debt are found.

In India and Mexico there are also national government grants to fund new BRT projects. The state and municipal governments responsible for implementing the projects have only needed financing for the portion not covered by the national government grant, which has lowered the borrowing needs on the part of localities for new projects.

In Indonesia, there is only BRT in Jakarta, and Jakarta has more money than it can spend in a way that is consistent with current government anticorruption protocols. DKI Jakarta has also been reluctant historically to borrow money from international development banks as it has wanted to avoid competitive bidding requirements.

17.3.2 Debt Financing Options

The above study found five main sources of BRT financing:

1. Bonds;
2. National Government and National Development Bank Loans (NDB);
3. Multilateral Development Bank (MDB) Loans;
4. Commercial Loans;
5. Bilateral Loans or Loans from Export Credit Agencies.

Each of these sources of financing has its advantages and disadvantages. The main differences include:

1. Eligibility for the type of debt (i.e., credit rating accepted);
2. Cost of the capital (i.e., the interest rate);
3. Length of the credit (the repayment period on the debt) and the grace period;
4. Conditions placed on the loan (conditionality);
5. Transaction costs of securing the loan (time and work required to secure the loan).

To the borrower, the ideal source of financing would have a very low interest rate, a very long repayment period with a long grace period, few conditions, and minimal transaction costs. To the lender, the riskier the project or the borrower, the more precautions are put in place and the higher the interest rate. There are generally specific reasons why certain types of financing have come to dominate borrowing in the urban transit sphere in each country.

Countries should pursue increasing access to the most familiar, lowest-cost debt finance for infrastructure, primarily that which bonds and development banks provide. Countries where cities' infrastructure development is constrained by lack of low-cost debt finance should consider programs that support improvement in cities' credit ratings and/or lending to cities through a National Development Bank.

Table 17.1. Characteristics of Different Financing Sources

	Bonds	Multilateral Development Bank	National Development Bank	Commercial Bank	Export Credit Financing
Cost of Capital	Low	Low	Low	High	Low
Credit Rating Required	High	Low	Low	High	Low
Length of Credit Term	Long	Long	Medium	Medium	Long
Conditionality	Low	High	Medium	Low	High
Transaction Costs	Low	High	Medium	Low	Medium

Bond Finance

Bonds issued by state, municipal, and public authorities are a popular mechanism for financing BRT infrastructure in the United States and Europe. It is likely that more cities in emerging markets with reasonably strong finances will turn to bond financing as a mechanism for financing BRT system expansion in the future.

Issuing municipal bonds requires that the municipal finances be audited by an internationally recognized rating firm like Moody's or Standard and Poor's. The city's financial conditions and ability to both raise revenue and live within its means must be found sufficiently transparent and legally sound by an international bond rating company in order to provide sufficient security to bond holders. This rating process itself is not that expensive, generally costing around US$1 million to US$2 million, but bringing the accounting systems of a municipality up to a state where they are sufficiently transparent and consistent with accounting norms to secure the necessary approvals from the bond rating companies may be a lengthy and expensive process. Nonetheless, this is a process that cities should go through as they develop.

The government body receives a rating, and the cost of capital (the interest rate) will be set based on that rating. The most established municipalities and state governments in higher-income economies with perfect payment histories generally have a AAA rating, and pay interest similar to the cost of a treasury bill, making the cost of capital for municipal bonds quite low. Historically, municipal and public authority bonds have been within 1 to 2 percent of the price of a treasury bill, sometimes higher and sometimes lower. The variance between the best rated and worst rated municipal bonds is also usually around 1 to 2 percent but it can be more in times of financial turmoil (WM Financial Strategies, 2017).

The Greater Cleveland Regional Transport Authority in the United States, which financed part of the Cleveland BRT, for instance, has a AAA rating from Standard and Poor's, allowing it to float twenty-year bonds at little more than the cost of a treasury bill (currently around 3.5 percent), while New York has a AA- rating and therefore pays around 5 percent. Maturity periods for bonds are typically long—usually at least ten years and can be up to thirty years, with no conditions and low transaction costs.

Table 17.2. Characteristics of Bonds

	Bonds
Cost of Capital	Low
Credit Rating Required	High
Length of Credit Term	Long
Conditionality	Low
Transaction Costs	Low

Most transit investments are made by transit authorities and are financed with either general obligation bonds of the state or city government that borrows against future general tax revenues or more project-specific revenue bonds that borrow against specific revenue sources. Those that borrow against user fees such as transit fares generally do not need to be voter-approved. Other revenue bonds impose new taxes earmarked to pay for transport infrastructure such as the half-cent sales tax in Los Angeles, known as Measure R, which was passed by popular referendum in 2008 to fund transport infrastructure.

While it is often difficult for cities in lower-income economies to get bond ratings for the first time, because it requires transparent and easily auditable accounting procedures, it is generally worthwhile in the long run for both better access to capital and improved financial transparency, since bond financing has the lowest cost of capital and the least conditionality. That Mexico City, for instance, was able to issue bonds for construction of its Metro Line 12 on the Mexican Bond market, most of it at 7.1 percent interest, or 3 percent below commercial rates, indicates that bond financing should be an attractive method of BRT financing moving forward (Corrales, 2010).

Multilateral Development Banks

In lower-income economies, by far the best and most important source of financing for BRT has come from the Multilateral Development Banks (MDBs). MDBs are intergovernmental financial institutions that are generally capitalized to some degree by higher-income member countries and whose purpose is to lend money to lower-income member countries (though some development banks, such as the European Investment Bank EIB, the house bank of the European Union, lend primarily within higher-income member countries).

In some countries, MDBs provide the dominant share of the overall transit infrastructure finance. The World Bank, for instance, was the main source of financing in Tanzania for the Dar es Salaam BRT, as well as for the BRT in Lima, and for one of the future BRT corridors in Pune, India. The World Bank, with support from the Inter-American Development Bank (IDB), and the Development Bank of Latin America (CAF, the Cooperación Andina de Fomento or Banco de Desarrollo de America Latina) was also instrumental in the rapid rollout of BRT in Colombia, after the success of TransMilenio Phase I in Bogotá. Two of the highest rated BRT projects in China, in Lanzhou and Yichang, were both financed by the Asian Development Bank. These ADB loans in China are one to two percentage points below the commercial interest rates, and hence are a very attractive form of project financing. The ADB's willingness to finance BRTs has helped create incentives for Chinese cities to build more cost-effective mass transit. Currently the ministry of finance has reserved MDB lending for "pilot" projects that require technical help, but China can well afford to do more MDB borrowing, and the quality of the projects was clearly improved by ADB involvement. Expanding MDB urban transit lending in China is thus a good opportunity.

Table 17.3. Characteristics of Multilateral Development Banks

	Multilateral Development Bank
Cost of Capital	Low
Credit Rating Required	Low
Length of Credit Term	Long
Conditionality	High
Transaction Costs	High

Multilateral development banks have significant advantages in financing sustainable urban transit infrastructure. The World Bank's International Bank for Reconstruction and Development (IBRD), the ADB, the EIB, the IDB, and the other regional development banks offer different borrowing mechanisms for client national governments and sometimes subnational governments and commercial clients. The IBRD, for instance, currently charges the London Inter-Bank Offered Rate (LIBOR) plus 0.85 percent for interest plus a 0.25 percent commitment fee and a 0.25 percent front end fee for an eighteen- to twenty-year variable rate loan (IBRD Lending Rates and Loan Charges 2016; http://treasury.worldbank.org/bdm/htm/ibrd.html). The other multilateral development banks offer comparable rates in somewhat different packages as they tend to compete with each other to secure borrowers. All the MDBs fund their lending by selling bonds on the international capital markets that are very low risk because they are backed by the full faith and credit of the member countries, and because governments tend to repay the World Bank before any other form of debt.

They then lend the money out at a marginally higher rate than they pay for it, and they charge service fees. The World Bank has an additional loan window called the IDA (International Development Agency), which makes no- and low-interest loans as well as grants to only the countries with the lowest economies. IDA was used for the Dar es Salaam BRT (World Bank, 2013).

The advantage of MDB financing is that the interest rate is usually as low, the grace period long, and the terms as long as any other lending source, without the loan being tied to companies of a particular nationality.

The disadvantages to borrowing from MDBs, from the perspective of the borrower, are several. First, the project must be opened up to international competitive bidding. Secondly, the fees are often expensive. Third, the transaction costs are high. Projects funded by the MDBs must pass a series of project evaluation criteria to secure approval from the bank board of directors, such as internal rate of return analysis and environmental, and social appraisals. As a result, project quality and transparency is often higher; however, from the perspective of the borrower it also means more administrative work. This all takes a long time, often several years, which may be beyond the political time horizon of a politically elected project proponent. The loans may come with a variety of other additional forms of conditionality. These conditions can be used to further a variety of purposes, some oriented to social and environmental outcomes, others more related to trade or balance of payment concerns. For instance, the loan may require that the cost recovery ratio on a transit system increase fares in a way that has adverse impacts on low income people, as a World Bank loan did to the Hungarian rapid transit authority, BKV (Hook, W., 1996).

On the other hand, the loan might be more likely to be approved if it is consistent with the development bank's stated policy goals and commitments. For instance, in 2012, the multilateral development signed an agreement to shift the US$175 billion they cumulatively planned to lend in the transport sector in the following twenty years to more sustainable modes. While enforcing this is difficult, the banks have formed the MDB Working Group on Sustainable Transport and associated observer organizations are now working to monitor and report progress toward these commitments. This creates incentives for the MDBs to lend more for rapid transit.

Finally, a significant problem for MDB finance of urban transit is that some of the development banks have limited ability to do sub-sovereign lending. For the World Bank, all lending to a city must be approved and facilitated by the national government. If a national government and a municipal government are from different political parties the municipality could potentially find it difficult to get a loan from an MDB. Some of the regional development banks are finding mechanisms to get around this to lend directly to cities and states without needing national government approval.

National Development Banks

National governments sometimes lend money to states, cities, and the private sector for urban transport projects. This is often done through a national development bank (NDB) that is committed to providing credit toward projects that encourage general economic development, though sometimes national governments make loans directly to projects. This can be a highly effective method for a country to ensure access to low-cost debt finance for infrastructure projects that are for critical for development, especially when credit ratings or other restrictions limit bond market access.

Table 17.4. Characteristics of National Government or Development Banks

	National Government or Development Bank
Cost of Capital	Low

Credit Rating Required	Low
Length of Credit Term	Medium/Mixed
Conditionality	Medium/Mixed
Transaction Costs	Medium/Mixed

National Development Banks (NDBs) allow national policy makers to set lending practices and requirements according to national policy objectives, and these can vary from country to country. Typically, NDB loans to cities and states have below-market interest rates, do not require a high credit rating, have medium- to long-term repayment periods, and lower transaction costs. Conditionality can be mixed—whereas MDB loans may require opening a project to international bidding, NDB loans may allow or require national bidding. While the goals of such national bank conditionality tend to focus more on economic growth and competitiveness than on sustainability considerations, they have the potential to also support environmental or social goals with low-cost loans to sustainable modes of transport.

The world's largest development bank is the China Development Bank (CDB), with four times the assets of the World Bank. CDB is directly involved in many rail rapid transit projects. Although it regularly lends money to the municipal investment corporations that fund the BRT infrastructure and is a main financier for urban rail projects, the CDB is not as important to the overall BRT financing picture as commercial credit or quasi commercial credit for BRTs in China. Its interest rates are not that different from that of other commercial credit available in most provinces. Also, its principal advantage is in the length of the loan repayment period and the larger size of the loans, which are far more difficult to achieve from commercial banks for rail projects.

Brazil is home to one of the world's largest development banks, the National Bank for Economic and Social Development (BNDES), as well as National Savings Bank (Caixa Economica Federal, or "Caixa"), both of which provide the vast majority of lending to urban transit investments in China at very low rates. Since 2005, BNDES was responsible for most of the rapid transit financing in Brazil. However, in 2008, the national government began using Caixa as the lending institution for its Accelerated Growth Program (PAC) that financed many new transit systems. Until recently, BNDES and Caixa loans were at around 5 to 6 percent interest and were so much lower than commercial rates in Brazil, which often are twice as high, that they effectively represent publicly subsidized loans. This was made possible by large transfers from the national treasury and by access to worker pension funds. Recently, Brazil has announced plans to increase the interest on BNDES loans as a way of addressing Brazil's growing debt problems.

Other countries have national development banks, but they have not had a significant role in any of the better-known BRT projects. The reasons for this are unclear, but the existence of NDBs in these countries does offer a mechanism for these countries to access financing and this could help grow their RTR. Mexico has a development bank, BANOBRAS, that has expressed willingness to finance or serve as a guarantor for BRT systems, but it has to date played a limited direct financing role in BRT infrastructure, aside from some facilitation of PROTRAM grants and UTTP loans. South Africa's national development bank has also not been active in financing rapid transit. Colombia has recently created its own national development bank, Findeter, but so far it has not been active in financing BRTs.

Some countries do not have national development banks. While France and the United States do not, they do still occasionally give national government loans to local governments. Some highway projects in the United States, for instance, received Federal Transportation Infrastructure Finance and Innovation Act loans. Given the mature bond markets in these countries, the need for a development bank may not be not high, though discussions regarding creating infrastructure banks have recently been raised in the United States. Indonesia does not have a national development bank. India had a development bank in the past, but over time its role as a development bank has been diminished, and it increasingly functions like any other commercial bank.

Commercial Credit

While development banks will often offer interest rates below those of commercial lending institutions, this type of concessionary financing may not always be available. A country may not qualify for concessionary terms, or a city may have reached its borrowing cap with a particular lender. Also, development banks may be wary of lending to a project if the loan will act to crowd out interested commercial banks.

In some circumstances, the commercial lending rate may be quite competitive with a development bank, if project development costs are included. Cities may also wish to include a commercial lender in the project for several additional reasons: (1) Greater project financing expertise; (2) Diversification of financing sources; (3) Development of a successful track record with a commercial lender could be useful in subsequent project phases.

Municipal, provincial, and national governments frequently approach commercial banks to participate in the financing of major infrastructure projects such as metros and BRT. As the experience with BRT has grown, commercial lenders have increasingly viewed BRT infrastructure as a viable lending opportunity. While private banks did not participate in the infrastructure part of the first phase of Bogotá's TransMilenio, the system's success has spurred a competitive environment for banks vying for participation in later phases.

A commercial bank loan to a municipality for BRT infrastructure is generally assessed based on the faith in the overall municipal finances. In such cases, the viability of the BRT system itself would be only a secondary concern to a private bank since the repayment obligation lies with the municipality.

Commercial loans from private banks play a role in lending to infrastructure projects in most countries especially to private sector partners but also to some public sector transit authorities. However, in countries where there is little access to bond markets or national development banks for transit investments and where MDB loans cannot finance a majority of the projects, project proponents will resort to commercial loans from private banks to finance their urban infrastructure.

Table 17.5. Characteristics of Commercial Banks

	Commercial Bank
Cost of Capital	High
Credit Rating Required	High
Length of Credit Term	Medium/Mixed
Conditionality	Medium/Mixed
Transaction Costs	Low

Commercial loans for public transit infrastructure occur in three basic types:

1. Direct commercial lending to governments;
2. Commercial lending to government owned enterprises (GOEs);
3. Commercial lending to private sector investors in public infrastructure through public private partnerships.

Direct commercial lending to governments happens in countries like Mexico where city and state governments borrow directly from private banks. In other countries, like China and India, city and state governments are not allowed to borrow directly from commercial banks but can create GOEs (also called special purpose vehicles or "SPVs" in India) that can borrow from private banks.

Commercial lending to private sector investors in public infrastructure through public private partnerships is the third form of commercial lending to public transit infrastructure. In such deals, a private company will borrow from a commercial bank (in some places private firms can also borrow from development banks) to raise funds for some form of capital investment, usually rolling stock but sometimes for infrastructure as well. The private firm will also often invest its own equity into a project (though usually 20 percent or less of total project cost). These investments will then be paid back over time either through user fees or payments for service by the government or a combination of the two. While the government is not technically taking out a loan in this scenario, the private sector investment can still essentially be thought of as a mode of financing for the government itself because it mobilizes private capital up front and uses essentially public funds (via transferring fare revenue collection rights and/or additional service payments/subsidies) to pay off that capital over time. This is another effective way for cities and states to get investment infrastructure when there are restrictions on other forms of lending. However, project proponents must gauge carefully the ultimate cost of capital and corresponding risk assumption under such arrangements.

Within China, the government makes a distinction between commercial banks and "policy" banks, which more directly seek to achieve policy outcomes through lending. Though both are owned by the government, the only "policy" bank that makes loans for urban transit is the China Development Bank. The other banks, though government owned, are all considered "commercial" banks because they lend at commercial rates for commercial periods of time and at a scale comfortable to a commercial bank. This is not to say that there is not governmental interference with commercial banks. Political influence over the municipally owned banks, in particular, seems to have an impact on urban transport project lending. Loans for the projects that are a priority of the mayor yet face the greatest economic uncertainty tend to be funded by the municipally owned banks, which the city's mayor has more control over.

Commercial loans in China are largely made to government-owned enterprises (GOEs) at the city level, which unlike city governments, are allowed to borrow directly from commercial banks. These GOEs are also controlled by the mayor and for most purposes are an extension of the municipal government, so loans are considered by the banks as direct loans to the municipality and thus enjoy lower interest rates. Most cities have municipal bus companies that are city-owned enterprises, and these enterprises tend to be in control of vehicle procurement in BRT projects. They tend to borrow from commercial banks. There are also a few private concession metro systems in China. In these deals, private investors borrowed money from commercial banks to pay for the rolling stock. The investors were repaid over time by the municipality in the form of lucrative operating contracts. The real cost of capital in these instances ended up being higher than for other available forms of financing in China, so this arrangement has not gained much traction.

In Mexico, states and especially cities have very limited means of raising tax revenues outside of the Federal District of Mexico City. State budgets are often so tight that states will take commercial loans to finance general budgets. Furthermore, in the wake of the 1994-95 financial crisis, debt ceilings were implemented, limiting states and cities from borrowing money from private Mexican banks using future federal government transfers as collateral, as these loans were a cause of the financial crisis. City and state governments are also not allowed to raise loans in foreign currencies, and some BRT projects require foreign exchange. Most rail and BRT projects in Mexico are set up—at least in part—as public private partnerships (PPPs) as a way of getting around borrowing limits and restrictions on international borrowing.

Mexico's BRT program known as PROTRAM (a national government program funded by national toll road revenue surpluses) mandated that a project needed 30 percent private sector investment to be eligible for PROTRAM grant funds. A large part of the commercial financing in Mexico is financing the private sector investment share of these PPP BRT projects.

Thus far, India has done very little debt financing of its BRT systems. India has two major state banks, both essentially commercial banks, that played a key role in financing urban rail infrastructure, but none to date have played any role in financing BRT. The Mumbai Metro was financed in part by loans from the IDBI (formerly known as the "Industrial Development Bank of India," and now known simply as "IDBI") and both the Hyderabad and Bangalore Metro systems were financed in part by loans from the State Bank of India. Both of these banks retain majority ownership from the Government of India, though they function as commercial banks rather than development banks since the Industrial Development Bank (Transfer and Undertaking and Repeal) Act of 2003. As such, these loans from SBI and IDBI are private commercial loans (Rajesh, R. and Sivagnanasithi, T., 2009, p. 8).

In India, the only commercial bank financing involved in its BRT projects has been for vehicle procurement. Most BRTS in India created special purpose vehicles (SPVs) to manage BRT systems, and these SPVs tender out their operations to private operators to form a particular type of PPP. The private operators, which tend to have a contract with the SPV, use their operating contract to secure financing for the procurement of the BRT vehicle fleet. Of five BRT projects reviewed in India, three received commercial bank financing, and the loans were to the operators for vehicle procurement. In all, the loans were for less than 10 percent of the total project costs. For highways, commercial banks financed two out of three projects, although lending levels varied widely. One project was for 84 percent of total project costs and one was for 9 percent. Rail consistently received financing at higher shares of the total project costs. Four out of five projects commercially financed between 10 to 63 percent of total project costs. This indicates that India could dramatically expand its rollout of BRT infrastructure by increasing its level of commercial lending for BRT infrastructure.

17.3.2.1 Export Credit Agencies (ECAs)

For some higher-income nations, Export Credit Agencies (ECAs) are a mechanism to promote national technologies and firms. A few ECAs, namely BNDES, JBIC, and the United States Exim bank, have direct lending programs in lower-income economies, and these require risk sharing or co-lending with banks. Export Credit Agencies work through commercial banks. Normally the ECA will provide a guarantee to a commercial bank, which will then provide the financing. As such it is important for operators/city sponsors to find an experienced ECA bank arranger/lender that can evaluate the BRT project and borrower risks and make a case for the ECA to provide support to its lending to the project. Currently the most successful ECA finance arranger for BRT projects is HSBC but Citibank and BNP have also worked on ECA financings for bus and coach projects in Mexico and Colombia.

Commercial Bank Loans supported by insurance from the ECAs can be extended to borrowers in countries with lower economies if there appears to be a benefit to the country with a higher economy's interests. Thus, if markets exist for construction companies, vehicle manufacturers, and fare equipment vendors from higher-income nations, then ECA-supported loans are a possibility for lower-income cities.

In the rail sector ECA financing has provided extremely low interest loans with very long repayment terms and minimal transactions costs. Export credit agencies sometimes offer intergovernment loans for rail projects at rates far below the cost of similar (long) term United States Treasury bills. The limitation of such loans is that they tie the borrower to procurement of goods and services from corporations from the lending country.

Table 17.6. Characteristics of Export Credit Financing

	Export Credit Financing
Cost of Capital	Low
Credit Rating Required	Low
Length of Credit Term	Long
Conditionality	High
Transaction Costs	Medium

While to date these bilateral lending institutions have not been involved in the infrastructure side of BRT projects, they have been involved in lending for BRT vehicle procurement, and several of them would be open to lending money for BRT infrastructure if their own construction companies were involved.

This form of "tied" aid may act to ultimately compromise the intended direction and quality of the project as well as increase the overall capital cost. Bilateral lending in the urban rail sector has led to considerable distortions in decision making, creating a powerful incentive to build expensive urban rail systems where BRT would have been just as effective and far cheaper and faster to build.

Bilateral and export credit agency loans were not a significant form of BRT infrastructure financing for any country. There have been significant ECA loans for urban rail projects, however. For Indonesia, there was just one export credit loan, for the Jakarta metro. The Jakarta metro was financed by a loan from JICA (Japanese International Cooperation Agency) at just 0.2 percent interest with a ten-year grace period and a forty-year repayment period (Japan International Cooperation Agency, 2017). This is a highly subsidized loan, far below the cost of any alternative sources of financing in Indonesia or internationally. However, the loan is tied to procurement from Japanese construction and rail companies for most key elements of the project. These can end up being monopoly supply relationships that can increase the long-term cost of the supply of spare parts, which constitute a large share of transit system operating costs.

India has also relied on export credit agencies for rail projects. The Delhi metro is also being financed by extremely low interest loans from JICA, which also financed the Kochi metro and the Bangalore metro. AFD (L'Agence Francaise de Developpement), the French development agency, also provided loans for the Kochi and Bangalore metros. In many of these cases, the availability of very low interest export credit financing from the country providing the technology can play a key role in the selection of rail technology. South Africa, China, and Brazil also received bilateral loans for a small number of urban rail projects, though it was a relatively minor share of their overall financing picture.

Figure 17.7. In Phase I of TransMilenio, the Brazilian development bank (BNDES) was the principal financing entity for the procurement of vehicles by the private operators. However, with the success of the system, commercial lenders have started playing a more active role. *Lloyd Wright.*

For BRT, ECA was used only for vehicle procurement. Many of the BRT projects also turned to the ECAs of the countries where vehicles are manufactured. Bogotá's TransMilenio and Johannesburg's Rea Vaya both relied on Brazil's BNDES bank for vehicle procurement, and Mexico City's Metrobus and TransMilenio relied on guarantees from the Nordic export credit agencies. The interest rates (1 to 2 percent, or 100 to 200 base points below the market rate) on these deals were closer to commercial interest rates but generally below the interest rates that would otherwise have been available from a commercial bank.

17.4 Examples of BRT Capital Funding and Financing

> *"I'm not a very good financing person. I don't even know how much money I have in my bank account. I never have opened one single envelope from the bank—they freak me out."*
>
> — Marjane Satrapi, graphic novelist, 1969–

While the previous section reviewed how in general BRT projects have been financed in a variety of cities and countries around the world, this section reviews more details on how specific projects were financed.

17.4.1 BRT Funding in Colombia

Phase I of TransMilenio in Bogotá was a 41-kilometer gold-standard BRT system passing through Bogotá's historic downtown. The capital costs for the first phase of TransMilenio, inclusive of the vehicle procurement, were approximately US$751.5 million (in 2013 dollars), of which US$623.4 million was for the infrastructure and US$138.1 million was for vehicle procurement. Of this, approximately US$367.8 million (48 percent) came from a grant from the national government, US$255.6 million (34 percent) came from the City of Bogotá, and US$138.1 million (18 percent) came from private investors. The 18 percent from private investors paid entirely for vehicle procurement and fare collection equipment, so the infrastructure alone was split between the city (41 percent) and the national government (59 percent).

Of the City of Bogotá's share, it came from the following sources:

- Local fuel surcharge: Colombian national law allows city councils to impose a surcharge on petrol. In 2003, President Uribe raised the maximum surcharge to 30 percent and Bogotá has already increased it to this new level, assuring resources for the future phases;
- General local revenues and de-capitalization of the municipal electricity company: In 1997, the Municipal Electricity Company was 51 percent owned by the municipality and the rest was privately held. At that time, the company had an excess of cash, and decided to de-capitalize itself. Some of these sources financed TransMilenio infrastructure.

Making this happen was not easy. Mayor Peñalosa had to convince the city council to raise the surcharge on petrol to make this possible.

In Phase I, only 19.4 percent of the total cost was debt financed. Roughly US$110.3 million, or 14.5 percent, came from three development banks: the World Bank, the Inter-American Development Bank (IDB), and the Development Bank of Latin America (CAF). The World Bank loan came from the reprogramming of an initial credit given to the City of Bogotá (with the authorization of the national government) to build a low-grade busway on "Calle 80" (80th Street). The World Bank allowed a change in the loan terms in order to use this credit for TransMilenio infrastructure. The other loan, for about US$36.8 million (4.8 percent), was for vehicle procurement. It was a loan given to the vehicle operators by the Brazilian National Development Bank (BNDES). The vehicle operators at that time were not well established, and they had a hard time procuring loans for the remainder of the vehicle procurement. Mayor Peñalosa had to intervene directly to convince BNDES to finance the vehicle procurement after local banks proved unwilling.

Phase II, which added another 42-kilometer of gold-standard BRT to the TransMilenio network, cost US$1,387.5 million. Of this, US$770.3 million came from a grant from the national government, US$535.3 million came from the City of Bogotá, and US$81 million was private investment for vehicle procurement from the vehicle operators. Phase II's infrastructure was more complicated that Phase I, with some expensive flyovers and interchanges, while the demand was lower so the fleet needed was also lower.

In Phase II the share that was debt financed increased, but it was mostly short-term debt. US$231 million, or 16.6 percent came from loans from the World Bank, CAF, and the IDB. US$50.8 million (5.58 percent) came from BNDES for vehicle procurement. This was traditional long-term debt. At this point, however, the nature of the infrastructure contracts was changed. The construction companies contracted to build Phase II were paid directly from the national government, but only in annual installments over five years, during which time the infrastructure had to be both built and maintained. To make this viable, the construction companies turned to local banks with whom they had long relationships, and local banks financed virtually all of the money for the construction companies on relatively short (five-year) terms.

Most of the other BRT systems in Colombia were funded and financed in the same way, with the national urban transport funding paying the majority of the cost, and municipal fuel tax and other revenues paying the balance.

17.4.2 BRT Funding in Brazil

Brazil's BRT systems are largely funded by municipal governments and financed by BNDES, but there are a few exceptions. While there is no systematic national program to fund municipal urban transportation, there are occasionally one-off grants for projects seen to be of national significance. Most of the metro projects in Brazil received grants from the national government, and a few of the higher-profile BRT projects have also received one-off national government grants.

When BRT was first developed in Curitiba in the 1970s, Mayor Jaime Lerner was developing a system with few precedents, so the financing was difficult to secure, and the municipality had to rely on its own cash resources. With the success of the project, the Inter-American Development Bank (IADB) agreed to provide debt financing for Phase II, but the debt had to be repaid by the city.

Curitiba's newest, gold-standard BRT system, the Linea Verde, is a 31-kilometer corridor with integrated express services and passing lanes. It cost roughly US$241.5 million, of which US$74.9 million came from a national government grant, US$144.9 million or 60 percent came from the municipality, and 9 percent or US$21 million came from the vehicle operators for vehicle procurement. Some 40 percent of the total cost was debt financed, of which the US$74.9 million paid by the national government was financed by a loan from the IDB and the French Development Agency (AFD), some 7 percent or US$14.7 million (for the vehicle procurement) was financed by commercial banks, and some US$7.2 million or 3 percent was financed by the Caixa Economica Federal.

The elevated silver-rated BRT in São Paulo, Expresso Tiradentes, cost US$1.29 billion, of which US$767 or 75 percent was funded by a national government grant, US$309.6 million was funded by the City of São Paulo, and US$16.7 million, or 1 percent was funded by the vehicle operators (vehicle procurement). As most of the system uses standard vehicles, vehicle procurement costs were low. Only 23 percent of the cost was debt financed, a US$283.8 million loan from BNDES.

The two new BRT corridors in Rio de Janeiro, the silver-rated TransOeste and gold-rated TransCarioca, are both funded almost entirely by the municipality. TransOeste cost US$838.25 million, of which 96 percent was paid by the municipality and 4 percent was paid by the vehicle operators for vehicle procurement. TransCarioca cost US$573.9, of which 94 percent was paid by the city and 6 percent by the vehicle operators. TransOeste debt financed only the vehicle procurement (vehicle operators secured commercial loans), while TransCarioca was 79 percent debt financed, some 75 percent from a loan from BNDES and 4 percent from commercial loans for vehicle procurement.

The only other Brazilian city with gold-standard BRT corridor, Belo Horizonte, financed its new BRT in the following way. Corredor Antonio Carlos: Pedro I cost US$361.9 in total, and was funded 34 percent by the State of Minas Gerais, US$123 million or 65 percent by the municipality of Belo Horizonte, and 1 percent by the private operators for vehicle procurement. Of this, 50 percent was debt financed, 49 percent from a loan from the Caixa Economica, and 1 percent from private commercial banks for the vehicle procurement.

17.4.3 BRT Funding in the United States

In the United States, the Cleveland HealthLine is the highest rated BRT, with a silver rating. Its 11-kilometer extension cost US$207.7 million, of which 49 percent was paid for by national government grants, mostly one-off congressional earmarks. Further, 30 percent was funded by State of Ohio grants, 16 percent was paid for by the capital program of the Greater Cleveland Regional Transit Authority (GCRTA), and 5 percent was paid by the City of Cleveland. About 18 percent of the State of Ohio share and a substantial portion of the GCRTA share was financed by the sale of bonds.

Figure 17.8. São Paulo's Interligado system is receiving financial support from the Brazilian national development bank (BNDES). *Gerhard Menckhoff.*

The 23-kilometer Orange Line in Los Angeles cost US$375.6 million, of which 6 percent came from national government grants, 48 percent came from the State of California, and 43 percent came from the City of Los Angeles. About 95 percent of this was financed by the sale of bonds, both for the state share (bonds sold under the Passenger Rail and Clean Air Bond Act of 1990) and the city share (Proposition C, backed by the sales tax).

While new projects in the United States are not highly leveraged with debt, the transit authorities responsible for building and operating systems in the United States are often deeply in debt, in part to cover a backlog of unmet maintenance needs and in part to cover operating losses.

17.4.4 BRT Funding in India

The highest rated BRT in India, the Ahmedabad Jan Marg BRT system, is 88 kilometers, built in two phases. It cost US$264.3 million, and was financed 32 percent by national government grants from the Jamal Nehru National Urban Redevelopment Mission (JNNURM). Some 14 percent was funded by the State of Gujarat, and another 46 percent was funded by the Municipality of Ahmedabad. Some 8 percent, the cost of the vehicle procurement, was funded by the private vehicle operators. Of this, only the 8 percent funded by the private vehicle operators, was debt financed, in this case by loans from commercial banks. The funding and financing for most of India's other rated BRT systems, such as Indore, Surat, Pune, and Pimpri-Chinchwad, were all funded and financed in roughly similar manners, with the exception of the Pimpri-Chinchwad project, which was 13 percent debt financed by a loan from the World Bank. This indicates that BRT in India could probably expand faster if it sought out more debt financing.

17.4.5 BRT Funding in Mexico

BRT systems in Mexico are funded differently depending on whether they are located in the Federal District of Mexico City (DF) or not. The BRT corridors in Mexico City are mostly paid for by the metropolitan government, which as the Federal District, has the status of a state government. The five BRT corridors in Mexico City cost US$641.7 million, of which 69 percent was funded by the DF (a state government), and 30 percent was funded by private investment from vehicle operators. About 34 percent of the total cost was debt financed, 2 percent from loans from the national government, and 32 percent from private commercial banks, mostly to the vehicle operators but 2 percent of the loan proceeds also went to the municipality. Most of Mexico's economic activity is concentrated in the DF, so the tax revenues of the DF are much higher than for most other state governments in Mexico.

Outside of Mexico City, the national government played a much larger role in BRT funding. For BRTs in the State of Mexico, Puebla, Monterrey, Chihuahua, the total projects cost between US$77 million and US$249 million. The national government funding, from the PROTRAM program (largely funded from the proceeds of intercity toll roads) covered between 15 percent (State of Mexico) to 37 percent (Monterrey). State governments provided about one-third of the total cost, except in two places, León and Chihuahua where the municipality funded some 20 percent of project costs. Unusually, private investors funded more than 30 percent of the total project costs. In Mexico, because of the rules governing the PROTRAM funds, private investors were expected to pay not only for the vehicle procurement but also some share of the infrastructure. In most cases, this is not proving sustainable, and most of the private investors will need to be bailed out by the government for some portion of their losses.

Mexico is also unusual in that on average 46 percent of these funds were debt financed, and most of this debt was from commercial banks. About 36 percent generally came from private banks like Banka Milfel, Interacciones, and BBVA Bancomer, some loans came from the state government, and 1 or 2 percent national government loans. The higher share of private commercial bank lending is linked to the higher share of the investment funds coming from private investment.

17.4.6 BRT Funding in African Cities

South Africa has three BRT systems, two corridors in Johannesburg ranked silver, a corridor in Cape Town ranked bronze, and a new unrated system in Tshwane (Pretoria). Phase Ia and Ib in Johannesburg cost US$459.2 million, Phase I in Cape Town cost US$404.5 million, and Phase I in US$96.8 million. Of this, 85 percent was paid by the national government in Johannesburg, 87 percent in Tshwane, and 100 percent in Cape Town. The municipality in Johannesburg paid about 16 percent, mostly for the vehicle procurement, and this was indirect. Tshwane paid about 14 percent, also for the vehicle procurement. These systems were essentially cash financed, with the exception of the vehicle procurement. The vehicle procurement in Johannesburg was financed by BNDES and the vehicle procurement in Tshwane was financed by the Swiss Export Credit Agency.

The Dar es Salaam BRT project, DART, is expected to open in early 2016. Phase I infrastructure was over US$200 million, and was entirely funded by the national government, with debt financing for everything but land acquisition via a loan from the World Bank. The procurement of the fleet was done entirely by private operators, details of which have yet to emerge as of this writing. The World Bank, the African Development Bank, JICA, the European Union, AFD, and the Chinese government have all been actively financing infrastructure in Africa, and all of these entities have expressed interest in financing planned BRTs in Nairobi, Kampala, Accra, Dakar, Addis Ababa, and other African cities.

17.4.7 BRT Funding in Indonesia

Currently, TransJakarta, one of the longest BRT systems in the world at 171 kilometers, was funded entirely by the DKI Jakarta government, which is the equivalent of a provincial government. TransJakarta Lines 2 and 3 cost US$81 million, and they were entirely cash financed by the DKI Jakarta government.

Figure 17.9. The limited funding expended on Jakarta's Phase I infrastructure was provided by the provincial government, DKI Jakarta. *Karl Otta, the GTZ SUTP Photo CD-ROM.*

For a time, TransJakarta relied on the vehicle operators to procure the vehicles, but the municipality reverted to public procurement around Phase III. Jakarta's reliance on its own cash funds in large measure reflects the relative wealth of the DKI Jakarta government, and the fact that Jakarta has a hard time spending the funds it raises as it cannot administratively process the transactions in a manner consistent with cumbersome procurement rules.

17.4.8 BRT Funding in China

China currently has two gold-rated BRT corridors, one in Guangzhou and one in Yichang. There are also a few silver-rated systems, in Lanzhou, Chengdu, and Xiamen, and many bronze-rated systems throughout the country. The Guangzhou BRT cost US$147.5 million. Some 96 percent was paid for by the municipal government out of general budget revenue, and 4 percent was paid for by the three vehicle operators, the major shareholder for which is also the municipality. Some 76.6 percent of this was financed by the municipality with a single commercial loan from ICBC.

The Lanzhou BRT cost about US$70.2 million, of which 53 percent was paid by the municipality (from land sales and general tax revenues) and 47 percent of which was paid by the municipal vehicle operating company. The system was 84.6 percent debt financed, with 53 percent of the debt covered by the Asian Development Bank and the remaining 31.6 percent coming from commercial rate loans from the Bank of Lanzhou (also owned by the municipality). The Yichang BRT cost US$163.5 million, of which 100 percent was paid for by the municipality, backed both by land sale and other general revenue. Of this, 92.4 percent was debt financed, which is composed of 62 percent from a loan of the Asian Development Bank, and 30.3 percent from commercial banks.

The majority of BRTs in China are funded and financed in a similar manner, with the exception that ADB financing is relatively unusual, and normally this share would be covered by additional municipal borrowing from commercial banks or the China Development Bank. China's BRTs are thus heavily leveraged.

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VOLUME V

Technology

Volume 5 provides details on a number of technological systems that are required to all work together in synchronization for a BRT systems to run smoothly.

Namely, there are varying types of fare systems used around the world, and these systems are complemented by the vehicles being used in the BRT system, all of which are connected through intelligent transport systems (ITS).

Further detail regarding the management of these systems in a central control facility is given in Chapter 27 of Volume VI.

18. Fare Systems

"Buy the ticket, take the ride."

— Hunter S. Thompson, journalist and author, 1937–2005

Fare collection systems play a vital role in success or failure of any public transport system. Unaffordable fares and inappropriate collection methods may result in dissatisfaction and disappointment of passengers, while affordable fares, simplicity, and ease of use can attract more ridership. This chapter provides a brief description of fare collection systems. An explanation of fare structures and policies is provided in Chapter 15: Fare Policy and Structure.

Relying on the manual issue of paper tickets for fare collection involves considerable human effort, resulting in delays for customers and revenue leakage. Recent technological advances have introduced smart means of fare collection by using electronic devices, making the fare collection process faster and more secure. However, technology has its own limits that should be understood before adoption.

There are two types of fare collection processes: onboard systems, inside public transport vehicles, and off-board systems, outside the vehicles. Historically, onboard systems have functioned by means of a conductor inside the vehicle who issues paper tickets and collects cash payments. Some onboard systems make use of handheld ticketing machines that issue printed paper tickets (but still require a conductor inside the bus to issue tickets and collect the fares). Other onboard systems do not involve a conductor but require the passenger to pay a cash fare to the driver. Onboard systems may also incorporate prepayment mechanisms by means of smart card or token readers.

Off-board systems emerged as a means of handling large passenger volumes efficiently and without the inconvenience of onboard collection. Most rapid transit systems, including BRT and metros, collect fares at the station, before passengers enter the vehicle. Most successful BRT systems, such as Bogotá's TransMilenio, rely on smart-card based, prepaid fare collection. Prepayment avoids the delays that occur when passengers need to file past the driver to pay their fares, or the inconvenience of having a conductor move through the bus and collect fares.

In general, a fare collection system must include:

- The payment media and devices for validation of payment media;
- Access control mechanisms;
- A central system for information processing and report generation with communication links between system components;
- Customer interface (signs, web pages, user complaints, etc.).

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The sections below discuss each of these components in more detail.

18.1 Fare System Functionality

> *"Customers require the effective integration of technologies to simplify their workflow and boost efficiency."*
>
> — Anne M. Mulcahy, businesswoman, 1952–

Rapid transit systems are designed to cater to large passenger volumes. Managing peak-hour volumes has been a challenge for public transport agencies around the world. While paper tickets were historically the primary mode of fare collection, public transport agencies have increasingly turned to electronic fare collection to cater to increasing demand, and to solve the problem of long passenger lines at ticket counters.

Any fare collection system must incorporate a mechanism to ensure payment by users. There are two primary means of ensuring compliance:

- Barrier control: Users need to pass through some kind of physical barrier to access the system. Typically this implies turnstiles on vehicles or at stations, sliding doors, or other such mechanisms. The users present a payment medium (e.g., a smart card or magnetic-strip card) for the barrier to open, and a payment is deducted from the medium;
- Proof-of-payment: There are no physical barriers to enter the system. Users either enter freely (an "open system") or show proof of payment upon entry and/or exit. In such systems, public transport staff conduct occasional checks to control fare evasion. For those caught without a valid fare during the random inspection process, a penalty is applied. Proof-of-payment systems entail pre-board fare collection, usually through a vending machine or kiosk. From the fare payment point onward, the customers proceed directly to the public transport vehicle without inspection.

Barrier control is common on trunk corridors of many BRT systems, as it minimizes stress of human work and labor to maintain records and data. Proof-of-payment systems are typical in many European public transport systems, but are not very common in BRT systems due to the difficulty of coping with high demand levels and the costs of enforcement personnel necessary to reduce leakage to an acceptable level. Rigorous enforcement of fare evasion is something of an unpleasant business. Enforcement authorities have to be quasi police, either armed or physically large. Sometimes people are unable to figure out how to pay the fare, either because the cash point was not working, or it was closed, or it failed to punch the fare card properly. People need to retain the fare card, and sometimes it gets lost. When one of these things happens, it is highly unsettling for passengers, for they face a stiff penalty, and a humiliating encounter with enforcement agents.

Proof-of-payment systems are prevalent in subsidized public transport systems where there is less direct institutional concern about collecting the fare revenue. This kind of system also requires a legal framework that allows verification staff (that usually are not police staff) to have de facto police powers in the collection of penalties from violators, and a procedure for collecting when the passenger does not have the money to pay the fine. This legal framework is absent in many developing countries. Fare verification by personnel walking through the buses is also difficult on very crowded systems. Even with stringent verification requirements, cities can face significant amounts of fare evasion. As such, the viability of operating an effective honor system is questionable.

Some BRT systems with direct services that extend beyond trunk corridors sometimes make use of both compliance mechanisms: fares are collected off-board at trunk stations, but the system relies on proof-of-payment on service extensions. Other systems require paying the driver when the vehicles operate outside of the trunk corridor, as in Guangzhou, China, and Cali, Colombia. Thus, different components of a BRT system may require varying fare collection solutions.

Fare collection systems are also a factor of the fare structure. Fare collection is fairly straightforward in the case of flat fares, whereas distance-based or zonal fare systems typically require a more intricate solution. The following sections describe common approaches for typical BRT service types.

18.1.1 Fare Collection on Trunk Corridors

Off-board fare collection is generally the most suitable process for BRT trunk corridors. Successful BRTs worldwide have adopted off-board fare collection systems to reduce boarding times and facilitate the use of electronic fare media. Bus frequencies on BRT trunk corridors are often so high that only electronic fare collection is a viable mechanism for handling fare payments during peak hours. For systems in which drivers are responsible for fare collection, passengers take as long as two to four seconds to pay the driver while entering the vehicle. Once passenger flows reach a certain threshold, the delays and time loss associated with onboard fare collection become a significant system liability.

By contrast, in a BRT system with pre-board fare collection, boarding and alighting is conducted from all doors at once. When fares are collected off the vehicle, there is no delay in boarding and alighting related to the fare collection and fare verification processes. A pre-board fare collection and verification process will reduce boarding times from 3 seconds per passenger to 0.3 seconds per passenger. In turn, the reduction in station dwell time greatly reduces vehicle congestion at the stopping bay.

The introduction of contactless smart cards and other modern payment systems can reduce onboard payment to fewer than two seconds per passenger. Systems such as the Seoul, South Korea, busway make use of onboard fare collection using smart card technology. However, any time the driver is responsible for verifying fares, the speed of the service is highly compromised, particularly if there is a large volume of passengers.

In the case of the Seoul busway system, passengers must remember to swipe their smart cards both upon entering the vehicle and when existing as well. Delays can occur simply if a person enters the vehicle and must search through their belongings to find the fare card. Onboard payment and verification psychologically also creates a lower-market image for the service. Off-board payment and verification gives the sense of a more metro-like system.

Table 18.1. Observed Boarding and Alighting Times for Different Vehicle Configurations. Table courtesy of ITDP.

Configuration characteristcs				**Boarding and alighting times**	
Fare collection method	Doorway width (meters)	Stairway boarding or level boarding	Vehicle floor height	Observed; boarding time;	Observed alighting time
Onboard, manually by driver	0.6	Stairway	High	3.0[1]	NA
Onboard, contactless smart card (no turnstile)	0.6	Stairway	High	2.0[2]	NA
Off-board	0.6	Stairway	High	2[3]	1.5[3]
Off-board	0.6	Stairway	Low	1.5	1.2
Off-board	1.1	Stairway	High	1.5	1.0
Off-board	1.1	Stairway	Low	1.1	0.9
Off-board	1.1	Level	High	0.75[1]	0.5[1]

Where:

1. Colombia/Mexico;
2. China;
3. Brazil;

NA not available.

Off-board payment collection is not necessarily the only way to reduce boarding and alighting times, but there are institutional reasons why this approach is generally more successful in the developing-country context. Passengers can also enter through all doors at once if there are sufficient conductors to check tickets once on board. Alternatively, many European light-rail systems utilize an honor system, where it is the responsibility of passengers to punch their own tickets that they purchase at shops and kiosks. Enforcement is then the responsibility of the police or contracted security personnel. However, in developing countries such enforcement is usually ineffective.

Off-board fare collection also reduces the potential for leakage because there are fewer points of cash collection in the system. When passengers pay on board, and do not have to pass through a turnstile, there is no clear count of how many passengers boarded the vehicle. Off-board fare sales to a third party make it easier to separate the fare collection process from the bus operators. By having an open and transparent fare collection system, there is less opportunity for circumstances in which individuals withhold funds. Further, by removing the handling of cash by drivers, incidents of onboard robbery are reduced.

Off-board payment also facilitates free transfers within the system. The enclosed, controlled stations also give the system another level of security, as the stations can be better protected by security personnel, thus discouraging theft and other undesirable activities. Payment off board also is more comfortable than juggling change within a moving vehicle.

The main disadvantage to off-board fare collection is the need to construct and operate off-board fare facilities. Fare vending machines, sales booths, verification devices, and turnstiles all require both financial investment and physical space. The average station cost in the TransMilenio system was approximately US$500,000 each. Of course, it is also possible to construct simpler closed stations for less; the stations on the Ecovía line in Quito, Ecuador, cost in the area of US$35,000 each. Closed stations, though, also bring other benefits besides increased system efficiency. Such stations provide more protection from inclement weather, such as rain, wind, cold, and strong sun. Also, closed stations hold advantages in terms of providing security from crime as well as discouraging loitering.

In a BRT system with limited physical space for stations in a center median, accommodating the fare collection and verification infrastructure can be a challenge. Depending on how the fare system is configured, there may be some time loss while paying off board, whereas paying on board theoretically means that the payment time occurs while the bus is moving. Of course, this type of activity can create safety issues if the driver is both handling fares and driving at the same time. Customers can also be uncomfortably jostled about when trying to pay at the same time the vehicle is accelerating.

Some systems employ a reservoir area within the vehicle to hold passengers while they go through the fare payment and verification process. This system is utilized in Brazil to allow the passenger queue to quickly file into the vehicle, which can then accelerate to the next station without waiting for passengers to complete the fare-verification process. However, this technique often requires onboard fare collection staff, which in turn raises operational labor costs.

There is no one precise point at which a system's capacity will determine if onboard or off-board fare collection is more cost effective. Much depends on demand figures from individual stations, station physical configurations, and average labor costs. However, the advantage of off-board payment clearly increases as the level of boardings and alightings at the station increases. In Goiânia, Brazil, the local public transport agency estimates that an off-board fare system is cost justified when the system capacity reaches 2,500 passengers per hour per direction. The development of a cost-benefit analysis may help determine this capacity point, provided the costing data is available.

Figure 18.1. Off-board fare collection system in Beijing. *Karl Fjellstrom.*

BRT systems with off-board fare collection may use manned points of sale, automatic ticket vending machines, or a combination of both. Paper tickets can be issued during initial stages from ticket counters at stations, but the system should move toward paperless operations by introducing and promoting the use of cashless travel by means of automatic access control barriers.

18.1.2 Fare Collection on Feeders

Depending on the system typology, feeder services can have onboard fare collection with conductors or proof-of-payment with electronic or paper tickets. Many BRT systems integrate fares between trunk and feeder services; feeder travel is discounted or free for passengers transferring to a trunk bus. In Bogotá's TransMilenio, the user gets a complimentary feeder bus ride once he or she pays the fare to travel in the trunk bus. Transfer discounts are facilitated through the use of cashless fare collection systems in both trunk and feeder systems. For example, there can be a common smart card that can be used in the BRT as well as feeder services.

Figure 18.2. Onboard fare collection on a feeder bus in Yancheng, China, allows customers to connect to the BRT using a smart card payment system. *Liu Henian.*

The operating costs of fare collection in feeder services are generally higher than on-station, since additional personnel and communication costs are incurred. Revenue from trunk fares helps cover not only the increased cost of collection but potentially the cost of the feeder services themselves.

18.1.3 Fare Collection on Direct Services

Some BRT systems have special services and routes that connect trunk corridors with high-demand areas located a short distance from the segregated corridors. While these systems may employ off-board fare collection at trunk stations, an alternate solution is necessary on the extensions. One possibility is to employ electronic fare cards. Passengers tap onboard smart card readers when boarding from an extension, while fare collection is still accomplished off-board at the trunk stations. Monitoring by the driver or some other proof-of-payment mechanism is necessary to ensure fare payment on the service extensions.

18.1.4 Integration with Other Public Transport Services

Integration of BRT fares with that of other forms of public transport has many advantages for passengers, reducing the need for cash payments and the inconvenience of learning multiple fare structures for different modes. In Guangzhou, China, customers may use the same fare card on the BRT, metro, and bicycle sharing systems.

18.2 Fare Collection Media

> *"The real problem is not whether machines think but whether men do."*
>
> — B. F. Skinner, psychologist, 1904–1990

The following payment mediums are in common use in BRT systems around the world:

- Coins;
- Tokens;
- Paper tickets;
- Magnetic-strip cards;
- Smart cards.

No one solution is inherently correct. The choice of fare collection system often involves a trade-offs among costs, simplicity, cultural conditions, and service features. The selection of an appropriate fare collection medium is generally guided by the following goals:

- Minimize the time a passenger spends in purchasing tickets and entering the public transport system;
- Make the overall fare collection process simple and easy to understand;
- Minimize human interference in order to reduce the possibility of revenue leakage and fraud;
- Minimize the cost of fare collection;
- Generate financial and travel data for use in system monitoring;
- Respond dynamically to changes in fare policies and service plans.

Two decades ago, printed paper tickets were the only economically and technologically viable fare collection system in public transport systems around the world. But with the advent of electronic fare collection systems, the scenario has changed. Across the globe, most BRT systems have adopted contactless smart cards as the preferred payment medium. This technology has become popular because it is relatively inexpensive both in terms of upfront investment and in recurring maintenance costs, while providing numerous operational features.

18.2.1 Coin/Token Systems

Mechanical coin and token-based systems are among the simplest technologies available to handle fare collection and fare verification. These systems can be quite robust and economical to operate. New York City's public transport system worked on a token-based system for more than a hundred years.

The number of sales personnel can be reduced and ticketing machines are not necessary with coin-based systems because the customer does not need to go through the cumbersome process of programming the electronic card. Instead, the currency acts directly as the fare payment and verification mechanism. There is no need to issue any paper tickets to customers. Also, there is typically no queue at the exit side of the trip, either. Thus, while other systems may involve at least three separate customer queues (purchase fare, verify fare at entrance, and verify fare at exit), coin-based systems require the customer to only enter one queue (verify fare at entrance). However, once a ticket is purchased, contactless cards tend to have higher throughput at the turnstile; coin-based systems will likely move only eight to twelve passengers per minute, versus fifteen to twenty passengers per minute with contactless cards.

In Quito, Ecuador, a simple coin-based system has worked successfully for both the city's Trolebús and Ecovía lines. The system thus avoids the need to purchase any payment medium whatsoever. In Quito, an attendant window does exist, but it is only to give change to those who require it. Upon exiting a system, passengers simply file through one-way exit doors without the need for further fare verification. Quito's system also allows the flexibility to utilize discount fare cards as well; these fare cards are based on magnetic-strip technology. However, the entire turnstile device can fit into a limited space, and thus permits two turnstiles within a relatively narrow station.

Naturally, coin-based systems depend on the availability of coins in the local currency. Further, the coins must be available in a combination that matches the desired fare level. If coins are not part of the local currency, then tokens are an option. However, the inclusion of tokens in the fare collection system defeats many of the benefits of coins. While still providing a relatively simple fare system, tokens require all customers to purchase from a machine or sales point. This activity increases the amount of customer queuing required to use the system. Another alternative is to utilize fare collection turnstiles that handle paper currency. However, this technology is not nearly as robust as coin readers. The extra moments required for authenticating the currency note will slow down the entry process and thus reduce system capacity. This problem is exacerbated by the poor quality of older currency notes.

But there are some limitations to this simple system. Coin-based systems are only usable with flat-fare structures, and cannot offer multi-trip discounts, time of day discounts, or free transfers to other modes without physical integration facilities. Of course, there are many conditions where a flat fare is desirable, as discussed in Chapter 15: Fare Policy and Structure. Also, by combining a coin-based system with another technology (such as magnetic-strip cards or smart cards), then multiple-trip fares are also possible.

Coin and token systems are subject to the illegal use of slugs and counterfeit coins. The handling and administrative requirements related to coin collection and transaction accounting are also more labor intensive.

18.2.2 Printed Paper Tickets

Printed paper tickets were previously a prime method of fare collection in public transport systems. Under most paper-based systems, preprinted tickets are issued to passengers against a cash payment of the fare. In many European public transport systems, paper tickets are sold off-board at vending booths, machines, kiosks, and other shops. The tickets are validated at the time of boarding by inserting the paper ticket into a stamping machine. This machine marks the time and sometimes the location of the validation. The validation process employed is important when paper systems have time limits on usage. Verification of paper tickets can take place manually upon entrance into the system, or may only be verified occasionally through random inspections.

In many public transport systems in Asia and Africa, a conductor inside the vehicle issues tickets. Often in such systems, the conductor manually issues and punches the tickets. Alternately, the tickets may be printed using a handheld ticketing machine; the conductor enters the codes of origin and destination on the numeric keypad of the machine and the ticket is printed using thermal paper. The continuous presence of a conductor helps ensure that all passengers are carrying valid tickets.

Paper tickets suffer from several drawbacks that limit their effectiveness in high demand rapid transit systems:

- For proof-of-payment systems without conductors, periodic checks are required on a frequent basis to ensure that passengers buy tickets. Such checks are difficult during peak periods when fare collection is highest;
- In the case of tickets issued on board by a conductor, the process of issuing tickets is onerous and inconvenient for passengers, especially on crowded buses;
- The likelihood of revenue leakage is high if the public transport agency does not record passenger and revenue data on a regular basis. There are numerous possibilities for fraud, such as the printing of fake tickets or the failure to issue official tickets to all passengers;
- The agency must digitize any manual records generated at points of sale and from conductors into electronic records in order to carry out any kind of statistical analysis;
- The system will have no record about who travelled with that ticket when the trip ends;
- Battery-operated paper ticketing machines require charging every day.

As a result of these drawbacks, paper tickets are rarely used on modern BRT systems. Agencies have turned to more robust fare collection media such as RFID smart cards (see below).

18.2.3 Magnetic-Strip Cards

Magnetic-strip cards were the first widely adopted form of automated fare collection to be used on many public transport systems around the world. Magnetic fare cards use the same technology found in consumer credit cards. Magnetic-strip cards can implement complex algorithms—including multiple trips and varying fare rates for different types of trips—and store data securely. They allow both read and write operations, and data from the verification turnstile can provide system operators with information on customer movements. In this way, they represent a major advance over paper-based systems. Magnetic-strip technology also has the advantage of the low cost of the fare cards themselves, about US$0.02–0.05 per card. However, the magnetic-strip technology requires the card to come into extremely close contact with the card reader. Most systems require the user to feed the card into a slot. The card is then ejected for the user to retrieve. When the user removes the card, the turnstile opens. The extra time taken to process the card increases the boarding delay. In addition, magnetic-strip cards are generally made of coated paper, and can be damaged relatively easily. Some system providers utilizing magnetic-strip cards also elect to permit discounted fares for individuals purchasing multiple trips.

Figure 18.3. All-purpose bus fare collection machine in Nagoya, Japan. *Karl Fjellstrom.*

18.2.4 RFID-Based Smart Cards

Smart cards are based on a microprocessor that can read and process a variety of information regarding cash inputs, travel, and system usage with the highest possible security level. Smart cards are capable of supporting complex fare policies and can facilitate integration among multiple public transport modes. Smart cards rely on radio frequency identification (RFID) that activates a turnstile when held in proximity to the reader, an act that generally requires less physical precision than swiping or inserting a magnetic-strip card. Smart cards permit a wide range of information to be collected on customer movements, which ultimately can assist in system development and revenue distribution. BRT systems in Bogotá, Colombia; Goiânia, Brazil; and Guayaquil, Ecuador, have successfully employed smart card technologies.

Contactless smart cards have embedded dynamic logic that enables the implementation of complex fare rules, including transfer discounts during specific time windows, discounted off-peak fares, and distance-based fares. Other payment media lack the dynamic logic necessary to carry out such operations. Smart cards also have a longer life cycle and are less likely to experience a loss of data when compared to magnetic-strip cards. Smart-card-based systems can also incorporate solutions for single-journey tickets such as RFID tokens. A passenger taps a token when entering the system and deposits it in a turnstile when leaving the system.

The main drawbacks of smart card technology are the relative cost of the card and its complexity. The system requires fare vending personnel and/or card vending machines. The system also typically requires verification machines at system exits if distance-based fares are utilized. In each instance, the risk of long customer queues, especially during peak periods, is increased at the point of sale but reduced at the turnstile. In addition to the costs of the vending and verification machines, each smart card is a relatively costly expense. Current prices are in the range of one to three US dollars per card. The card cost depends on the card complexity.

Virtually all smart cards conform to the ISO 7816 size standard. The card material can vary with options such as PVC, PET, and even paper. Different manufacturers have developed their proprietary protocols and operating systems that define the security and compatibility between cards and reading devices. The most common standard is defined in the ISO 14443 A/B standard, which details the card characteristics.

The microchip on a smart card can either be "memory only" or "memory with microprocessing" capabilities. Cards with a memory chip can only store data, and have pre-defined dedicated processing capabilities. The addition of microprocessing allows the smart card to actually execute applications as well. For example, a microprocessor chip can allow the stored value of the smart card to be used for purchases outside the public transport system.

In Hong Kong, the Octopus card permits users to make purchases at shops as well as pay for public transport. The Octopus card allows up to HK$1,000 (US$125) of stored value to be placed on the card. While this feature can be quite convenient, smart cards with microprocessing capabilities tend to be more expensive than other types of cards. However, for systems such as Hong Kong, the flexibility and utility of the cards make them a worthwhile investment. There are currently an estimated 26 million Octopus cards in circulation in Hong Kong. Approximately 13 million transactions take place in Hong Kong each day using the Octopus card.

Once a card brand such as the Octopus is established, its ability to penetrate into a wide variety of related markets is significant. Octopus started with a core network of transport services in 1997, and soon expanded into almost all forms of transport payment services.

Likewise, the Octopus card is finding utility in several applications outside the transport sector. Some of these outside payment applications include supermarkets, convenience stores, fast food franchises, vending machines, photocopiers, cinemas, and sports venues. The flexibility of such cards means that the system's marketplace and potential for profit can extend well beyond the transport sector. Such market diversity can help strengthen overall company performance.

The Seoul, South Korea, T-money system is in many ways quite similar in performance to the Octopus card. T-money can be used both on the city's metro system as well as other transport services such as the BRT system. Likewise, T-money is crossing over into many non-transport applications, such as retail purchases. The fare card systems in Hong Kong and Seoul are also showing much creativity in the form of the cards themselves. Both cities allow customers to accessorize with fare chips that are inserted in a range of products such as watches and key chains. Also, in the future it is likely that customers will be able to swipe their mobile telephones in order to make payments.

Typically smart cards for transport applications have from one to four kilobytes of memory. A four-kilobyte card will be able to support multiple applications, including e-money transactions.

Unlike magnetic-strip cards, though, smart cards have a long life and can be reused for periods in the range of five to ten years. As smart cards become more common, the cost of the cards will undoubtedly continue to fall.

From a financial point of view, although smart cards have a relatively high initial cost (one to three US dollars per card), the cost per transaction is significantly less than that of magnetic-strip cards. Some system designers estimate that maintenance costs for contactless smart card equipment are between 7 to 10 percent of the initial investment, compared with 15 to 20 percent for magnetic-strip systems.

Besides the cost of the cards, the chief disadvantage of smart cards is the relative complexity of the implementation. In the case of TransJakarta, the BRT system operated for more than one year before the smart card system could actually function. Implementing a smart card system is an order of magnitude more difficult than many other payment mediums. Smart-card systems are not yet in the category of a "plug-and-play" technology, as much software programming and specialized skills must accompany the implementation.

Figure 18.4. A fare collection machine in Chengdu, China, that accepts tokens and smart cards. *Xianyuan Zhu.*

18.2.5 Advanced Technologies

Several emerging technologies offer the promise of simplifying fare collection in the future. One such technology is near field communication (NFC), a short-range wireless technology used in mobile phones. This technology, covered under the ISO 14433 standard, allows a smartphone to function similarly to an RFID smart card in conjunction with contactless readers at station turnstiles. It offers great flexibility, since the money pocket can be added to in several ways, including SMS or internet. An example of an NFC solution is the Google Wallet, an application that can store credit and debit account information securely on a phone, and then use the NFC capability to pay at enabled payment readers. At present, the biggest obstacle to more widespread use of NFC is the limited availability of NFC-ready phones, especially in developing countries. However, with increasing market penetration of smartphones, this technology may become viable for transport applications in the near future.

18.3 Gates and Turnstiles

> *"The world is all gates, all opportunities, strings of tension waiting to be struck."*
>
> — Ralph Waldo Emerson, poet, 1803–1882

Off-board fare collection systems generally employ physical barriers to prevent passengers from entering the system without paying. Most early entry control systems made use of rotating turnstiles. Later developments have resulted in improved and more efficient access control mechanisms with retractable wing gates. Gate arms that pivot horizontally are inexpensive but are generally avoided because they allow entry of more than one person before the arms close.

The turnstile, or tripod gate, is probably the most common access control mechanism used in BRT systems across the world. Once the fare reader authorizes a passage, the tripod is released from a fixed position to rotate a third of a revolution and ensure passage for one person. The TransMilenio BRT system in Bogotá, the Trolebús and Ecovía lines in Quito, Ecuador, and many other systems in South America make use of tripod gates. Tripod gates are not universally accessible to persons with disabilities and users with strollers and suitcases. Alternative access may be provided through manual gates operated by a station attendant. Despite these accessibility challenges, tripod gates are common because of their low maintenance and operating costs.

Retractable wing gates have become standard on many large rapid transit systems such as the London Underground, Hong Kong Metro, and Washington, DC Metro. They also have started to appear in BRT systems, including the Janmarg system in Ahmedabad, India, and the Beijing BRT. The wings are manufactured from durable plastics, glass, or stainless steel. They automatically fold back once the fare reader completes a successful fee transaction. Wing barriers provide a professional appearance while simultaneously preventing fare evasion. They also have advanced detection systems that prevent the flaps from closing while a person or other object—such as a suitcase or stroller—is still passing through. The barriers can also stay open if a second legal passage is detected. The clear opening between the wings can be designed to meet customers' requirements, including wider gates that permit the passage of wheelchairs.

One consideration in the design of retractable-flap systems is the height of the gate. Most systems utilize waist-high gates, but higher gates are used where there is little oversight and/or a high incidence of fare evasion. The higher the gate, the heavier it becomes, ultimately placing more restrictions on the type of mechanism, flap material, and the speed of opening and closing. Some systems use gates with both heights, with waist-high systems at entrances where there are fare agents and full-height systems where there is less oversight. For example, Quito employs a half-body height turnstile at the entrances that also include the presence of a fare agent.

Figure 18.5. The BRT system in Chengdu, China, utilizes wing gates to control access to the system. *Karl Fjellstrom.*

The typical dimensions and capacities of the different gates are summarized in Table 18.2 (turnstile dimensions are also often customized). The space limitations for BRT stations constructed in road medians pose a challenge in terms of providing sufficient capacity for peak demand at fare gates. Many systems stagger gates or employ bidirectional gates that can be used in any direction, allowing the system to set the orientation of the gates to match the direction of peak passenger flows.

Figure 18.6. Urumqi, China, streamlines customer flow by offsetting the gates and making them unidirectional. Image *Karl Fjellstrom.*

Table 18.2. Turnstile Widths

Category	Type	Height (mm)	Opening Width (mm)	Installation Width (mm)	Capacity
Waist Height	Retractable	960–1095	500–990	820–1580	60 persons/min
	Angle Wing	1060–1200	650–700	760–1250	60 persons/min
	Rotating Arm (Tripod)	950–1090	430–520	750–820	25–40 persons/min
	Swinging Arm	965–1100	600–1200	720–1400	30 persons/min
Full Height	Angle Wing	1200–1829	500–950	760–1690	30–60 persons/min
	Rotating Tripod	2200	600–700	1450	20 persons/min

A few BRT systems with onboard fare collection employ onboard physical barriers. Passengers board the bus into a holding area and must tap in to pass by a turnstile. Some other systems, such as the Rea Vaya BRT in Johannesburg, South Africa, also employ fare gates on feeder buses to facilitate the use of an integrated, distance-based fare on the entire BRT network. Rea Vaya feeder buses have tripod gates at the exit doors of buses. The passenger must tap to exit the bus, allowing the system to calculate the distance traveled and the appropriate fare.

Table 18.3. Different Fare Collections Systems in Place in BRT Systems around the World.

City	BRT Standard Level	Name of System	Type of Collection	Barrier Control	Fare Collection Media	Fare Type
US						
Cleveland, Ohio	Silver	RTA Healthline	Off board	Machine for validation before boarding	Magnetic card	Flat rate
Los Angeles	Bronze	LA Metro Orange Line	Off board	TAP card must be tapped before boarding at validating stations	Smart card	Flat rate
Eugene, Oregon	Bronze	Emerald Express (EmX)	Off board	Off-board fare machines	Proof-of-payment, random inspection	Flat rate
South America						
Lima, Peru	Gold	El Metrobolitano	Off board	Electronic readers/turnstiles	Electronic pre-paid card	Flat rate
Buenos Aires, Argentina	Bronze	Metrobus	Onboard	-	Coins/ SUBE smart card	Zonal rate
Curitiba, Brazil	Gold	Green Line	Off board	Pre-pay station, turnstiles	Smart card	Flat rate
Rio de Janeiro, Brazil	Gold	Transoeste	Off board	Pre-pay station, turnstiles	Electronic prepaid card	Flat rate
Barranquilla, Colombia	Silver	Transmetro	Off board	Electronic readers/turnstiles	Electronic prepaid card	Flat rate
Cali, Colombia	Silver	MIO (Masivo Integrado de Occidente)	Off board	Contact-free magnetic ticketing	Smart card	Flat rate
Perreira, Colombia	Silver	Megabus	Off board	Contact-free magnetic ticketing, turnstiles	Smart card	Flat rate
Medellín, Colombia	Gold	Metroplus	Off board	Contact-free magnetic ticketing	Smart card	Flat rate
Asia						
Guangzhou, China	Gold	Guangzhou BRT	Off board	Fare verification, turnstiles	Smart card	Flat rate
Jakarta, Indonesia	Bronze	TransJakarta	Off board	Fare verification, turnstiles	Tickets, prepaid card	Flat rate
Ahmedabad, India	Silver	Janmarg	Off board	Fare verification, wing gates, turnstiles	Smart card, tokens	Zonal rate
Africa						
Johannesburg, South Africa	Silver	Rea Vaya	Off board	Fare verification, wing gates, TAP card entering and exiting stations	Smart card	Zonal rate
Cape Town, South Africa	Bronze	MyCity	Off board	Fare verification, wing gates, TAP card entering and exiting stations	Smart card	Zonal rate

18.4 Back-End Components

"The way to build a complex system that works is to build it from very simple systems that work."

— Kevin Kelly, publisher, 1952–

Fare collection systems require a robust back-end to process fare payments, store fare data, and generate reports for system managers. Most systems incorporate a computer at each fare collection location (i.e., each station or bus). The computer compiles data from turnstiles or onboard ticket machines and sends this information via a secure data channel to a control center on a real-time basis. Control center staff can monitor system status, respond to defective or malfunctioning machines, and generate reports. All systems should have backup power to ensure that the system can continue to operate in the event of electricity outages. In addition, the stations and control center should have backup capabilities.

During the implementation of the information system, the BRT agency should ensure that the fare collection service provider provides complete details on the data protocols used to transfer fare collection data. These details are required in the event that a future fare collection contract is given to a different provider. The BRT agency should develop an in-house team of experts who conduct regular monitoring of the fare collection system.

18.5 Institutional Structure

"Whatever affects one directly, affects all indirectly. I can never be what I ought to be until you are what you ought to be. This is the interrelated structure of reality."

— Martin Luther King Jr., civil rights leader, 1929–1968

Institutional arrangements for the fare collection and verification system vary widely from system to system, with different benefits and risks. Most successful BRT systems have adopted a public-private partnership model to handle fare collection. These systems involve the following parties:

- The manager of the money (usually a bank or money manager);
- The equipment provider;
- The fare provider;
- The fare system operator;
- The public transport authority or its parent agency.

How these functions are related institutionally depends on the technical competence of the public transport authority or its parent agency, the level of concern about corruption, the type of system desired, and the need for financing it with private money.

It is fairly standard for the manager of the money, the equipment provider, and the fare provider to be closely associated, while the fare system operator is separate. This allows the equipment provider/financial manager to monitor the fare system operator in order to avoid corruption. Figure 18.7 outlines a typical system structure.

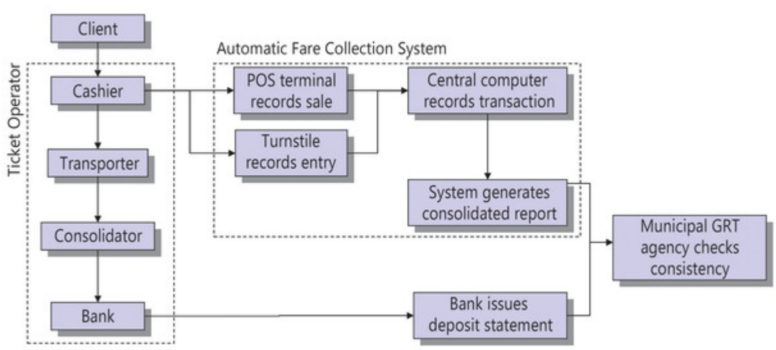

Figure 18.7. Institutional relationships in a typical fare system. Graphic *Fabio Gordillo.*

In the case of TransJakarta, splitting the responsibility for operating the fare system and procuring the fare system equipment led to major problems. When problems with the equipment technology emerged, the fare-system operator was unable to fix them, and claimed to have no legal responsibility for fixing the problem. The fare system equipment supplier should have been liable, but the contract signed with TransJakarta did not provide for this eventuality. There was nothing inherently wrong with the structure, but any structure not backed by solid legal contracts outlining financial liability for service failures can lead to disaster.

In the case of TransMilenio in Bogotá, the fare system was implemented through a unique build-operate-transfer (BOT) model. In this case, there was a competitive tender for a single company to both procure the fare system equipment and operate the fare system. The company that won this tender, Angelcom SA, both selected and paid for the fare equipment and operates the system (Figure 18.8). The contract signed was between the public operating company (i.e., TransMilenio SA) and the private firm, not between the Department of Transport or the Department of Public Works and the private firm. The private company in turn receives a fixed percentage of the revenues from TransMilenio. A third company was contracted by TransMilenio to be responsible for managing the revenue once collected. All fare revenue in TransMilenio is placed by the operator into a trust fund, and this company manages the TransMilenio Trust Fund on behalf of all the parties with a vested interest in the fair and accurate division of this revenue: TransMilenio SA, the trunk line operators, the feeder bus operators, and the fare collection company.

This build-operate-transfer institutional model for the fare system had some advantages and disadvantages. The system was eventually able to attract private investment for the fare system equipment in a country where private investment was difficult to secure due to political risk. This private financing reduced the initial capital cost of the TransMilenio BRT system. However, the fare system operator receives 10 percent of TransMilenio's total revenue, whereas its operating costs are probably much lower. As such, it puts an unnecessary financial burden on system operations. It would have been less costly if the fare system were simply purchased outright by TransMilenio.

Figure 18.8. In Bogotá, the contract for purchasing and operating the fare collection equipment was awarded to a single private firm. *Lloyd Wright.*

This structure did assure that the fare system functioned on a basic level. Because Angelcom SA's profits are determined by the success of the system, the company has a vested interest in making sure the system operates properly. Because it is also responsible for operating the system, the company has a vested interest in getting equipment that functioned properly. Because Angelcom SA was a fare system operating company, it also knew more about the appropriate technology than the government, and was able to negotiate better equipment contracts with subcontractors and receive lower prices. By privatizing the procurement contract, the risk of corruption in the procurement process is lessened.

On the other hand, Angelcom SA bought relatively cheap equipment in an attempt to save money. The company complied with its contractual obligations but the quality standards were reasonably poor, the design was inflexible and of poor quality, implementation was slow, and there were a host of technical problems in the first month of operation. These problems could have been solved within the current structure by imposing harsher penalties for poor performance, and by having TransMilenio specify in the tender a higher technical standard for the fare equipment. TransMilenio could even have handled the procurement independently and then awarded the contract to the winning fare system operator. In this way, the operating system bidder becomes the owner of the new equipment, and can be required to pay for the investment, but the government would retain tighter control over the equipment selection process.

It is fairly common in the public transport industry to separate initial equipment procurement from operations. This practice is usually done when there is a public transport authority that directly collects the fare-box revenue, and where there is no expectation that the operating company will invest in the system. Technology providers such as Ascom Monetel, ERG, INDRA, or Scheidt and Bachmann have focused their attention on the technology development and integration tasks, leaving the fare system operation to the public transport agencies. This structure can reduce the on-going financial burden that a BOT would impose. However, if equipment procurement and operations are separated, contracts will have to be structured carefully to ensure that the equipment providers are responsible to the operating company for system maintenance.

18.6 Tendering Process

> *"If you cannot be on the project each day to check on things, then you should not try and be your own contractor."*
>
> — Robert Metcalfe, inventor, 1946–

The contract for fare collection systems is often integrated with that for passenger information (i.e., in-station and in-vehicle audio and visual announcements) because the two systems utilize the same communications infrastructure. Passenger information systems are discussed further in Chapter 11: Marketing and Customer Service.

The tendering documents should state the technology protocols that the service provider is expected to follow as well as quantitative service levels to be monitored over the course of the contract. The initial contract term should be limited to five years so that the BRT agency can switch to a different provider if the initial operator does not perform well. As discussed above, the tender should explicitly state that the service provider must provide data transfer protocols to the BRT agency for compatibility in the future. The evaluation process should take into account both technical and financial criteria.

The tender process for implementation of fare collection systems should begin as soon as general BRT infrastructure construction is initiated. Considering the time span required in pre-tender (planning, RFP documentation, amendments, publishing) and post-tender (pre-bid meetings, bid submission, bid scrutiny, negotiation, bid award, mobilizing resources) processes, the BRT agency should start the process accordingly as soon as the work order for infrastructure construction is given.

18.7 Costs

> *"The price is what you pay; the value is what you receive."*
>
> — Anonymous

Calculation of various costs involved in planning, implementing, and maintaining intelligent transport systems is a critical component for the transit agency. The BRT agency should estimate the probable capital and operating costs of the fare collection system during the planning stage, before the tendering process begins. Capital costs depend on the fare collection technology and the system scope—the number of buses, stations, depots, and terminals and expected passenger volumes. Keeping the system operational requires regular upgrades of software systems to update security and communication protocols. In addition, regular maintenance is required to ensure the proper functioning of fare gates and other hardware components.

Fare collection for BRT systems typically accounts for 7–12 percent of total operating costs, but has varied from 5 to 15 percent. In Bogotá's TransMilenio, the fare collection operator receives between 7.56–9.1 percent of system revenue.

Table 18.4. Fare and ITS costs (Phase I Project of 50 kilometers)

Item	Cost per unit	Units	Reference info.	Quantity requested	Cost
Fare collection readers			**No. of stations**	**Enter no. of stations w/ each type**	
Smart card system (4 readers per station)	10,000	US$ per station	100	100.0	$1,000,000.00
Magnetic strip system (4 readers per station)	7,000	US$ per station	100		$0.00
Coin-based system (2 readers per station)	1,500	US$ per station	100		$0.00
Fare collection turnstiles			**No. of stations**	**Enter no. of stations with turnstiles**	
Rotating turnstile (4 turnstiles per station)	7,000	US$ per turnstile	100		$0.00
Drop-arm turnstile (4 turnstiles per station)	2,800	US$ per turnstile	100	100.0	$280,000.00
Fare registering unit / vending machine			**No. of stations**	**Enter no. of stations with machines**	
Smart card system	15,000	US$ per machine	100	100.0	$1,500,000.00
Magnetic strip system	10,000	US$ per machine	100		$0.00
Coin-based system	0	US$ per machine	100		$0.00
Fare media			**No. of cards**	**Enter no. of cards**	
Smart card system with microprocessing ability	3.50	US$ per card		500,000.0	$1,750,000.00
Smart cards w/o microprocessing ability	1.20	US$ per card			$0.00
Magnetic strip cards	0.05	US$ per card			$0.00
Coin-based system	0.00	US$ per card			$0.00
Fare system software			**No. of software**	**Enter no. of software**	
Smart card system	500,000	US$ per software	1	1.0	$500,000.00
Magnetic strip system	300,000	US$ per software	1		$0.00
Coin-based system	100,000	US$ per software	1		$0.00
Intelligent Transportation Systems (ITS)			**No. of stations/inters.**	**Enter no. of stations/inters.**	
No ITS options	0	US$ per station	100		$0.00
Green light phase extension for BRT	20,000	US$ per intersection	100	20.0	$400,000.00
Real-time information displays	7,500	US$ per station	100	100.0	$750,000.00
Broad-band service at stations/terminals	750	US$ per station	100	100.0	$75,000.00
Fare and ITS technology sub-total					$6,255,000.00

Table 18.5. Capital Cost Components

Fare Collection	Card validators; Ticket printers; POS (point of sales) machines; Computers; Access control barriers; Station servers; UPS; Communication network; Smart cards;
Control Center	Servers; UPS backup; Communications network; Bulk Initialization Machine (BIM); Printers; Computers; Biometric readers; Screens;
Software	Automatic vehicle location, fare collection, financial management, PIS, depot management, vehicle scheduling and dispatching, asset management and inventory, POS, BIM, card validators, web portal, servers, dashboard module, antivirus and cybersecurity, accounting, data transfer, data backup, report generation

Table 18.6. Operating cost components

Manpower	Perks, benefits, salaries, fines
Transportation costs	Fuel, vehicles used by staff
Software	Upgrade and calibration, license and renewal fees, copyrights
Hardware	Regular equipment check, software calibration, life cycle analysis
Electricity	Power consumed by all hardware at stations, terminals, depots, interchange stations, transfer stations, central control center and administrative office
Communication costs	Telephone, mobile phones, and internet usage charges
Administrative costs	Stationery, printing, auditors' fees, consultancy fees, advertisement and marketing, insurance, accident claims, legal matters, and other administrative work costs
Infrastructure costs	Maintenance, repairs, and rehabilitation works
Security	Stations, corridors, control center
Housekeeping	Cleaning of infrastructure (stations, terminals, depots)
Landscaping	Costs toward maintenance and planting of landscaping along corridor

18.8 Case Studies

> *"No rules exist, and examples are simply life-savers answering the appeals of rules making vain attempts to exist."*
>
> — André Breton, poet, 1896–1966

Fare collection and fare validation are critical for quality of service and financial stability of the BRT system. Nevertheless, less effort is often assigned for its preparation, procurement, and supervision than the effort given for trunk-vehicle operations.

Both Bogotá, Colombia, and Jakarta, Indonesia had troubles in the fare collection system at the beginning of their operation, which were gradually solved throughout the first years of operation.

In both cities, there were initial operational difficulties with the fare collection systems, such as long queues for card acquisition, low throughput at the turnstiles, and loss of trips stored in the cards. There were also problems with the quality and integrity of the data (sales, validation). These problems resulted in some loss of confidence among customers in the system. These problems could have been avoided with better planning, procurement design, and supervision.

Bogotá and Jakarta wanted their systems to have up-to-date electronic fare collection systems using contactless cards. In both cases they allocated relatively little time for system design, testing, and implementation. Both systems also had contractors without previous experience in public transport operations.

The main differences between Bogotá and Jakarta were the institutional setup and the contracting procedures. Bogotá procured and supervised the firm through a single organization, the public company known as TransMilenio SA. By contrast, Jakarta split equipment and operation between two different agencies. The equipment was procured by the Department of Transportation (Dinas Perhubungan or DisHub). The system supervision and operation was managed by the newly created operational entity known as TransJakarta. There was an apparent lack of coordination between these agencies. Furthermore, equipment and software procurement was separated from day-to-day operations, contracted afterward directly by TransJakarta.

In terms of contracting procedures, TransMilenio SA conducted an open bidding process, while the Department of Transportation in Jakarta apparently selected the provider directly. Later in the process TransJakarta selected the operator from a short list using an accelerated contracting process. Both companies operating the systems in Bogotá and Jakarta were visionary and entrepreneurial, but lacked the capacity to timely comply with the contract requirements. They were able to sort out the difficulties, but solutions only came after many months of problems.

Initial operations in both cases were not smooth. Bogotá initiated with paper tickets that were replaced in the first four months of operations by contactless smart cards. Despite the requirement in the contract of using Edmondson tickets for one or two customer trips, and contactless cards for multiple trips only (three or more), the local contractor asked for contactless cards only, which was accepted by TransMilenio SA under the operator's own risk. Cards were not charged to the users, and hence the required card stock was, and still is, very large. Initial operation of the validation (check-in and check-out) was not reliable, and customers lost confidence in multiple fares, which in turn increased queues at fare booths.

Problems with Bogotá's validation process resulted in an important change in the operational scheme: exit validation was eliminated due to numerous complaints from customers. Additionally, part of the stock of cards was unreliable and needed to be retired. Finally, some turnstiles using local integration were below the required standards and were replaced by more reliable equipment at the operator's expense.

In the case of Jakarta, most of the problems were the result of implementing a fare collection system without careful adaptation to the local conditions by a contractor without enough expertise to comply with the system requirements. Reliability of the power supply also caused problems, as did the wireless communication scheme. There were even disputes on the property of the software rights. TransJakarta was reluctant to use the system procured by the Department of Transportation, and the contracted fare collection operator was also concerned.

Both cities found ways to improve the operations and quality of service of the fare collection component through their contractors. Current operations do not exhibit the problems reported in the first year of operation. Nevertheless Bogota's and Jakarta's experiences provide lessons on some recommended practices:

- There are no "off-the-shelf" systems ready for "plug-and-play." Time is required to adapt the system to local conditions and requirements (e.g., reduced fares for certain populations such as students, zone- and time-based rather than flat fares, level of integration with the feeders). It is unlikely that a system could be adapted, developed, deployed, and tested in fewer than six months. Hence, fare collection often becomes the critical step in system implementation;
- Open and competitive bidding is preferred to direct contracting, even if it takes more time and introduces relatively high transaction costs. In an open bidding process, competition forces prices down (for the benefit of the customers) while keeping the quality and service standards at a high level;
- Selection criteria for a contractor should include experience implementing and operating fare collection systems. It is important that experience is verified and that the contractor (in case of consortiums) has an important share of the responsibility of ensuring contract compliance;
- Integration of installation and operation is recommended, as the operator is part of the decisions on system design and equipment and software acquisition. If contracts are separated, it is likely that the operator may claim that problems are the result of design and installation, not their own inability to perform according to the standards set forth;
- Performance-based contracts are preferred over standard procurement contracts. The concept behind this is that the BRT system is acquiring a service, rather than the hardware and software of the fare collection system. What is important is the throughput and reliability of the solution provided. Which solution is finally provided is the operator's decision;
- It is necessary to test each component and its integration, hopefully well in advance of commissioning the system;
- Supervision of fare collection is as important, if not more so, than bus operations. This should be taken into account when organizing the agency in charge of planning, developing, and supervising BRT system operations;
- Having one agency running the entire system is better than trying to coordinate efforts by several agencies;
- Provide for contracting arrangements that promote system growth (additional sales). It is advised that remuneration for the fare collection provision and operation grows with passenger ridership. Current formulas in Bogotá's contracts do not promote increased sales, at least from the perspective of the operator;
- Charging the reusable fare cards (e.g., contactless cards) through, for instance, a returnable deposit can be better than providing them for free. Users may take responsibility for the cards and this reduces damages and required stock. However, charging for cards adds considerable administrative complexity and it can discourage use of the system.

19. Technology

"Any sufficiently advanced technology is indistinguishable from magic."

— Arthur C. Clarke, author and inventor, 1917–

Information technology (IT) systems are an important component of high-quality BRT systems. BRT services are designed to cater to large passenger volumes and must deliver fast, accurate, and reliable services in the form of financial transactions, customer information, and operations systems. IT systems address the complexities of day-to-day operations management, reducing manpower and contributing to sizable cost savings. Over the years, the level of integration has increased so that IT now takes a system-oriented approach. IT can be leveraged to foster cooperation among the various transport modes and coordinate management of mobility systems. This chapter provides broad guidance on the planning, implementation, and operations of IT systems. For a more comprehensive guide to IT systems for BRT and bus systems, refer to the World Bank Toolkit on Intelligent Transport Systems.

Table 19.1. Key IT System Functions

Operations Monitoring	**• Ensures on-time performance by facilitating information sharing among the control center, stations, and buses; • Documents system operations for determining compensation for the bus operator. • Generates data that can be used to improve service efficiency and system performance.**
Customer Information	• In stations, the IT system informs passengers of upcoming departure times and destinations; • On buses, electronic displays indicate the destination; • In buses, the IT system informs passengers of upcoming stop names and transfer opportunities; • Emergency notifications.
Fare Collection	• Records sales, payment collection, and system usage; • Provides opportunities to integrate fare payment mechanism across multiple transport modes.
Signal Control	• Facilitates efficient junction management and signal priority for buses.
Fleet Management	• Manages manpower and allocates duties; • Schedules maintenance.;
Surveillance Systems	• Ensures station security.

Contributors: Giorgio Ambrosino, *consultant*; Brendan Finn, *consultant*; Christoff Krogskeepers, *ITS Engineers*; Pratik Dave, *consultant*

19.1 Vehicle Tracking

"Don't worry, sweetie, don't worry. Nobody in New York notices a bus until it's about to hit them!"

— Samantha, "Sex and the City", 1998

IT systems can aid in the management of bus operations from a central control center (CCC). Known as automatic vehicle monitoring (AVM) systems, such systems preserve reliability by helping the BRT system maintain planned headways. They also allow the CCC to respond to unexpected levels of demand, disruptions, and emergencies such as bus breakdowns, riots, or traffic jams. The CCC can respond with corrective measures such as vehicle substitution, added vehicles on the line, or driver replacement. The CCC also uses the data produced by the AVM to record all arrival and departure times at stops, time points for calculating the service performance index, and restructure service plans (see Section 19.6 Management Information Systems).

An AVM system consists of a number of key components:

A CCC, from which the operations are managed. CCC computers run AVM software, which facilitates a wide range of service management processes;

A global positioning system (GPS)–equipped device on each bus that records the distance and time logs and maintains the record of driver duty and attendance schedules. This information is transmitted to the CCC in real time;

A communications system between the vehicle and the CCC that can prompt the driver with service information, and facilitates driver communication with the CCC.

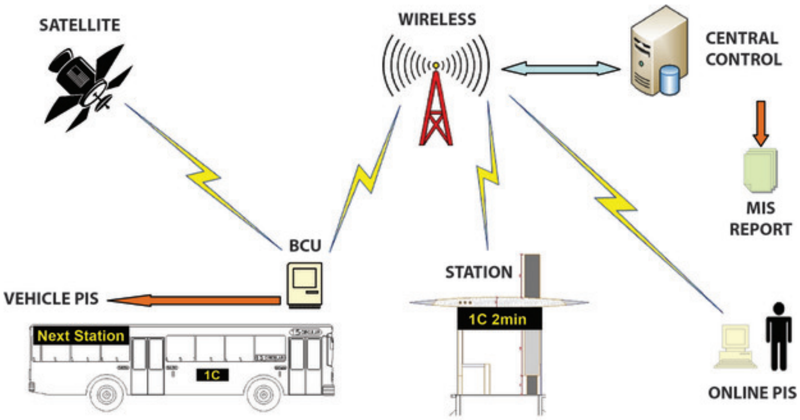

Figure 19.1. The automatic vehicle location system. *Prodigy Electronics.*

The functional requirements of an AVM system depend on the organization modalities and operation procedures adopted by the agency implementing the BRT. Two important planning issues should be considered when organizing the CCC:

Figure 19.2. TransMilenio control center for BRT operations management in Bogotá. *ITDP*

Degree of centralization: some transport operators establish a single, centralized control center from which all of the operations are managed. Other transport operators decentralize operations management. In this case, the AVM system allows client access from any workstation connected via the web and makes control and monitoring functionalities available at different locations;

Degree of hierarchy: for either centralized or decentralized systems, AVMs can be configured for a single implementing agency or multiple agencies. In the latter case, appropriate access/read/write rights must be defined in order to guarantee the confidentiality of data. Recorded data transmitted from vehicles and gathered by the CCC are stored in the same database, but one agency can monitor and manage the information only from its own system.

Table 19.2. Descriptions of AVM Devices

Component	Description
Mounting	Built into the dashboard or over the bus dashboard near the driver seat
GPS unit	To assure accurate geographic location, track the distance logs and calculate trip kilometers, bus journey speeds, etc.
Wireless Communication Module (WCM)	Based on high-speed data transmission protocols like GSM/CDMA/WCDMA, interface to transmit location information wirelessly to CCC and receive alerts and on-the-air updates. In addition, the WCM should have integrated two-way communication facility between driver and CCC through speakers and microphones
Driver Interface Unit (DIU)	This module has alphanumeric keypads, an LCD screen to display text messages relayed from CCC, and basic information stored within BCU, such as route details, duty log information, etc. LED indicators for alerts and system status updates. Drivers should be able to send and receive predefined text messages and read them on the screen. DIU allows the driver to log on his duty information, such as driver badge number, change route details, trip start time, and schedules information
Bus Control Unit (BCU)	BCU is essentially an integrated unit composed of modules like WCM, GPS, and DIU. It may be like an onboard computer CPU with partial integration, with few logical units, and interface with other external components such as the GPS module, etc. To log location data, store other data like the bus-route database, send Passenger Information System (PIS) information received from CCC to on-bus displays and speakers. This controller shall be the interface between all on-bus devices. It shall transmit location information through a secure wired connection to on-bus PIS to make audiovisual announcements
Integration	BCU unit should be able to allow Automatic Fare Collection (AFC) devices, such as handheld ticketing machines with card validators, to use the BCU's wireless communication module as a data path to transmit AFC data to CCC. The BCU should have flexibility to incorporate a short-range wireless and wired interface to allow it to act as a data path between on-bus AFC devices and the CCC
Primary Output	BCU should be able to help the CCC generate the following primary output reports: vehicle start-stop, driver begin-end shifts, daytime operations summary and fleet status, detailed activity, bus speeds, alerts, unit on/off reports.

19.2 Customer Information

"The number one benefit of information technology is that it empowers people to do what they want to do. It lets people be creative. It lets people be productive. It lets people learn things they didn't think they could learn before, and so in a sense it is all about potential."

— Steve Ballmer, businessman, 1956–

The passenger information system (PIS) relays real-time, pre- and in-trip information on bus arrivals, destinations, and service changes or disruptions in stations. The PIS can also disseminate this information through the web, SMS, and other platforms. Displays on the outside of buses indicate the destination of the vehicle. In buses, voice and visual announcements inform passengers of upcoming stations and transfer opportunities. The information that feeds the PIS is generated through data provided by the AVM system, and is transmitted to stations via hard wiring and/or GPRS (General Packet Radio Service). Onboard information is programmed in advance of the journey and uploaded to the onboard device.

Figure 19.3. Bus tracking interface in Chicago. *Chicago Transit Authority.*

Table 19.3. Onboard PIS Components

Display Area	Display Type	IT Component	Output
Front side of bus	Visual	LED board	Route name and number
Rear side of bus	Visual	LED board	Route name and number
Sides of the bus	Visual	LED board	Route name and number
Inside the bus	Audiovisual	LED board, Speakers, LCD screens	Next station, advertisements, general messages

Table 19.4. 4 Off-Board PIS Components

Display Area	Display Type	IT Component	Output
Stations	Visual	LED board	ETA, route name, route number, platform number, general messages
Terminals	Audiovisual	LED board; speakers;	ETA, route name, route number, platform number, general messages
Depots	Audiovisual	LED board; speakers;	Route name, route number, general messages, staff instructions

19.3 Fare Collection

"When you buy a ticket, you're basically voting for whatever you see."

— David A. R. White, actor, screenwriter, and producer, 1970–

IT systems for fare collection handle revenue management, financial management systems, and automatic fare collection (AFC). BRT systems function well with off-board, automatic fare collection systems, which reduce vehicle boarding times, allow the rapid introduction of new tariffs and services, reduce revenue leakage, provide data to support system optimization, and support integrated ticketing across multiple modes. Fare collection consists essentially of revenue management processes. The income received by the BRT agency and its expenses are managed by IT systems.

BRT stations have fare collection cabins where passengers may recharge electronic fare-payment media or purchase single-ride media. Passengers are able to use smart cards or other payment media at access control barriers inside the stations. These devices read the payment medium, determine if the medium has sufficient value, and then deduct the appropriate fare. The fare payment data are transmitted to the CCC via the station server.

The AFC system may be integrated with payment mechanisms on feeder buses and other non-BRT buses. Passengers use electronic media or buy tickets from conductors using handheld ticketing machines. At the end of a shift, the information is downloaded to a terminal server, where it is transmitted to CCC.

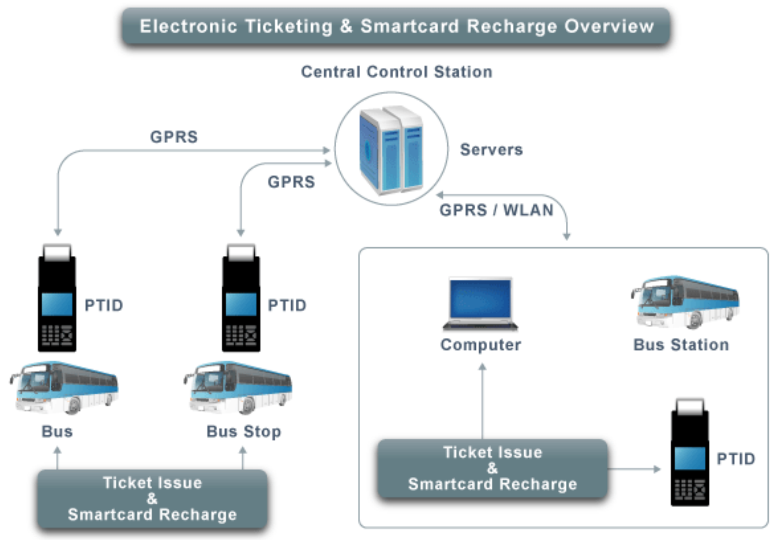

Figure 19.4. Electronic Ticketing and Smart Card Recharge Overview. *Prodigy Electronics.*

Data from all AFC transactions are stored at the CCC. Authorized BRT agency staff can view the financial transaction data through a secure dashboard developed by the IT service provider. The BRT agency can use the output from the AFC system to monitor financial performance on a continual basis. The BRT agency and an IT service provider may jointly staff the CCC. Cash collection from stations and terminals can be the responsibility of a service provider or bank. The service provider issues a daily report on total cash collection, and the bank issues a daily deposit report to the BRT agency.

Table 19.5. AFC Devices Required in Different Parts of the System

Device	Place of Deployment	Function
Handheld Ticket Machine		
Fig 19.5	Onboard	Issue paper tickets
Fig 19.5	Off board	For use in emergency situations, like power failure at stations
Smart Card Reader		
Fig 19.6	On the handheld ticketing device	Read the smart card and deduct appropriate fare
Fig 19.7	Onboard	
Fig 19.8	Off-board	

Figure 19.5. Handheld Ticket Machine. *ITDP*

Figure 19.6. Handheld smartcard reader. *ITDP*

Figure 19.7. Onboard smartcard reader. *ITDP*

Figure 19.8. Off-board smartcard reader *ITDP*

19.4 Signal Control

Automatic signaling systems respond to real-time changes in traffic volumes to offer priority to BRT vehicles and reduce intersection delay for all users. Techniques for signal management for bus priority include: single-phase and cycle adjustments, bus-only turns, and bus-only phases. For the management of priority for buses at traffic signals, it is necessary to balance the objective of improving the public transport performances against the impacts of doing so in mixed traffic. In some cases, bus frequencies may be so high that signal priority would result in continuous green lights, and therefore is not practical. Coordination between the BRT agency and other entities responsible for traffic management is necessary to arrive at a common set of criteria for managing signaling systems.

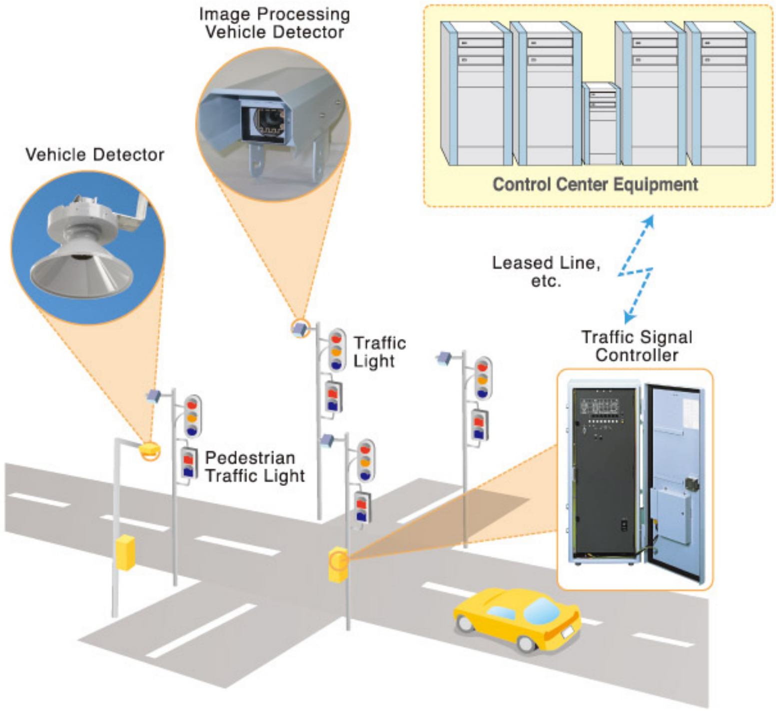

Figure 19.9. Signal control system. *Sumitomo Electric.*

19.5 Surveillance

"There cannot be a crisis today; my schedule is already full."

— Henry Kissinger, diplomat and political scientist, 1923–

Surveillance systems in and around stations, in vehicles, and at other facilities can improve personal security for BRT customers. Surveillance can also be used to enhance enforcement against busway violations and to detect blockage or incidents. Real-time footage can also help the CCC respond to surges in passenger demand. The most common ITS-related security technology is CCTV (closed-circuit television). Video surveillance systems typically consist of two components:

Video cameras and a recording and processing unit in buses and stations;

Control center system for display and logging of footage.

In the case of onboard surveillance, planners must determine whether the objective is only to log frame images to be viewed later or to allow for real-time viewing at the CCC. The latter requires high-speed communication connectivity for real-time data transfer. Although the image quality is low to moderate, it allows the CCC to assess what is occurring on the vehicle during an emergency situation. Online image transfer can be activated by the driver pushing an alarm button. For offline management, recordings are transmitted to the control center post-event, when the bus is in the depot or terminal. The images can be viewed on an as-needed basis (e.g., in case of reported incident, police request).

Figure 19.10. The management information system. *ITDP.*

19.6 Management Information System

"All of the biggest technological inventions created by man—the airplane, the automobile, the computer—says little about his intelligence, but speaks volumes about his laziness."

— Mark Kennedy, politician, 1957–

The management information system (MIS) uses data from the AVM and fare collection systems to generate information to aid in optimizing planning and service. The information generated can support a wide range of planning, analysis, reporting, and administrative functions. This includes service planning, scheduling, resource optimization, performance, and contract management. The MIS helps identify loopholes and deficiencies in the system and make quick decisions to address any shortcomings.

The IT service provider can develop a graphic dashboard that provides real-time output pertaining to bus operations and financial transactions. For example, the dashboard can have different modules and tab functions to show summaries of real-time passenger boarding at various stations, tickets issued, buses in operation, bus positions, and bus speeds. There can be many different types of output reports generated for personnel at different levels of management. The reports can be provided on a daily, weekly, and monthly basis.

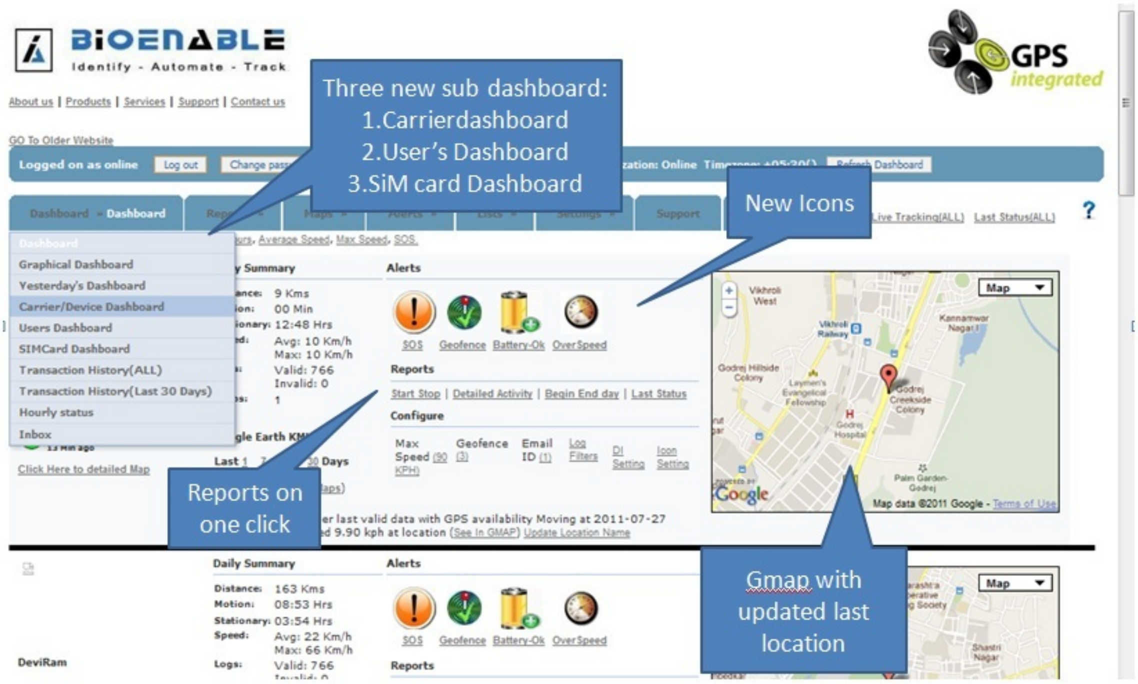

Figure 19.11. Example of a dashboard screen. *GPS Integrated.*

- Bus operations reports can include the following:
- Trip summary;
- Bus equipment fault summary;
- Bus service disruption, speed violations, unauthorized stoppage, vehicle breakdown, infrastructure damage, accidents, etc.;
- Route summary (number of buses, kilometers operated, average speed, alerts summary, infractions, performance in comparison with previous weekly and monthly average);

- Operations summary of individual bus (kilometers operated, hours in operations, average speed, alerts summary, infractions, performance in comparison route average over past week and month);
- Summary of bus operations by depot;
- Summary of bus operations by terminal;
- Staff and duty schedule reports;
- Financial reports.

Staff duty and schedule reports are required to be maintained in order to comply with prevailing labor practices and plan for systems operations and management. Staff and duty reports can include:

- Bus driver login reports;
- Noncompliance issues of different drivers for the shift;
- Bus operators supervision and maintenance staff login reports;
- Asset management and materials inventory at depots and CCC;
- Maintenance and supervision staff login reports;
- Administration and CCC staff login reports;
- All staff service hours and leave reports;
- Reports on staff requirement, accumulations, benefits, perks, etc.;
- Alerts to transport authority for duties towards staff like salary payments, leave approvals, material requirements, judgments and decisions, etc.;
- Reports on violation of duty terms and conditions by staff.

Financial reports can include the following:

- Payment for journey by passengers by purchase of paper tickets or use of smart cards;
- Payment toward purchase and recharge of a smart card;
- Fines paid by passengers;
- Daily cash collection at stations;
- Payment to bus operator and different subcontractors like fuel pump attendants, etc.;
- Payment to various service providers of the system like IT service provider, housekeeping agency, fare collection agency, other vendors supplying stationery and assets to transport authority, electricity and communication bills, etc.;
- Payment for civil works and infrastructure construction and maintenance;
- Payment to auditors;
- Compensation to staff, passengers, and contractors;
- All other administrative costs and payments.

19.7 Planning and Implementation for IT Systems

> *"All things are created twice; first mentally; then physically. The key to creativity is to begin with the end in mind, with a vision and a blue print of the desired result."*
>
> — Stephen Covey, author, 1932–2012

19.7.1 Feasibility Study

For any proposed IT investment, it is strongly recommended to carry out an in-depth feasibility study of the system to be implemented. The feasibility study is the opportunity to specify the functional requirements and objectives to be achieved. The feasibility study is also an opportunity for all internal and external stakeholders to understand the ITS and its long-term potential. The study must also define the milestones and expected outcomes at each stage of the end of implementation. It will also facilitate the planning and management of the implementation process, within the specified budget constraints and deadlines.

The feasibility report should include the following components:

- Context analysis: service typology and dimensions;
- Identification of the actors involved;
- Functional, technical, and operational specifications for each component and subsystem;
- Technological infrastructure analysis, exiting network performance and coverage, and existing devices, software, and databases with which the IT system to be implemented will be integrated;
- Implementation plan;
- Maintenance process and related operational procedures;
- Investment/operational costs and benefits;
- Modalities for the purchasing of the system (service or direct investments), possible cofinancing sources;
- Performance and quality gains, including ridership and revenue gains;
- Data generation and ancillary system support;
- Corporate capacity;
- Risk assessment;
- Legal requirements of ITS solutions/technologies (i.e., communication technologies and related laws).

The feasibility study should enable the leaders/owners of the BRT agency to make a sound business decision on whether to proceed with the IT investment, with a reasonable understanding of the system capacity, anticipated benefits, investment and lifecycle costs, and implementation risks. It should provide the implementers with sufficient guidance to proceed to detailed design.

19.8 Implementation Phasing

> *"It is not always what we know or analyzed before we make a decision that makes it a great decision. It is what we do after we make the decision to implement and execute it that makes it a good decision."*
>
> — William Pollard, clergyman, 1828–93

Preparation of implementation schedule is very important in deployment of IT systems for BRT. The aim is to minimize the organizational/operational impacts, avoiding large-scale problems that frequently occur when complex systems are introduced in a single step. Each phase must be clearly identified through a milestone. The implementation phase should be defined on the basis of realistic timing and carefully estimated deadlines. This will help avoid common problems such as delays, contract-conflicting behavior of contractor, effort/resources required by contracting body/transport operator, etc. The definition of a step-by-step implementation plan and the setup of related milestones facilitates the management of penalties due to delays during the implementation (sign-off of each phase, positive results of the testing procedure, final acceptance, etc.).

The plan can be made by consultants/advisers to the transport authority jointly seeking inputs from the authority. The plan should highlight important milestones to be achieved, deadlines, time frame for implementation including resource mobilization, equipment procurement, demo and testing, actual fitments, staff hiring, etc. The preparation of pre-implementation plan facilitates transport authorities to know well in advance about budget requirements and the time span that will be required by the service provider to commence system operations. It helps transport authorities plan for and allocate their monetary and manpower resources accordingly.

Project-management tools should be used, with detailed time line and resource tracking and analysis, manpower allocation of tasks, milestones, dependency analysis, critical path analysis, responsibility assignment, etc. The initial planning should commence during the detailed design phase, so that there is a clear vision of how the ITS deployment will be achieved. This will ensure that adequate resources have been mobilized, responsibilities are clear, and potential barriers have been foreseen and mitigated. The plan should be comprehensive and cover all aspects of the ITS deployment through to installation, testing/commissioning, sign-off, and the initial operational period.

19.8.1 Tendering

At a general level, the main objective of the procurement process is to select a supplier whose proposal complies with the technical objectives and requirements determined by the implementing agency, and offers the lowest cost among the bidders. The overall tendering procedure should be defined so that the financial factor only comes into play among the bidders whose proposals are acceptable in technical terms. Various tendering schemes are available to achieve this objective. A typical tendering procedure includes the following steps:

1. Tender specifications;
2. Invitation to tender (which may follow from prequalification);
3. Pre-bid meeting;
4. Proposal application and evaluation;
5. Negotiation and contracting.

The tender specifications must clearly identify the systems/tools (hardware, software) and the support services in order to allow bidders to define the price. The overall cost estimation should include not only the cost of the technology (individual hardware and software components), but also the costs related to the operation and support services (e.g., total days for the installation in different depots, meeting with contractors, resources necessary for detailed design, management, etc.).

The following are key articles of tendering prescriptions and contractual rules:

- Award criteria (technical and financial qualification criteria, experience).
  The mutual relevance between technical and financial criteria must be defined in such a way to preserve the technical value of the proposal. The most common approach is to require bidders to submit the financial proposal in a separately sealed envelope. The technical proposal is evaluated first, and only proposals with a satisfactory technical score (or which are deemed to be compliant) proceed to the stage of financial assessment. There are various ways to define evaluation criteria and related calculation formula. The options usually relate to the relevance the Client should assign to the criteria. Factors used as technical criteria are: technical quality of the proposal, quality of the maintenance service, description of the implementation modalities, technical assistance for the start up of the system, technical documentation, etc.;

- Warranties. Warranties can be of different form and objective: requirement for the eligibility of the offer, for the compliance of the implementation to technical specifications and contract rules, for the compliance of services and prescriptions after the implementation is completed (in case also the operation of system/service is contracted). The tender should oblige the bidder to provide unlimited software licenses. Unlimited software licenses means not only that the licenses are not time limited, but also that no extra costs will occur in case of the license up-scaling (e.g., increase of vehicles connected to the AVM, of equipped depots for data upload and download, etc.). The tender documentation should require bidders to declare/list the cost of each device, component, or services (onboard terminal, onboard unit, gate, contact/contactless reader, training day, etc.). It should also require that the contractor is obliged to maintain these prices for a specified time period (e.g., five years in case of up-scaling of some system components);
- Technical specifications and annexure. Technical specifications of products required and annexure are based on the main results of a feasibility analysis. It is recommended to focus on functionalities and operative requirements rather than technology solutions and technical features of each component. Functional specifications should be described in terms of "operational scenarios." This provides the bidder with sufficient freedom to propose the most effective solution, while still meeting the client requirements. The specifications should not include technical conditions or requirements that could be seen as a restriction of open competition, or that give an unfair advantage to a specific bidder. Restriction on competition could occur if the tender specifies the use of a specific type of equipment, or a specific piece of software, even though other makes could equally do the job. It is reasonable to state a preference for something if it is already in widespread use in the organization, but it is not reasonable to make it mandatory if there is no technical barrier to alternatives. Sometimes, integration is required between a proposed system and an already existing system. In this case, the previous supplier will have strong advantage of thorough understanding of the existing system and knowledge of the amount of work involved in the integration. To overcome this, the tender process should provide all the information about existing system including system description, functionality, data elements, etc. The technical specifications part of the bid document should mention in general the requirements of the system, of various gadgets and compulsion of certified standards. The annexure section should provide bidders with all the required formats for bid submission like cover letter, price bid, declaration form, power of attorney, etc.;
- Implementation timeline. This should include milestones and corresponding payments;
- Service level benchmarks and service provider obligations. This should include penalties for inadequate performance and procedures for conflict resolution.

As a standard practice, the bid submission process should follow a two-cover system: one sealed cover with technical bid and the other with financial bid. To perform the evaluation phase of the technical part of the bid proposals, an iterative methodology can be used. The evaluation is based on the repeated identification of the evaluation factors (at N+1 level) that contribute to the evaluation of each criteria/sub criteria (at N level) according to the weighted factors. This methodology is applied starting from the bottom level of criteria or sub-criteria defined in the tendering documentation, up to the level that is considered appropriate. One example of this methodology is based on a scoring system. The bidder must score minimum marks as specified in technical capability criteria. Sample criteria and their corresponding weights are presented in Table 19.6.

Table 19.6. Technical Criteria for the Bidding Process

Criteria	Points
The number of projects for smart card-based AFC solutions to be used in bus/rail-based public transport services, implemented in the past seven years and the cost for each project should be more than ___ USD. 20 Points for each project subject to a maximum of 100 points.	100
1. Number of AFC smart card clearinghouse solutions delivered in the past seven years by the bidder that clear and settle revenue between multiple independent transit operations operating various modes of transport systems; and/or; 2. Service providers that manage AFC infrastructure, implemented in the past seven years.;	50
Vehicle tracing/PIS display/AFC system/vehicle dispatching and scheduling/depot management system	150
Overseas Experience:; International experience of projects costing more than one million US dollars (10 points for each project subject to a maximum of 50 points);	50
CVs of the key professionals (employees or full-time consultant)	50
Quality System Certification	50
Number of Projects for which at least 50 Units of Turnstiles/Flap Gates supplied/commissioned in Public Transit System during the last three years from the due date of tender. (Per Project—10 Points up to maximum of 5 Project)	50
Project execution methodology (to be judged through a write-up of not more than 5,000 words and presentation)	200
Total Marks	700
Minimum Qualifying Marks Required	490

19.8.2 Implementation Oversight

Each and every step of implementation has to be carefully planned, supervised, and monitored. An IT deployment team should be established at an early stage, and ideally at least some of its members should be involved in the functional specification and detailed design phases. This is necessary to ensure that they have a deep understanding of what the IT system should achieve and how it is intended to work. Building relevant expertise and capacity of this team can be achieved by:

- Engaging consultants and technical experts for roles such as project management, system integration, design verification, system and component testing, system commissioning, supplier interface;
- Bringing in IT and software specialists who have experience with complex IT projects and system integration (not necessarily in the ITS or even transportation domain);
- Partnering with cities and/or transport operators who have ITS system experience, and who are willing to act as mentors and perhaps provide some of their staff on a support basis or temporary reassignment;
- Organizing study tours for the team at places where such systems are already successfully functional;
- Enrolling a third party as a project management consultant with expertise in sector.

The team may be built up as deployment approaches, gradually bringing in people from the units that will utilize the ITS functions, and from support functions that will be involved in the installation and commissioning (e.g., maintenance section, IT department). The team should have members with different skills and professional backgrounds in order to cover all the required domains (technical, financial, operative, management, etc.). Capacity building is essential and needs to be carefully planned and adequately resourced. This will include core skill training, up-skilling, and training and skill transfer by suppliers.

The testing procedure takes place at the end of each implementation phase (milestone) and at the end of the realization (for final acceptance of the whole system). The testing of the results of each phase (both intermediate and final) is organized into three different levels:

- Quantitative and technical congruency of system supply and components;
- Functional test (base/core functions, other functions);
- Performance test.

The testing procedures should be devised and agreed with the supplier(s), and conducted either in-house or by an independent firm with the relevant expertise. The conformance of the system is based on the following verifications:

- Actual number of installed components;
- Technical and operational conformity of installation activities;
- Presence of software licenses;
- Technical documents and manuals included in the object of the contract.

Functional tests measure the level of responsiveness of functions to contractual specifications: they can be divided in tests of a single subsystem and of the whole system. Each functionality must be tested under a wide range of operational conditions. Functional tests prove that the function complies with specification (during the specified test). Performance tests measure how long the system is able to provide the functionality properly over a certain time period or number of tests. The positive verification of each milestone (phase) testing leads to the processing of related payment. If not all the results of the testing are positive the contracting authority can decide if:

- The test should be entirely repeated and the implementation activities/ installation of the next phase should be stopped (waiting for positive verification of repeated tests). In this case no payment will be processed—this situation implies major incompliance from the supplier side and the presence of critical factors impeding the work progress;
- The test should be partly repeated, the system functionalities and performances are such to go on with the implementation activities/installation for next phase. A percentage of the payment will be transferred to the supplier, and the remaining quota will be paid too when current problems are solved—in these situations incompliance is less significant and has no impact on the following stages of work.

The supply and installation of components does not imply that these components are operated by the transport companies (or accepted by the contracting body). It is normal to have a period of live operation and debugging: even more the start-up and operation of the system is mandatory to allow the overall IT system(s) to be tested in live conditions in order to detect problems that were not apparent in the testing of the individual units. The positive results of the phase test regulates the payments but they do not mean the final acceptance of the testing: all hardware and software products should not be accepted until they have passed the final testing where each component and subsystem will be tested as part of the comprehensive system. The guarantee should commence its period from the date of final acceptance of the system (positive acceptance tests). The reference date for the guarantee should not become the date of the installation of each component, or its initial testing. Project personnel need to be cautioned on what they sign off on at various testing phases.

19.8.3 Pilot Demonstration

A pilot demonstration will help identify and solve problems before the overall system comes online. The subsequent phases are managed as "extensions" of the components and consolidation of functionalities. Payments should be scheduled according to each implementation milestone in terms of the percentage of the total price. Each payment would be carried out after the successful test planned for each phase. The last payment (i.e., 10 percent of the total) should be linked to the successful final testing (acceptance) of the overall system and to the proven compliance with all the contract obligations. Value and timing of the payments will assure adequate cash flow for the provider (especially in the first phase of the implementation), without leaving the BRT agency overexposed.

19.9 Monitoring and Evaluation

"A truthful evaluation of yourself gives feedback for growth and success."

— Brenda Johnson Padgitt, author, 1970–

Continuous monitoring of the IT deployment is required to ensure that the bidder adheres to prescribed quality and standards and provides the materials that are agreed as per contract. Monitoring and evaluation can be jointly carried out by the IT team and project management firm as a third party inspection. In order to ensure that the service provider adheres to required service standards and delivers quality output, the implementing agency should select performance indicators and include corresponding benchmarks in the IT operator contract(s). Some examples of performance indicators and desired service levels are presented in Table 19.7. For a full description of performance indicators, see the World Bank's document, "ITS Toolkit for Intelligent Transport Systems (ITS) for urban passenger transport".

Table 19.7. Sample Performance Indicators and Benchmarks

Service	Parameter	Desired Service Level	Metric	Penalty
Project; Management;	Submission of reports	100%	Minutes of meetings	2% of monthly CCC charges for every default
Data Center Operations	MIS reporting of health checkup of all; systems and modules; installed;	95%	Report	0.2 % of monthly charges
Incident & Management	Resolution of ticket logged in incident; management tool	99%	Reports generated from ticket logging system	0.5% of monthly charges

19.9.1 Additional References

Several bodies have worked toward creating standards for IT systems:

- In the USA, the National ITS Architecture is published at . This website also contains detailed technical information and guidance on how to use it;
- In Europe, the ITS System Architecture is called FRAME (http://www.frame-online.net/node/38).

Communication protocols:

- TPEG for transmission of language independent multimodal travel and traffic information systems, from the format/technical solution to exchange data;
- DATEX/DATEXII for traffic data, RDS-TMC over radio communication;
- SIRI in the domain of public transport;
- WFS/WMS specifications, xml protocol, etc.;
- Location referencing (AGORA-C, OpenGIS standard, etc.).

20. Vehicles

"Don't worry, sweetie, don't worry! Nobody in New York notices a bus until it's about to hit them! (Samantha in "Sex and the City")"

— Kim Cattrall, actress, 1956–

Overview

Few decisions in the development of a BRT system invoke more debate than the choice of vehicle-propulsion technology and vehicle manufacturer. Even though BRT is far more than just a bus, the choice of vehicle technology is important, as it will strongly influence the system's performance.

Regardless of whether the vehicle procurement is public or private, the technical specifications of the vehicle selected will mostly have to be set by the system's designers, so that they interface properly with the infrastructure. The current common practice is for the public agency to set vehicle standards while the private sector actually purchases and operates the vehicles. Thus, while a standard set of basic requirements must be met, many decisions, such as vehicle manufacturer, are actually left to the operating companies. The public agency will likely develop a detailed set of vehicle specifications that each operator will be required to fulfill. However, it is up to the vehicle operator, who is paying for the vehicles, to determine how to best meet the specifications. For example, within Bogotá's TransMilenio system, different operating companies have selected different vehicle manufacturers. However, thanks to the detailed specifications, from the perspective of the customer, all of the vehicles look and operate identically. This commonality is important to creating and preserving a clear system identity.

Operators purchasing BRT vehicles must weigh many factors in choosing a fuel and propulsion-system technology. Beyond basic vehicle prices, a host of issues must be considered. Will the vehicle technology meet required emission standards? Will the size and design of the vehicle fulfill capacity requirements? Does the technology have a history of operating consistently in developing-city conditions? Does the technology require maintenance personnel with highly specialized skills? Are spare parts for the technology expensive and difficult to obtain in a developing city? Are special refueling stations required for the technology? Is the technology selected financially viable? An attractive, sophisticated vehicle technology may entice decision-makers to make an instinctive choice, but nevertheless, basic questions about maintenance, spare parts, and operational costs should be an integral part of the decision-making process (Figure 20.2).

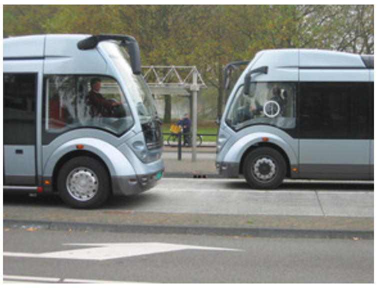

Figure 20.1. The sophistication and attractiveness of a technology are factors to consider, but so are basic issues such as maintenance and operational-cost efficiency. *Advanced Public Transport Systems (APTS).*

20.1 Decision-making Matrix

"You can't make decisions based on fear and the possibility of what might happen."

— Michelle Obama, first lady of the United States, 1964-

Vehicle-fleet technology selection, provision, and operation are complex and depend on legal, operational, institutional, and strategic factors particular to each individual case. Figure 20.2 displays a recommended methodology for vehicle selection and provision mechanisms.

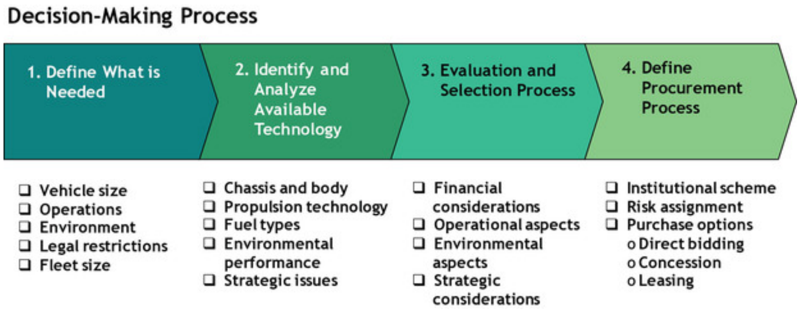

Figure 20.2. Decision-making process for vehicle selection. *ITDP*

Following through the four main activities described in Figure 20.2 can guarantee that the characteristics of the chosen vehicle will meet all the operational requirements necessary to ensure the system's financial viability

The first and most important activity involves identifying the project's specific needs and requirements for its fleet. Most of this analysis should already have been done in the operational-design process, covered in detail in Chapter 4: Demand Analysis and Chapter 8: Traffic-impact Assessment. Vehicle characteristics should not be defined based only on aesthetic or political interests, but must be defined based on optimizing the system's operations.

It would be a serious mistake to select the vehicle prior to performing the operational analysis. Selecting the vehicle type prior to defining the system's operational design can result in either purchasing far more expensive vehicles than is necessary or vehicles too small to provide the required capacity without serious overcrowding or busway congestion. Table 20.1 summarizes many of the factors to consider in deciding on a technology and a manufacturer.

Table 20.1. Decision Factors for Choosing a Vehicle Technology

Category	Factor
Cost	• Purchase cost; • Maintenance costs; • Re-sale value in local market;
Vehicle features	• Customer capacity; • Interior design options; • Aesthetics;
Manufacturer support	• Manufacturer support office in country; • Capabilities of manufacturing technical assistance staff; • Warranty coverage and conditions;
Robustness	• Track record of technology in a developing city; • Degree to which specialized skills are required for maintenance and operation; • Feasibility of making repairs on the road; • Expected percentage of up-time in operation; • Reliability; • Vehicle longevity;
Re-fueling	• Re-fueling time; • Type and cost of required re-fueling stations; • Availability of refueling stations;
Safety	• Strength of body structure; • Chassis design; • Brake system effectiveness; • Anti-fire protection; • Emergency devices;
Environment	• Local emissions (NOx, SOx, CO, PM, toxics); • Global emissions (CO2, N2O4, CH4); • Noise levels; • Other waste products (e.g., solid waste, waste oil, etc.);
Compliance with local regulations	• Maximum weight per axle; • Height, width, and length restrictions.

Once the principal system requirements and needs have been identified, there remain many additional technical considerations that need to be decided before finalizing the technical specification. In general, the basic decision areas for the vehicle include:

1. Vehicle size;
2. Chassis and body configuration;
3. Interior design options;
4. Fuel and propulsion technology;
5. Aesthetic options;
6. Vehicle docking options.

20.2 Vehicle Size

"It's not the size of the dog in the fight, it's the size of the fight in the dog."

— Mark Twain, author, 1835–1910

The size and required customer capacity of the vehicle are largely determined by the modeling analysis conducted at the outset of the project. The analysis process will have determined a projected customer volume for a particular corridor. Vehicle capacities, in conjunction with service frequency, are the primary factors that will help achieve a required volume of customers.

Table 20.2 summarizes the various vehicle-length options, along with the associated customer capacity. The actual customer capacity depends upon a range of factors, including interior layout, the number of seated versus standing customers, and cultural norms regarding the space required per customer.

Table 20.2. Vehicle Options and Customer Capacities

Vehicle type	Vehicle length (meters)	Capacity (customers per vehicle)
Bi-articulated	24	240–270 customers
Articulated	18.5	120–170 customers
Tandem-axle	15	80–100 customers
Double decker	12–15	80–130 customers
Standard	12	60–80 customers
Midi-bus	6	25–35 customers
Mini-bus (vans)	3	10–16 customers

20.2.1 Calculating the Optimum Vehicle Size

The methodology for calculating the appropriate vehicle type in any given situation has already been put forward in Chapter 6: Service Planning. Equation 20.1 summarizes the principal calculation required to determine the optimum vehicle size.

Eq. 20.1 Determining Required Vehicle Capacity

Where:

C_b = Customer capacity of the vehicle, in passengers per vehicle

$C_{corridor}$ = Number of people the corridor can transport, in passengers per hour per direction (pphpd)

L = Load factor, is the average occupancy of the vehicles, expressed as a percent

F = Service frequency, is the number of vehicles per hour

SB = Number of independent stopping bays in each station

The so-called "optimum" vehicle size, though, may vary from corridor to corridor. One option is to operate different-sized vehicles in different corridors of the city. However, this lack of commonality can be disadvantageous for several reasons. First, purchasing different vehicle types will tend to reduce economies of scale in procurement and lead to higher-overall vehicle costs. Second, different vehicle types may have different maintenance needs and different sets of spare parts, and thus again undermining overall economies of scale. Third, managing a fleet of different vehicle types reduces operational flexibility in using vehicles in different corridors, especially when breakdowns and other maintenance requirements may take some vehicles offline for a period of time. Fourth, different-sized vehicles means that station sizes will need to accommodate multiple types of vehicles.

For all these reasons, it is typically preferred to choose a single vehicle type that can serve the spectrum of trunk-line routes. Likewise, one or two smaller vehicle types can be chosen for the feeder services.

A common mistake involves assuming that larger vehicles are somehow better. In truth, the best vehicle size is one that allows for a cost-effective operation for the given volumes and service frequency. If a large vehicle requires ten-minute headways so that the optimum load levels can be achieved, then choosing a lower-capacity vehicle might be more convenient. Customers prefer headways in the range of one to four minutes. Long wait times will ultimately lead customers to choose alternative modes of transport, such as private vehicles. It is important that the operational design include a preference analysis that studies time valuation by customers in such a way that the optimum vehicle type and fleet numbers can be chosen, and that an appropriate quality level can be achieved with the allocated budget.

20.2.2 Bi-articulated, Articulated, and Standard-sized Vehicles

High-volume systems (over seven thousand customers per hour per direction) will likely require both large-sized (articulate or bi-articulated) vehicles and high-frequency service (Figures 20.3 and 20.4). Lower-volume systems should also strive for high-frequency service, but obviously with smaller vehicle types. Systems in Brisbane, Australia, and Jakarta, Indonesia, operate trunk corridors with twelve-meter standard-sized vehicles (Figure 20.5). The smaller size does not mean these systems are inferior to cities operating with larger vehicles. Instead, the size may just be a reflection of the appropriate configuration for the particular demand characteristics.

Figure 20.3. In Curitiba, 24-meter bi-articulated vehicles are utilized on trunk corridors. *Volvo Bus Corporation.*

While the numerous vehicle manufacturers offer a wide range of options, consideration of market availability is also a key factor. Engaging in informal discussions with vehicle manufacturers at the outset can help highlight the availability of different product features. Clearly, the vehicle specifications should not be designed around any one manufacturer, but a broad understanding of the existing options from manufacturers can help shape the analysis.

Figure 20.4. Bogotá's system uses a mix of 18-meter articulated and 24-meter bi-articulated vehicles. *TransMilenio SA.*

Along the same lines, the number of manufacturers providing a particular vehicle type is a legitimate consideration. A single-sourced vehicle will tend to increase costs due to the lack of a competitive manufacturing environment. As an example, currently only one major manufacturer produces a bi-articulated vehicle. Thus, if this type of vehicle is chosen the bidding process is more likely to be less competitive. The lack of competition ultimately results in higher prices for operators, which will then translate into higher customer fares.

Figure 20.5. In Brisbane, Australia, trunk corridors are served by standard 12-meter vehicles. *Queensland Transport.*

20.2.3 Double-decker Vehicles

Increasing the length of the vehicle is just one way of increasing customer capacity. Adding another customer level with a double-decker configuration is another option that is occasionally utilized. Despite being less popular at a global level, double-decker vehicles have successfully created a niche market in such cities as Singapore, London, and Hong Kong (Figure 20.6).

Figure 20.6. In Hong Kong, the double-decker represents an iconic image for the city. *Volvo Bus Corporation.*

The double decker has been successful in creating an iconic image for cities. Double-deckers can generate an intriguing image to a public-transport system and can be quite popular when applied to tourist routes, as the vehicle's upper deck offers a great vantage point for sightseeing.

However, double-deckers can bring many complications and additional costs. The costs of adding a second floor to the vehicle are not entirely devoted to customer space. A significant amount of space is consumed by the stairway on both decks of the vehicle. The stairway also creates potentially troublesome difficulties for customers, particularly during boarding and alighting. Moving up and down the stairway as the vehicle moves can be dangerous. The width of the stairway also makes two-way customer movement difficult. The net effect is dramatically lengthened customer boarding and alighting times. London has phased out its iconic "Routemaster," in part due to the severe injuries and even deaths resulting from customers falling from either the interior stairway or the back alighting step.

Double-deckers are also not particularly suitable for high-volume operations where customers are frequently boarding and alighting. Double-deckers are best used on conventional commuter routes where most of the boarding and alighting takes place at a few station points in the center of the city and then again at a distant suburban location. To date, double-decker vehicles have not been utilized in a full BRT system.

20.2.4 Fleet Size

The vehicle size will impact the number of vehicles needed to meet the demand. Depending on that decision, the fleet size may need to be adjusted and is determined entirely by the operational plan. A method for calculating the fleet size needed based on projected customer demand and the needs for a reserve fleet is outlined in Chapter 6: Service Planning.

20.3 Vehicle Floor Height

"A lot of people are afraid of heights. Not me. I'm afraid of widths."

— Stephen Wright, comedian, actor, writer, and producer, 1955–

After the physical length, the floor height tends to be one of the most crucial physical characteristics of the vehicle. The floor height will affect decisions on boarding and alighting strategies, customer convenience, vehicle costs, and maintenance costs.

In general, there are a full range of options including low floor, semi-low floor, and high-floor vehicles. With any of these options, a level (step-free) boarding is possible. Most of the well-known Latin American systems, such as Bogotá and Pereira, Colombia, Curitiba and Goiânia, Brazil, and Guayaquil and Quito, Ecuador operate high-floor vehicles with platform-level boarding.

Vehicle chassis tend to be produced in certain standard floor heights. Two of the most common interior floor heights are 38 to 40 centimeters (low-floor) and 90 centimeters (high-floor). There are also low-floor models with an interior floor height of less than 38 to 40 centimeters.

20.3.1 Low-floor Versus High-floor Vehicles

From the perspective of BRT systems, the debate over low-floor versus high-floor is somewhat secondary to the preference for platform-level boarding and alighting. Steps of any type will slow dwell times, as well as make a system off-limits to many of the physically disabled. Even low-floor vehicles, if not at level but still requiring a small step up or down, can slow boarding times, as well as create a usage barrier to persons in wheelchairs.

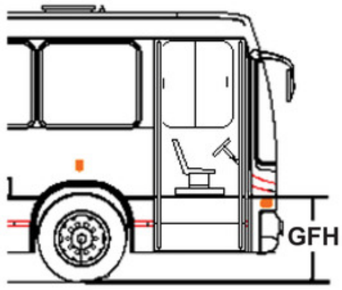

Figure 20.7. GFH 960 mm maximum Long Bus; Rear Engine High Floor *ITDP*

Fig. 20.7, 20.8, and 20.9 The distance from the ground to the vehicle floor differs depending on vehicle length and engine location.

Attempting to operate stepped boarding and alighting in high-volume operations can be detrimental to system performance, regardless of floor height. Both low-floor and high-floor vehicles can be adapted for usage with platform-level boarding. The Transantiago system in Santiago, Chile, elected to operate low-floor (20-centimeter) vehicles without platform-level boarding. In conjunction with the decision to have on-board fare verification, the result has been serious station delays (Figure 20.10). Likewise, the Brisbane, Australia, system also combines low-floor vehicles and on-board fare verification (Figure 20.11). While these types of systems may provide an adequate service, they cannot match the operational performance levels of cities utilizing platform-level boarding.

Figure 20.8. GFH 960 mm maximum Short Bus; 1,150 mm maximum Medium Bus; Front Engine High Floor; *ITDP*

Low-floor vehicles have predominantly been deployed in conventional bus systems in developed nations in Europe and North America. These systems generally operate without closed stations, platform-level boarding, or pre-board fare verification. In such cases, low-floor vehicles provide a somewhat better physical image and make boarding easier in comparison to high-step entry.

As low-floor bus technology becomes more affordable and widely available in developing countries, it has become a matter of debate whether new BRT systems should be designed for use with high- or low-floor vehicles, and whether the high BRT platform is necessary or desirable.

The principal advantages of low-floor vehicles relate to the physical image of the vehicles, as well as some aspects of operational flexibility. The principal advantages of high-floor vehicles relate to the procurement and maintenance costs of the vehicles Further, high-floor vehicles in conjunction with platform-level boarding actually offer smaller dwell times and greater access for the physically disabled than low-floor vehicles without platform-level boarding.

Figure 20.9. GFH 360 mm maximum; Low Entry; Short and Long Bus; *ITDP*

Figure 20.12. High-floor vehicles in conjunction with platform-level boarding have been the cost-effective solution for most high-quality systems in Latin America, such as the system in Belo Horizonte, Brazil. *ITDP.*

Figure 20.10. Low-floor vehicles without platform-level entry and pre-board fare verification can result in longer dwell times and not actually provide access to the physically disabled, as shown in this image from Santiago, Chile *Lloyd Wright*

Figure 20.11. Low-floor vehicles without platform-level entry and pre-board fare verification can result in longer dwell times and not actually provide access to the physically disabled, as shown in this images from Brisbane, Australia *Queensland Transport.*

Low-floor vehicles offer greater operational flexibility since the vehicles can operate with and without boarding platforms. For BRT systems where the vehicles are likely to operate both on trunk corridors and in direct service, where no boarding platforms will be available, the low floor height helps increase customer boarding and alighting speeds during the curbside boarding sections of the route

In instances where the trunk vehicle operates with two-sided doorways, the low-floor design can ease customer movements within the vehicle. If a vehicle operates with high-floor on one-side (median station) and low-floor on the other (curbside station), then there will be steps inside the vehicle. This configuration is utilized in Porto Alegre, Brazil.

Low-floor vehicles can also be preferred for aesthetic and urban design reasons. The 50-centimeter difference in vehicle floor height means that the station height is reduced by 50 centimeters. This height reduction can help to mitigate concerns over roadway severance.

However, low-floor buses have their drawbacks. Being closer to the ground, the buses typically incur more structural stress and thus have higher maintenance costs. Road surfaces must be maintained at a very high level for low-floor bus routes in order to avoid and minimize any potential vehicle damage. These problems will be made worse if flooding is a risk along the BRT corridor. Small imperfections in the road surface will also tend to make the ride less smooth and comfortable for the users.

Low-floor vehicles have somewhat lower customer capacity in comparison with high-floor vehicles, because the wheel wells encroach on the customer-seating area. Low-floor vehicles also always have stairs inside them, as the rear vehicle seats are elevated above the wheels. This constrains customer circulation and limits access for all. Standard tow trucks are not always able to move low-floor vehicles when there are mechanical problems, so specialized towing vehicles are required.

Low-floor vehicles also somewhat complicate preventing fare evasion. With a ramped-entry high-floor vehicle, the height of the platform acts as a natural barrier against individuals trying to enter from outside the station. With low-floor vehicles, fare evaders can sneak between the station and the vehicle, and then enter the vehicle with relatively little difficulty. A way to avoid this is to install platform screen doors.

Low-floor vehicles also typically cost 20 to 30 percent more than standard models, and in some cases, upwards of 100 percent more (as is the case in India). Manufacturing low-floor vehicles requires the use of modern manufacturing technology, which is not always available in developing countries. In some cases, this means that the use of a low-floor vehicle will affect whether the vehicles can be assembled locally or will need to be imported, and thus have a significant impact on the cost of both procurement and maintenance. Table 20.3 summarizes the various trade-offs between high-floor and low-floor vehicles.

Table 20.3. Comparison between high-floor and low-floor vehicles.

Factor	High-floor Vehicle	Low-floor Vehicle
Purchase cost	Lower purchase costs	More complex chassis results in a purchase cost approximately 20 to 100% higher than high-floor vehicles
Maintenance cost	Distance from roadway impacts reduces maintenance costs	Higher maintenance costs (10%to 20%) due to proximity to roadway imperfections
Urban design aesthetics	Station profile will be 50 centimeters higher	Station profile will be 50 centimeters lower and thus will somewhat reduce visual severance
Customer convenience	High-floor vehicles with platform-level boarding eases boarding and alighting and has better circulation for all	If at-level boarding, then access for all, but internal circulation compromised by stairs. Often, low-floor stations are not at-level, but still require a step up, making wheelchair entry difficult
Vehicle towing	In case of breakdown, high-floor vehicles can be towed by a conventional tow truck	Many low-floor vehicles require a special type of towing vehicle
Fare evasion	Provides a better natural defense against fare evasion	More susceptible to fare evasion
Vibrations	Higher suspension somewhat reduces roadway bumps and vibrations	Somewhat more susceptible to roadway vibrations and thus making reading potentially more difficult
Seating	Little to no impact on seating arrangement from the wheel-wells	Some impact on the height and number of seats due to the wheel-well

20.4 Vehicle Interior Design

> *"Art has to move you, and design does not; unless it's a good design for a bus."*
>
> — David Hockney, painter and designer, 1937–

From a customer perspective, the interior of the vehicle is far more important than the mechanical components propelling it. The interior design will directly affect comfort, customer capacity, security, and safety.

A basic starting point for developing the interior design is to determine the amount of seated and standing space in the vehicle. The amount of space dedicated to standing areas and to seated areas will be based upon expected customer flows, especially accounting for peak capacities. In general, customers will have a preference for as much seating as possible. However, the operational economics of the system may require a certain number of standing customers, especially during peak periods, in order to deliver an affordable fare.

A sharp peak period will tend to force a greater number of standing customers. However, there are also other considerations. If travel distances are relatively long in the city (e.g., an average trip distance over fifteen kilometers), then it will be quite tiring for customers to be standing. By contrast, if average trip distances are relatively short (e.g., under five kilometers), then standing is less of an issue (Figures 20.13 and 20.14).

However, even in cases of relatively short trip distances, the value of a seat to a customer should not be underestimated. After a day of work or school, many patrons are not pleased to stand for even a few kilometers (Figure 20.15). Every effort should thus be made to provide sufficient seating and/or manage operations to minimize standing.

A standard 18-meter articulated vehicle may have anywhere from forty to fifty-five seated customers, depending upon the seating and doorway configuration. With more doorways, there will be less space for seating. The width of aisleways will also be part of this equation. To lessen the discomfort of standing, quality holding devices

Figure 20.13. In cities, such as Quito and Bogotá, with relatively short average-trip distances, there can be more tolerance for having many standing customers. In cities with long travel distances, it can be quite tiring to customers. *Lloyd Wright*

Figure 20.14. In cities, such as Quito and Bogotá, with relatively short average-trip distances, there can be more tolerance for having many standing customers. In cities with long travel distances, it can be quite tiring to customers. *Carlos Pardo.*

Figure 20.15. Customers in Bogotá make their own seating on the floor of the vehicle. Every effort should be made to maximize seating to the extent possible. *Carlos Pardo.*

(poles, straps, etc.) should be provided. Table 20.5 shows how the dimensions of the customer areas vary between vehicles sizes and engine location.

Table 20.4. Dimensions of the customer compartment from the Mexico City Manual on Safety, Accessibility, Comfort, and Manufacturing of Buses

DESCRIPTION	SHORT VEHICLE		MEDIUM AND LONG VEHICLE	LONG VEHICLE
	HIGH-FLOOR	LOW-ENTRY	HIGH-FLOOR	LOW-ENTRY
Distance from floor to ceiling	2,000 mm minimum, measured in aisle	2,250 mm minimum, measured in aisle	2,000 mm minimum, measured in aisle	2,250 mm minimum, measured in aisle
Width of customer compartment	2,280 mm minimum, measured at 800 mm height from the floor		2,320 mm minimum, measured at 800 mm height from the floor	

Seating facing to the sides, rather than to the front, can be effective in opening up space for standing customers (Figure 20.16). Front-facing single seats can also be preferred by customers who wish to maintain a degree of privacy. Double seats can create difficulties when customers prefer the aisle seat in order to be more accessible to the exit. In such circumstances, other customers must step over the aisle-seated customer to access the window seat. In other cases, customers may place belongings on one of the double seats in order to prevent others from sitting alongside. These circumstances can create conflicts between customers. Instead, good design practices should be employed to avoid potentially awkward customer situations.

Figure 20.16. Side-facing seating, as shown in this example from Jakarta, Indonesia, will tend to maximize space for standing customers, and thus such a configuration will maximize overall customer capacity per vehicle. *Karl Otta, courtesy of GIZ.*

The vehicle's internal layout must comply with legal restrictions and also consider the number and location of doors in the vehicle, in such a way that internal circulation, handicap access, and access at stops is readily available in the least amount of time possible.

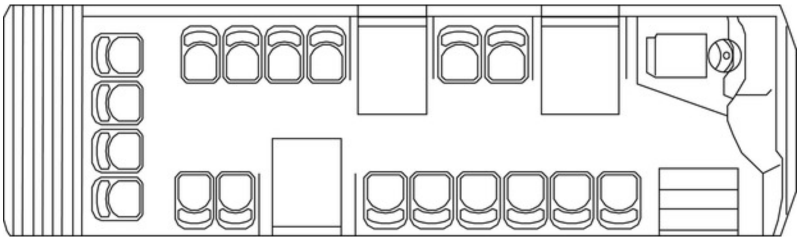

Figure 20.17. Example of customer configuration for a short vehicle. *ITDP*

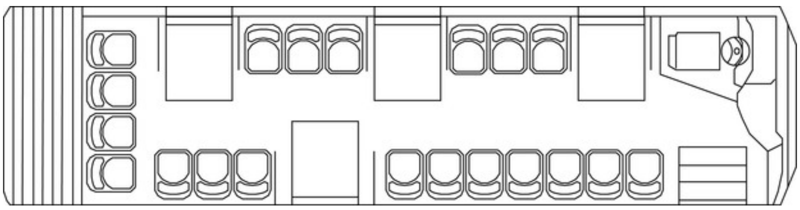

Figure 20.18. Example of customer configuration for medium and long vehicles. *ITDP*

An 18-meter articulated vehicle will typically have either three or four sets of double doorways. There is a trade-off with each configuration. With only three doorways, there will be more space for seating. However, four doorways are considerably more efficient in allowing rapid boarding and alighting (Figure 20.20). As always, much depends on the local context to determine which trade-off is the most important.

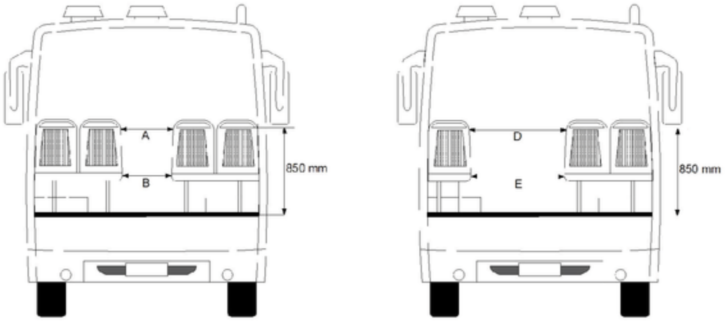

Figure 20.19. The aisle located between the doors in all types of vehicles must not have double seats on both sides. *ITDP*

Special arrangements should also be made to cater to the needs of physically disabled and elderly customers. The station entry ramps are an important feature, but likewise, adequate interior space for wheelchairs is key. Additionally, the safe attachment of wheelchairs to a fixed interior structure may be required. Space for wheelchairs can also double as standing capacity during peak periods (Figure 20.24). See Chapter 30: Universal Access for more information about universal access.

Figure 20.20. Bogotá utilizes a four-door configuration that helps to reduce boarding and alighting times. *TransMilenio TM.*

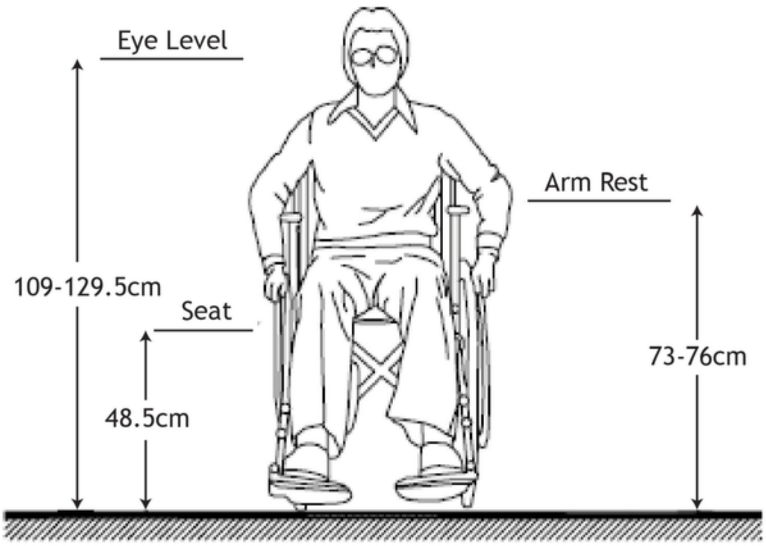

Figure 20.21. Wheelchair dimensions and the anthropometric measurements indicated in the preceding diagrams should be considered in sizing the backrest. *ITDP*

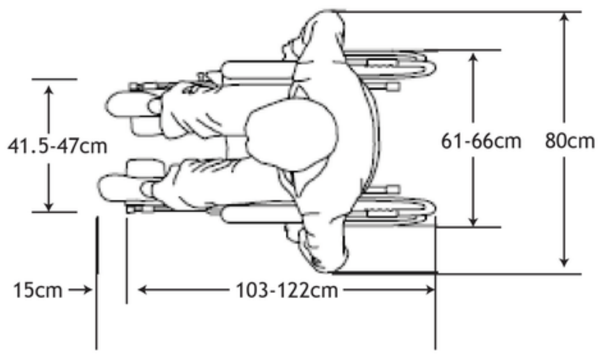

Figure 20.22. Wheelchair dimensions and the anthropometric measurements indicated in the preceding diagrams should be considered in sizing the backrest. *ITDP*

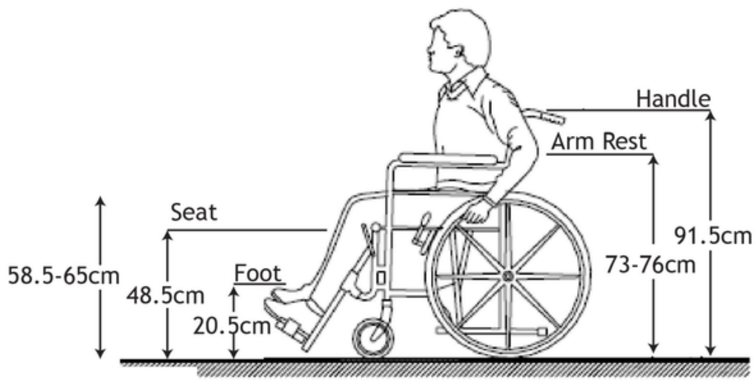

Figure 20.23. Wheelchair dimensions and the anthropometric measurements indicated in the preceding diagrams should be considered in sizing the backrest. *ITDP*

Figure 20.24. Space allocated for special-needs customers, such as those with wheelchairs, can also be useful in meeting standing capacity during peak periods. *Lloyd Wright.*

Bicycles can also be safely and effectively secured inside the vehicle. With the ramped entryways of BRT vehicles, bicycles can easily be brought on board, especially during non-peak periods. The space permitted for bicycles can also be an effective open space for standing customers during peak times. Unfortunately, the bicycle is needlessly banned from many bus systems.

In typical conditions, a seated customer consumes as much as twice the space as that required by a standing customer. However, the amount of personal space each customer requires can vary between different cultures. In Latin America, it is somewhat acceptable to tolerate relatively packed conditions. Knowledge of local preferences in conjunction with stated preference surveys can help evaluate the best spatial arrangement. The interior of the Bogotá TransMilenio vehicles is designed to a standard of as many as seven customers per square meter. In other cultures this level of crowding would be completely unacceptable.

The type of seating can greatly affect customer comfort. Cloth and padded seating offers additional comfort to customers (Figure 20.25). However, there are cost and maintenance issues to consider with these types of seats. While plastic seating is not as comfortable, such seating is less costly and is easier to clean and maintain.

Special panoramic windows allow better views of the external environment. Panoramic windows offer a larger visible area for customer views (Figure 20.26). Being able to see upcoming stations and station name plates is especially important for customers unfamiliar with a particular corridor. Clean and highly visible windows also make the journey more enjoyable for customers who wish to view the outside environment.

Figure 20.25. Cloth seating can enhance the customer experience, but may be harder to maintain. *Advanced Public Transport Systems.*

Figure 20.26. Panoramic windows, as in this bus in Aichi, Japan, can dramatically improve the customer's ability to see the outside environment. *Lloyd Wright.*

The aesthetic design of the interior can also affect the customer's opinion of the system. As shown in Figures 20.25 and 20.26, the right choice of shapes, colors, and textures can all do much to create a professional and friendly environment.

20.5 Environmental Performance

> *"The system of nature, of which man is a part, tends to be self-balancing, self-adjusting, self-cleansing. Not so with technology. (Small is Beautiful)"*
>
> — E.F. Schumacher, economist, 1911–1977

In addition to complying with the governing legislation, the project must define its minimum environmental standards. Because of the profitability of BRT, it is usually possible to set a higher environmental standard on BRT vehicles than is required under the law without compromising the profitability of operations. As BRT projects play an important role in improving environmental conditions, raising environmental standards that can be financially sustained is generally recommended.

Generally, the following must be considered in assessing the environmental quality of a system:

- Emission levels;
- Ambient air-quality standards;
- Fuel quality;

- Fuel type and propulsion system;
- Levels on interior and exterior noise;
- Ventilation and temperature standards (air renewal/time unit).

In the needs-assessment phase of the project, it is important to set the environmental goal. From an emissions standpoint, there is no one clear technical solution that is necessarily superior to another. Much will also depend on the availability of a particular fuel. Each fuel carries with it different trade-offs of costs, emissions, infrastructure, and potential operating constraints. In some instances, a fuel may emit less of one type of pollutant, but more of another type of pollutant. For example, CNG may do well in terms of reducing particulate emissions, but its life-cycle greenhouse gas emissions may not offer a significant advantage over diesel technology.

Some fuels may produce less local emissions, but may produce significant emissions at the point of electricity generation. Some fuels may produce few emissions from the standpoint of fuel tank-to-wheels but can produce significant emissions when the full fuel cycle is considered (e.g., well-to-wheels). For example, electric vehicles and hydrogen-fueled vehicles may produce zero emissions at the tailpipe, but the emissions generated at the power-plant or through the hydrogen generation process can be quite substantial. Some fuels may work well in ideal conditions, but are more polluting in circumstances when maintenance and road conditions are poor, or at high altitudes.

20.5.1 Emission Standards

Box 20.1. BRT Standard: Minimizing Bus Emissions – 3 points maximum

Bus tailpipe emissions are typically a large source of urban air pollution. Especially at risk are bus passengers and people living or working near roadsides. In general, the pollutant emissions of highest concern from urban buses are particulate matter (PM) and nitrogen oxides (NOx). Minimizing these emissions is critical to the health of both passengers and the general urban population.

The primary determinant of tailpipe emission levels is the stringency of governments' emissions standards. While some fuels, like natural gas, tend to produce lower emissions, new emission controls have enabled even diesel buses to meet extremely clean standards. However, "clean" fuels do not guarantee low emissions of all pollutants. As a result, our scoring is based on certified emissions standards rather than fuel type. Over the last two decades, the European Union and the United States have adopted a series of progressively tighter emissions standards that are being used for this scoring system. Buses must be in compliance with Euro VI and U.S. 2010 emission standards to receive 3 points. These standards result in extremely low emissions of both PM and NOx. For diesel vehicles, these standards require the use of PM traps, ultra-low-sulfur diesel fuel, and selective catalytic reduction. To receive two points, buses need to be certified to Euro IV or V with PM traps (note: 50 ppm sulfur diesel fuel or lower is required for PM traps to function effectively).

Vehicles certified to the Euro IV and V standards that do not require traps emit twice as much PM as vehicles meeting more recent standards. Therefore, these vehicles are awarded one point. Ideally, buses will include contractually stipulated requirements in the purchase order to control real-world NOx emissions

from buses in use, because the actual NOx emissions from urban buses certified to Euro IV and V have

been tested at levels substantially higher than certified levels. Because that is hard to verify, it

is included as a recommendation, but not as a requirement, for receiving the one point.

Zero points are awarded for U.S. 2004 and Euro III standards and less stringent standards, because these standards allow ten times as much PM emissions as the U.S. 2010 and Euro VI standards.

Buses also generate greenhouse gas emissions. Since no clear regulatory framework exists that requires bus manufacturers to meet specific greenhouse-gas emission targets or fuel-efficiency standards, there is no obvious way to identify a fuel-efficient bus by vehicle type. For CO2 impacts, we recommend the use of the TEEMP model, which incorporates The BRT Standard into a broader assessment of project-specific CO2 impacts.

Table 20.5. (empty)

Emissions Standards	Points
Euro VI or US 2010	3
Euro IV or V with PM traps or US 2007	2
Euro IV or V or Euro III CNG or using verified PM trap retrofit	1
Below Euro IV or V	0

Emission standards are the most typical mechanism for differentiating between the emissions levels of different vehicle options. The standards set forward by the United States Environmental Protection Agency (US EPA) and the European Commission are most typically used to classify emission performance of different technologies. Table 20.5 gives an indication of how European and US EPA standards are related in terms of Nitrogen Oxide (NOx) and Particulate Matter (PM) emissions. For the most part, the two systems follow similar long-term objectives, although there are a few differences.

In many developing nations, the “Euro” (i.e., European) standards are being applied. Table 20.6 provides more detail on the Euro emissions standards, along with the likely fuel and technology requirements.

Table 20.6. Euro Emission Standards for Heavy Vehicles

Level	CO (g/kWh)	HC; (g/kWh);	NOx (g/kWh)	PM (g/kWh)	Certification fuel sulfur content (ppm)	Likely technological requirements
Euro I	4.5	1.1	8.0	0.612	2000	Higher pressure fuel injection for PM control, timing retard for NOx control
Euro II (1996)	4.0	1.1	7.0	0.25	500	All engines are turbocharged, improved high pressure fuel injection and timing optimization
Euro III (2000)	2.1	0.66	5.0	0.1	350	In addition to above, electronic control for fuel injection, timing retard for NOx, common rail (CR) fuel injection, some exhaust gas recirculation (EGR)
Euro IV (2005)	1.5	0.46	3.5	0.02	50	In addition to the above, further NOx reduction using EGR or selective catalytic reduction (SCR). Some systems will use diesel particulate filters (DPFs) and most will incorporate oxidation catalysts.
Euro V (2008)	1.5	0.46	2.0	0.02	10	Similar to above, with more reliance on SCR.
Euro VI; (2013)	1.5;	0.13	0.40	0.01	10	

In order to achieve desired emissions standards or reductions from existing vehicles, several different components of the emissions-control program must be taken into account, including:

- Fuel quality;
- Engine technologies;
- Emission-control technologies;
- Inspection and maintenance program; and
- Driver training.

In order to ensure the greatest possible emissions reductions from both the new vehicles and the existing fleet, a comprehensive emissions-control program will be required.

In determining the appropriate emissions standards and technologies within a specific city or fleet perspective, many considerations must be taken into account, including the reliability of the fuel supply to meet quality standards, the mechanisms and incentives that are in place to ensure follow-up and compliance with driver training and maintenance procedures, and the applicability of the technology in context to the operating conditions of the fleet. Each component has a different ramification in the developing-nation context. Can the quality of the incoming fuel be assured, and how will adulteration of fuels be avoided? If advanced engine and emission-control technologies are utilized, how robust are these technologies in developing-city conditions? If an improved driver and maintenance program is established, what mechanisms and incentives are in place to ensure follow-up and compliance?

In addition to emission standards, system planners may also specify the maximum allowable age of vehicles operating on the system. The age specification will help to maintain long-term system quality as well as ensure all private operators are competing on an equal basis. The maximum age will also play a fundamental role in calculating the operator's amortization rate for the vehicle.

Figure 20.27. Technology is not the only solution to ensuring low emissions, as maintenance, fuel quality, and driving habits all contribute to the actual emission levels. *Lloyd Wright*

20.5.2 Fuel Quality

In a BRT project, it is fairly typical that the BRT authority has control over the vehicle standard, but only limited influence on the fuel standard and fuel availability. However, in several cases a BRT project has been used to pressure the energy companies to provide cleaner fuels. The additional operational controls within a BRT system may make it possible to ensure a higher-quality fuel supply than is available within the rest of the city, and should make it possible to reduce the problems of fuel adulteration. In any case, the technical specification has to be set with awareness of available fuel quality. In Ecuador, the city of Quito maintains higher-fuel quality standards than other cities in the country. This higher level is in part due to the city's unique climatic and geographical conditions, 2,800 meters of elevation, as well as the presence of a BRT system.

It is generally best to set the minimum-allowable vehicle-emission standard without specifying a specific technology, as this gives the operator greater flexibility to consider a range of factors such as fuel costs, fuel availability, maintenance, reliability, refueling times, and performance when complying with the standard. These factors will vary by location and situation, and the private sector may be in the best position to weigh the relative economic value of each factor. For instance, in Bogotá, the BRT authority specifies that vehicles must meet a minimum Euro II emission standard and have set forward a schedule to move towards Euro IV standards. TransMilenio does not specify a particular fuel or propulsion technology. These decisions are left to the private operators. There are also incentives in place for operators to propose vehicles exceeding the minimum standard. Such operators receive more points during the bidding process.

For BRT, the cleanest new vehicles that are compatible with available fuel quality are generally advisable. In some cases, BRT systems have been operated with a mismatch between the vehicle technology and the available fuel (Figure 20.28). Somewhat cleaner vehicles may be able to cope with dirtier fuels but may face increased maintenance issues. While Euro II and III vehicles are generally more forgiving than Euro IV or V vehicles, higher sulfur levels than are found in certification fuels may still increase maintenance costs for sensitive electronic engine equipment, such as high-pressure or common rail fuel injection. Lower sulfur fuels will reduce maintenance costs and improve vehicle durability for all vehicles, regardless of emissions standard.

Figure 20.28. On the Quito Central Norte corridor, the Euro III-compliant vehicles are not producing the desired results due to the use of 500 parts per million of sulfur in diesel fuel. *Lloyd Wright*

However, in some instances, there may be reason to specify a particular fuel type. In Delhi, India, all public-transport vehicles have been mandated to utilize compressed natural gas (CNG) as fuel (Figure 20.29). Adulterated fuels are those that have been tampered with by suppliers in order to improve their profits. For example, some fuel suppliers in India mix kerosene, which is subject to much lower taxation rates, into the diesel. The result of fuel adulteration such as this is poorly performing vehicles, higher emissions and air pollution, and more costly maintenance requirements. Thus, requiring Euro II or Euro III technology can be meaningless in such a scenario, since there is little control on the input fuel. By contrast, it is quite difficult to adulterate CNG, and thus its quality is more assured. Despite the rationale of this course and the relative availability of CNG in India, Delhi's conversion from diesel fuels to CNG has been fraught with conflicts and political recriminations. Ultimately, it required the intervention of the national Supreme Court to ensure that the conversion process was finally undertaken.

Figure 20.29. All public-transport vehicles in Delhi, including the oldest vehicles, faced a mandatory conversion to CNG fuel in order to overcome difficulties with adulterated fuels. *Lloyd Wright*

20.5.3 Fuel Types and Propulsion Systems

Many governments and promoters of clean technology rightly see BRT as a possibility for introducing cleaner vehicle technology. Because of BRT's profitability, it creates the potential of having a much cleaner vehicle without undermining the profitability of the service. However, this profitability is case-specific, and clean technologies should not be forced on BRT systems without first assessing the impact the technology will have on the quality of service, the profitability of the system, the transparency of the vehicle procurement process, and other factors.

The choice of fuel and propulsion technology will have a profound impact on operating costs, maintenance costs, supporting infrastructure, as well as emission levels. Local circumstances play a central role in fuel choice, as the availability of a fuel and experience in maintaining a particular vehicle technology are key factors. Further, as attention focuses more and more on the human and environmental costs of both local pollutants and global climate change, system developers are under increasing pressure to deliver cleaner vehicles options.

The following is a list of some of the most common fuel options currently being considered for public-transport vehicles (Figure 20.30):

- Diesel, both standard and clean;
- Compressed natural gas (CNG);
- Liquid petroleum gas (LPG);
- Electric trolleybuses;
- Bio-fuels, such as bio-diesel and ethanol;
- Hybrid-electric (diesel-electric and CNG-electric);
- Hydrogen (fuel-cell technology).

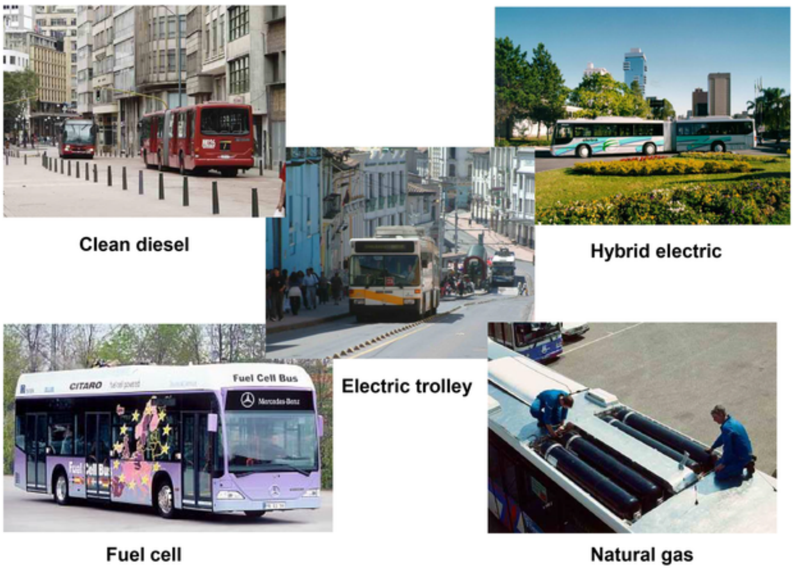

Figure 20.30. Fuel and propulsion system options. Image *ITDP.*

A range of other possibilities also exists, such as fly-wheel technology, di-methyl ether (DME), and blended fuels (e.g., water-in-oil emulsions).

Choosing the type of engines that will be purchased and the fuel that will be used requires that consideration be given to several important issues. The following factors are the most important when considering a fuel and propulsion technology:

- Fuel availability and price volatility;
- Vehicle cost;
- Reliability;
- Government policy;
- Environmental impact.

Diesel (Standard and Clean)

A clean-diesel system implies that the propulsion-system technology and the fuel quality are such that the end result is much lower emissions than a standard diesel vehicle. The International Energy Agency notes that (IEA, 2002b, p. 61):

"Diesel engines are recognized and favored worldwide for their fuel efficiency, excellent durability and low maintenance requirements. They offer the convenience of using a liquid fuel that is easily dispensed through an established fueling infrastructure. The technology is mature, widely produced and competitively priced. Although diesel engines have historically produced high levels of pollutant emissions, especially oxides of nitrogen (NOx) and particulate matter (PM), recent improvements in engines and fuel and emissions-control technology have resulted in new diesel systems for buses that are substantially cleaner than they were only a few years ago."

For diesel, sulfur content is the most critical factor to consider, as many of the pollution-control devices used in the cleaner buses require lower sulfur fuels. In some cities, diesel fuels may contain over 2000 parts per million (ppm) of sulfur. To achieve Euro II standards, a sulfur level of less than 500 ppm is likely to be required. To achieve “ultra-low-sulfur diesel” (ULSD), the fuel must contain less than 50 ppm. Many emission-control technologies will only function properly if the fuel sulfur levels are below acceptable levels.

Reducing sulfur from diesel fuel also carries with it other emissions benefits, such as simultaneously also reducing particulate matter (PM), which is a key pollutant from a public-health perspective. As shown in Figure 20.31, sulfur contributes to the production of particulate matter in all diesel engines. At higher sulfur levels, sulfate can account for up to 5 to 15 percent of PM emissions from diesel. At lower sulfur levels, after-treatment emissions controls can reduce PM emissions much more substantially, either as retrofit devices or as standard equipment on new vehicles meeting more stringent standards. Diesel oxidation catalysts, which can reduce PM emissions by 20 to 30 percent, can generally be used with sulfur levels up to 500 ppm. Diesel particulate filters, which can reduce more than 90 percent of PM emissions, generally require sulfur levels to be under 50 ppm.

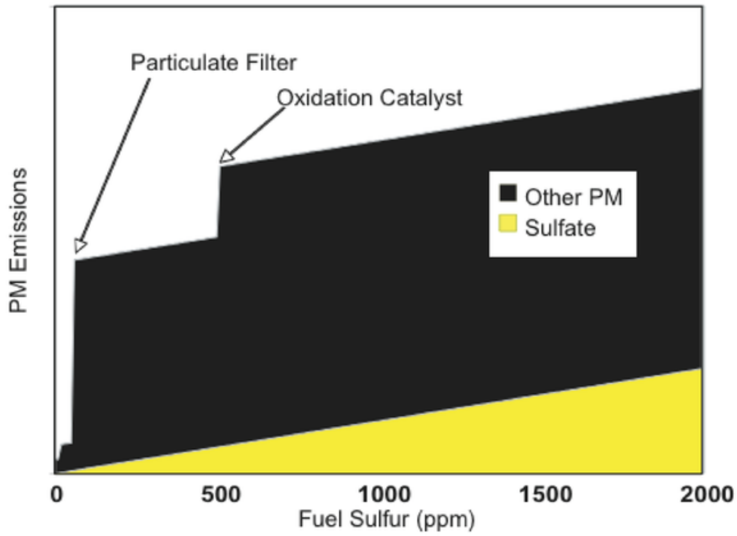

Figure 20.31. There is a close relationship between the emissions of sulfur and emissions of particulate matter (PM). *Luis Willumsen.*

Hydrocarbons (HC), carbon monoxide (CO), and even nitrogen oxides (NOx) are also affected by emissions standards and contingent on fuel quality. As can be seen in Table 20.5, the Euro standards are scheduled to reduce emissions of all major pollutants. Euro II and III each represent a 60 percent reduction in PM emissions from the previous standards. Euro IV standards have 80 percent lower PM emissions than Euro III, and thus representing a 97-percent reduction from Euro I standards. The cleaner the vehicle, however, the more sensitive it is to fuel quality.

Emissions from diesel vehicles will vary depending on local conditions such as altitude, atmospheric pressure, humidity, and climate. The quality of ongoing vehicle maintenance and the integrity of the fuel supply chain will also affect specific system emissions. Nevertheless, with the right fuel quality, diesel vehicles can produce emissions reductions in line with many of the more costly alternative fuels. In general, it can do so with a lower vehicle cost and with a more robust maintenance regime.

Compressed Natural Gas (CNG)

CNG is highly touted as a reliable fuel option that “inherently” achieves lower emissions. CNG contains virtually no sulfur and naturally burns quite cleanly. However, CNG is not a perfect solution. For some emission types, the performance of CNG may not be that much better than clean diesel vehicles.

In the case of greenhouse-gas emissions, the entire well-to-wheels analysis of CNG production, distribution, and use may imply that there is little, if any, advantage over diesel. Upstream methane losses along pipelines can significantly increase total life-cycle greenhouse emissions for CNG. Some studies estimate that with the inclusion of methane leakage, CNG will actually produce significantly more total greenhouse-gas emissions (CVTF, 2000).

There are also other issues to consider with CNG. The low energy density of the fuel means that the gas must be compressed for on-board storage in large, bulky cylinders. CNG vehicles also require different maintenance skills that may not be common. In some cases, CNG vehicles may face power issues on steep hills, at high altitudes, and in some temperatures. The refueling infrastructure for CNG can also be costly to develop.

Refueling time is also a consideration for CNG vehicles. Typically, refueling time per vehicle will range from 20 to 40 minutes.

Figure 20.32. Los Angeles has developed the infrastructure to use CNG technology for the entire fleet on its Orange Line. *Los Angeles County Metropolitan Transport Authority.*

Nevertheless, CNG holds much potential for emission reductions of PM and sulfur oxides, and thus, if the fuel is available locally, then the technology should be given serious consideration. Further, as experience grows with CNG, the technology is becoming increasingly robust from a maintenance standpoint.

Electric-Trolley Vehicles

Electric-trolley vehicles are a well-established technology that produces zero emissions at the point of use. The total fuel-cycle emissions of electric-operated vehicles will depend upon the fuel used in the electricity generation. Fossil-fuel-based electricity generation, such as electricity from coal or petroleum, will produce high levels of total emissions, while renewable sources, such as hydro-electric and wind sources, will be relatively emission free. Thus, in countries with clean electricity generation, electric trolleys can be a low-emitting option to consider. Electric-trolley vehicles are also extremely quiet in operation. Table 20.6 summarizes the different issues to consider in choosing electric-trolley technology.

Table 20.7. Advantages and Disadvantages of Electric Trolleybus Technology

Advantages	Disadvantages
Zero emissions at point of use (total emissions will depend on fuel type for electricity generation)	Vehicles can cost up to three times the amount of a comparable diesel vehicle
Quiet operation	Operating costs highly dependent on electricity prices; subsequent electricity deregulation can destabilize financial model
Smooth ride characteristics	Route modifications are very expensive
Longer vehicle life (up to twice the vehicle life of diesel vehicles)	Longer implementation time required to build the electric conduit network
	Risk of service disruption during power failure unless vehicles have backup diesel motor
	Infrastructure costs can be over twice that of a non-trolley BRT system
	Presence of wiring, posts, and transformers can create aesthetic concerns, particularly in historical centers
	If the electric-trolley vehicle pantograph comes off the overhead wires, it can cause significant system delay

Biofuels (Ethanol and Bio-Diesel)

Ethanol is a fuel produced from the fermentation of sugars in carbohydrates, derived from agricultural crops like corn and grains, wood, or animal wastes. Currently, ethanol is derived predominantly from corn and sugar cane (Figure 20.33). Brazil possesses an extensive ethanol program using sugar cane. In the future, cellulosic ethanol may become viable, in which the fuel can be derived from a broader range of plant and agricultural species. However, commercial production of cellulosic ethanol is yet to be fully realized.

Figure 20.33. Sugar cane production in Mauritius. *Lloyd Wright*

Bio-diesel is a fuel derived from biological sources that can be used in diesel engines instead of petroleum-derived diesel. Through the process of transesterification, the triglycerides in the biologically derived oils are separated from the glycerin, creating a combustible fuel. Bio-diesel fuel is currently derived predominantly from soya.

Biofuels hold the potential to deliver a product with net zero greenhouse-gas emissions. The CO2 emitted by biofuels can be balanced by the CO_2 absorbed during plant growth, potentially resulting in a fixed carbon cycle. However, the reality is more complicated. Total greenhouse emissions from biofuel production are still quite poorly understood, including certain factors that could increase net greenhouse gas emissions considerably. These factors include: energy inputs into the cultivation of crops; secondary emissions that have climate-change impacts (e.g., black soot); amount of fertilizer use and resultant emissions of nitrous oxide (N_2O); amount of pesticide use; and, type of biomass being displaced by energy crops. In some instances, such as soy-based fuels, the resulting greenhouse-gas emissions from nitrogen releases may overwhelm other benefits (Deluchi, 2003). Additionally, it is unclear if the amount of agricultural land is sufficient to produce biofuels in a quantity sufficient to dramatically offset petroleum fuels (IEA, 2004).

Biofuel production may have an array of other unintended side effects. As the market for biofuel builds, there will be growing pressure on sensitive ecosystems to be converted into crop production. This phenomenon is already clearly evident in the Amazon region of Brazil, where increased demand for soya is leading to further illegal destruction of the Amazon ecosystem. Each year, approximately 20,000 square kilometers of the Amazon rainforest are cleared for agricultural use (Economist, 2006). More intensive biofuel production can also imply greater depletion of input resources such as soil quality and water (Figures 20.34 and 20.35).

Figure 20.34. The growing demand for soy has fueled further destruction of the Amazon rainforest. *iStockphotos.*

Figure 20.35. As the demand for biofuel increases, production inputs, such as water, will also come under increasing demand. *Lloyd Wright.*

There is also increasing concern over the impact biofuel production will have upon food prices. It is reported that the grain required to fill the typical 95-liter petrol tank of a sport utility vehicle with ethanol will feed one person for a year. The grain to fill the tank every two weeks over a year will feed 26 people (Brown, 2006). In the United States, the amount of the corn (maize) crop dedicated to ethanol production increased 34 percent from 2006 to 2005. In 2006, some 54 million tons of maize went to ethanol production, even though ethanol only represents a small percentage of the fuel used in vehicles in the United States (Planet Ark, 2006). In late 2006, an increase in maize prices due to biofuel demand caused tortilla prices to triple in Mexico. Since tortillas represent the staple of the local diet, many low-income families were severely affected by these increases. With strong protests from the population, the government was eventually forced to adapt price controls. These types of conflicts may become more common as the market for biofuels expands.

Hybrid-Electric Vehicles (Diesel-Electric and CNG-Electric)

Hybrid-electric vehicles will likely be one of the first of the advanced technologies to gain large-scale acceptance in the market. Hybrids utilize both conventional fuels (e.g., diesel, CNG, etc.) and electrical motors to propel the drive-train. Electric power can be generated during vehicle deceleration and then utilized to operate motors attached to each wheel. Since electric motors are used for part of the vehicle's operation, hybrids offer superior fuel economy, reduced emissions, and lower noise levels (Figure 20.36).

Figure 20.36. The potential of hybrid-electric vehicles to cost-effectively reduce tailpipe emissions has drawn the attention of most manufacturers. *Volvo.*

However, even with this technology, the emission-reduction benefits can vary depending on the driving-duty cycle. The city of Seattle, Washington, USA has made one of the largest investments in hybrid-electric technology within its bus system. However, despite manufacturer claims of fuel efficiency gains of 25 percent or more, the initial results in Seattle were significantly less due to the route choice (Hadley, 2004). If the bus-duty cycle does not involve sufficient stop-and-go travel, then the efficiency gains from regenerative braking are not realized. The additional weight of the hybrid-electric vehicle offsets the gains from the on-board electricity generation (Wright and Fulton, 2005).

Like all new technologies, a certain period of adjustments and experimentation are required prior to optimum results being achieved. However, the complexity of propulsion system and cost of the hybrid components mean that hybrids may not be well suited for all developing city applications.

Currently, efforts are being made to produce hybrid-electric vehicles in Brazil. Because of various local conditions, such as lack of driver familiarity with the technology, the environmental benefits have been less than anticipated, but the problems are likely to be resolvable.

Hydrogen (Fuel-Cell Technology)

National research and development budgets have heavily invested in fuel-cell technologies. In 2003, the United States launched its five-year Hydrogen Fuel Cell Initiative with a commitment of US$1.7 billion in research funding. Likewise, the European Union is supporting a US$3.7 billion public-private partnership in a 10-year fuel cell development program. In 2003, Japan dedicated US$268 million of its government research budget to fuel cells. Likewise, other governments such as Canada and China also have their own fuel-cell program (Science, 2004).

Fuel-cell vehicles are undergoing testing in both developed and developing cities. Through a grant from the Global Environment Facility (GEF), several developing cities, such as Beijing and Cairo, have had an opportunity to evaluate the technology. However, none of these cities are actually operating full fleets with these technologies. The costs, environmental benefits, and performance of these vehicles are not entirely proven. Since most hydrogen is currently produced from electrolysis, the emissions benefits are directly tied to the type of technology utilized for the generation of the electricity.

The International Energy Agency notes that there are no certainties when hydrogen fuel cells will become commercially viable (IEA, 2004). Hydrogen storage capabilities, the dependence on expensive rare-metal catalysts (e.g., platinum), and the development of appropriate infrastructure all represent formidable uncertainties in the timely delivery of a commercial product. By depending solely on a technology without a known delivery date, action on transport-sector emissions can be significantly delayed:

"…by skewing research toward costly large-scale demonstrations of technology well before it's ready for market, governments risk repeating a pattern that has sunk previous technologies, such as synfuels in the 1980s. By focusing research on technologies that aren't likely to have a measurable impact until the second half of the century, the current hydrogen push fails to address the growing threat from greenhouse gas emissions from fossil fuels" (Science, 2004)."

20.5.4 Fuel Availability and Price Volatility

Not all fuels are widely available. Many alternative fuels may simply not be available at the time that the BRT system is going into operation, and thus fuel availability will constrain the selection of propulsion technology.

Diesel and electricity are by far the most widely available fuels. Low-sulfur diesel is available in a growing number of countries, but its availability is still fairly limited in developing countries. Current price levels in different countries are well documented through the GIZ International Fuel Prices publication (Wagner et al., 2012/2013). As evidenced in Figure 20.37, subsidy and tax levels can make a significant difference in actual fuel costs.

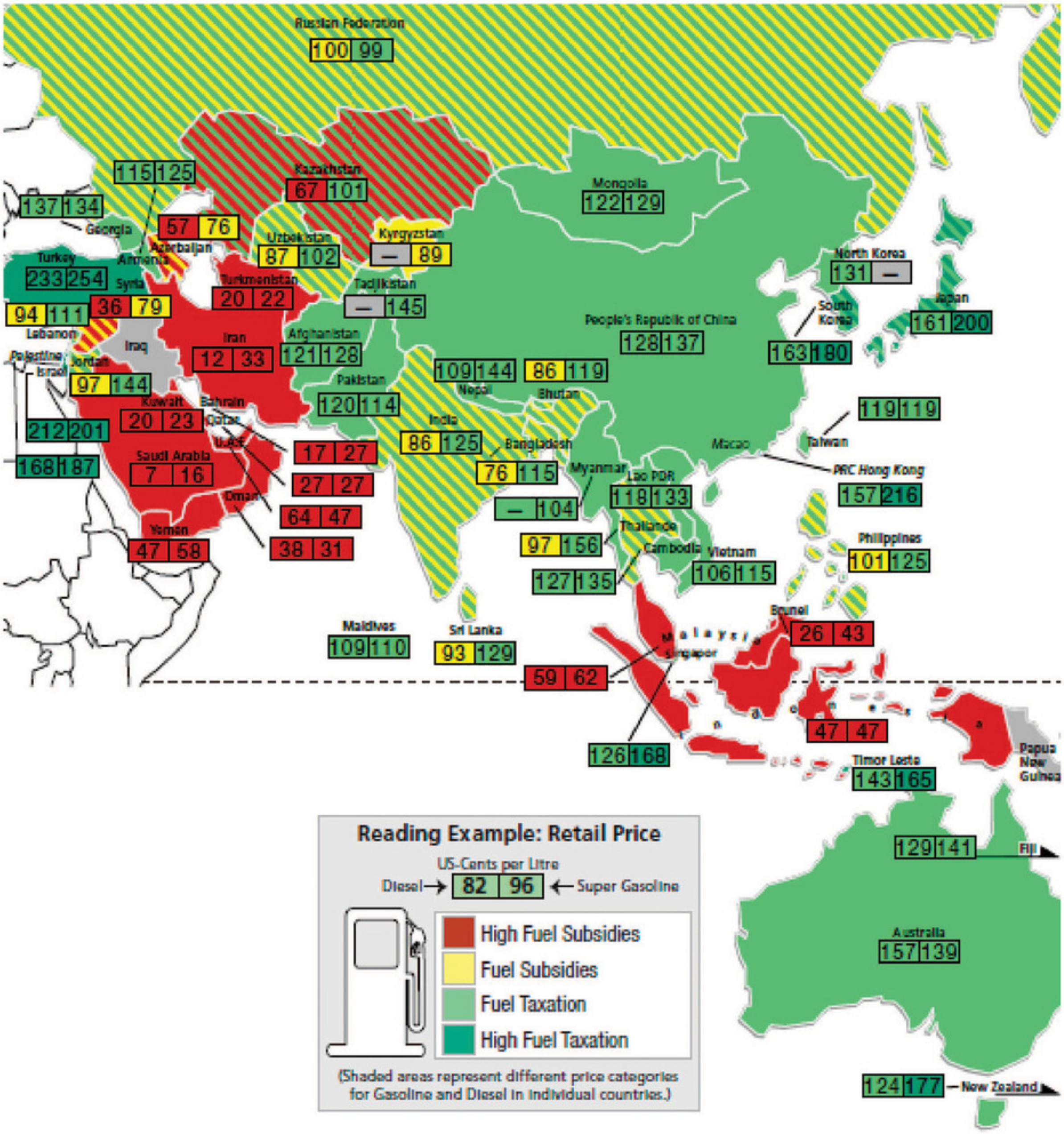

Figure 20.37. The yellow and red areas represent countries with significant fuel subsidies as of November 2012. *International Fuel Prices 2012/2013 provided by GIZ.*

Natural gas as a bus fuel requires a supply network in close proximity to fleet maintenance and parking areas. Some cities have natural gas and others do not. Some cities have the gas, but have not yet invested in the specialized equipment such as the pipeline, compressors, dehumidifiers, and other equipment necessary to make the fuel usable as a bus fuel. When Delhi, India, was forced to switch to natural gas, the lack of sufficient sources of supply led to severe disruption of bus services. TransJakarta also faced a similar problem where buses would have to queue in long lines due to the lack of refueling stations. These problems can be mitigated with proper planning.

Hydrogen fuel cells are currently not commercially viable without massive subsidies, but an additional problem is the availability of hydrogen. Hydrogen is not found in any substantial quantities in the natural environment. For this reason, hydrogen is not really a fuel type, but rather it is an energy carrier, in a similar manner that an electric battery is an energy carrier. Most of the hydrogen fuel-cell projects developed to date have relied upon electrolysis, which generates the hydrogen from passing an electrical current through water. This requires special equipment and electricity. The other likely source of hydrogen is natural gas, which then requires a natural-gas supply. Both approaches require expensive specialized equipment. Further, depending on how the electricity is generated to produce the hydrogen, the life-cycle emissions from a fuel-cell vehicle can actually be considerably higher than a standard diesel vehicle.

The electricity for electric trolleybuses is less of a problem than the cost and maintenance of the electric conduit and the electricity stations that feed them. Electric-diesel hybrids which do not require electric conduits mitigate the need for expensive conduits.

In every case, a vulnerability and risk analysis associated with fuel-supply systems is necessary, as public services like transportation cannot risk interruptions in operation due to problems within gas pipes tubes or power outages.

The risk of future fuel-price volatility is a related issue. System operators will want to insulate themselves against the risk of sudden future increases in fuel prices. A vehicle technology should be selected which reduces the risk of future fuel price increases.

While predicting future fuel supplies is difficult, this risk can be mitigated by having the vehicle operator negotiate long-term fixed-rate contracts with the relevant fuel suppliers, or by buying futures options in the fuel. The risk can also be mitigated by the use of vehicle technologies that can run on multiple fuel types.

If a city has a nearby natural gas supply, it may be worth the investment in the necessary infrastructure and equipment to provide natural gas at the depot, if a reasonably priced long-term supply contract can be negotiated with the gas supplier. A local supply of natural gas is important because it is relatively easy to pipe but expensive to ship. Similarly, if oil is produced in the country, particularly if it is produced by a state-run oil company, it may be possible to negotiate a long-term fixed-rate supply contract.

Conversely, if a country has hydroelectric power, or large supplies of coal, or declining electricity demand (as in the case of the former socialist countries of Central and Eastern Europe and the former Soviet Union) it may be that future electricity supplies are more predictable than prices for diesel or natural gas. Again, the issue may be more whether or not a long-term supply contract can be negotiated. It is not enough to assume that a government company will mean stable future fuel prices. System operators should still protect themselves with long-term supply contracts or futures contracts. Long-term supply contracts also may be possible from commercial providers, though they will cost more.

In the case of Quito, for example, the decision to go with electric trolleybuses was initially related to low electricity costs. While the initially low electricity rates made the operational costs competitive with diesel-based systems, a subsequent deregulation of the Ecuadorian electricity sector has seen electricity costs increase.

Figure 20.38. Sudden changes in fuel costs can jeopardize a system's entire economic viability. *Lloyd Wright.*

20.5.5 Reliability

Reliability of the propulsion technology is a major concern for a BRT system. Vehicle breakdowns in a BRT system are more serious than in a normal bus operation, because a broken down bus will congest the BRT lane and lead to a significant disruption of service.

One of the main advantages of diesel fuel is that the vehicle technology is more mature, and with proper maintenance, vehicle breakdowns are more predictable and easier to repair (Figure 20.39).

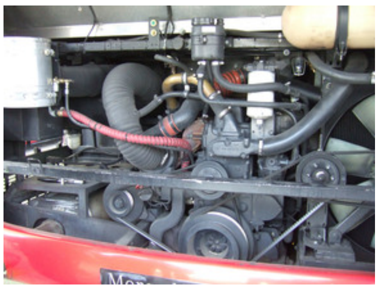

Figure 20.39. Diesel technology has a long operational track record, and thus the technology's robustness and maintenance requirements are well known. *Lloyd Wright.*

Electric trolleybuses themselves have excellent maintenance records, but there can be problems with power failures and maintenance failures in the electric conduits. Electric trolleybus technology is used in São Paulo's Corredor Metropolitano ABD BRT system in São Paulo. Some operational problems were experienced due to poor maintenance of the overhead conduit line, but it could be partially controlled by turning over control of conduit maintenance to the vehicle operator, who has a bigger stake in a breakdown than the power company.

In any case, most important is a maintenance contract with the supplier. In the case of TransMilenio in Bogotá, manufacturers have staff at the depot for major repairs (Figure 20.40). It is therefore critical that the degree of technical support offered by the vehicle supplier be a major consideration in the procurement contract. In Quito, for example, Spanish electric trolleybus suppliers were selected over lower-cost Russian suppliers, largely because of the quality of maintenance support offered.

If the risks of vehicle breakdown are extremely high, local maintenance capacity is low, and the ability of the local operators to mobilize capital is weak, it may be worth exploring the option of leasing the vehicles from the manufacturer.

For any vehicle, it is also advisable to run fuel and general-performance tests locally that simulate the anticipated conditions of operation, before reaching a decision. Vehicles that work well in developed countries in temperate climates may work poorly in tropical climates on poor roads with major drainage problems.

Figure 20.40. Many of the operating companies in Bogotá directly contract the vehicle manufacturers to provide maintenance services for the vehicles. *Lloyd Wright.*

20.5.6 Noise

Acceptable noise levels should also be specified within the vehicle-procurement specifications. Excessively loud vehicles are both a health hazard and a detriment to the marketing image of the public transport service.

Noise levels are determined by several variables including:

- Fuel and propulsion system technology;
- Design of propulsion system;
- Size of vehicle relative to engine size;
- Dampening technologies and exhaust system employed;
- Quality of road surface; and
- Maintenance practices.

Some fuel and propulsion systems, such as electric vehicles, are naturally quiet. In other instances, the design of the propulsion system can encourage smooth operation, as well as the dampening of sounds. Ensuring incentives for well-maintained vehicles and roads will also help achieve lower noise levels. In Bogotá, the vehicle specifications mandate that internal noise levels of the vehicles are not to exceed 90 decibels.

A very quiet vehicle does introduce other issues. Electric-trolleybus technology operates with little noise. However, in turn, the lack of noise can create a hazard for pedestrians who may not be aware of the presence of an oncoming vehicle. This type of hazard is particularly a concern for the sight-impaired, who are often quite dependent on noise to guide their movements.

20.5.7 Ventilation and Temperature Standards

The presence or absence of climate control inside the vehicles can have an enormous impact, not only on the quality of service, but also on the costs of operations. In some climate conditions, air conditioning is not that critical to customer comfort, but in other cases, the lack of air conditioning alone may be enough to induce middle- and upper-income customers to stay in cars. Requiring air conditioning is critical to a high status image for the system, but it will also put upward pressure on the fare, because vehicles will be more expensive and will use more fuel. As a general rule, climate control inside the vehicles is preferred, if it is at all possible, given the profitability of the system.

Whether air conditioning is used or not, attention should be given to the amount of air turnover inside the vehicle. In highly crowded vehicles, the air quality can quickly deteriorate without adequate ventilation.

20.6 Other Physical Characteristics

"Whatever good things we build end up building us."

— Jim Rohn, businessman, 1930–2009

Besides the vehicle length and propulsion system type, there are a range of other characteristics that will define the vehicle. The specifications set forth during the operational design will determine many other additional factors regarding the technical specification required for the vehicle, including the following:

- Body type (segregated from chassis, unified);
- Number of doorways and size of doorways;
- Type of system for opening and closing the doorways;
- Doorway location;
- Transmission type (automatic, manual, retarder);
- Type of propulsion system;
- Engine location (front, center, rear);
- Engine power rating;
- Acceleration capacity;
- Braking technology;
- Braking capacity;
- Suspension type (springs, hydraulic);
- Road turning radius (internal and external);
- Axle-load capacity.

If decisions on these parameters are made without reference to the operational design, serious design mistakes can occur. For example, in Jakarta, Indonesia, a vehicle with plenty of capacity was procured, but the vehicle had only one door. This single-door decision seriously delayed customer boarding and alighting speed, and the entire capacity of the corridor was severely compromised. Similarly, vehicles with axle loads above the weight-bearing capacity of the road surface treatment on the corridor led to rapid deterioration of the roadbed.

Table 20.8. Specifications from the Mexico City Manual on Safety, Accessibility, Comfort, and Manufacturing of Buses.

DESCRIPTION	HIGH-FLOOR VEHICLE								LOW-ENTRY VEHICLE			
	SHORT				MEDIUM		LONG		SHORT		LONG	
	REAR ENGINE**		FRONT ENGINE *				REAR ENGINE **					
	DIESEL	CNG	DIESEL	CNG	DIESEL	CNG	DIESEL	CNG	DIESEL	CNG	DIESEL	CNG
Vehicular weight	7,000 kg max	8,500 kg max	7,000 kg max	8,500 kg max	8,800 kg max	10,300 kg max	11,600 kg max	12,500 kg max	7,000 kg max	8,500 kg max	11,600 kg max	12,500 kg max
Gross vehicular weight	10,500 kg max	12,000 kg max	10,500 kg max	12,000 kg max	15,000 kg max	16,000 kg max	18,600 kg max	19,500 kg max	10,500 kg max	12,000 kg max	18,600 kg max	19,500 kg max
Nominal capacity	50 customers max				80 customers max		100 customers max		50 customers max		100 customers max	
Entry angle	8° minimum								6° minimum			
Exit angle	8° minimum								6° minimum			
Rear overhang	65% max distance between axles		70% max distance between axles				65% max distance between axles					
Front overhang	0.55 max distance between axles											
Distance between axles	Distance will be acceptable provided that the arrangement of axles allows for the proper distribution of the loads as well as the maneuverability and internal and external dimensions specified for each vehicle.											
Total height	3,800 mm maximum including external elements above top (Natural gas tank and air conditioning)											
Total length	7,500 to 10,000 mm including both bumpers				8,400 to 10,500 mm including both bumpers		10,000 to 12,500 mm including both bumpers		7,500 to 10,500 mm including both bumpers		10,000 to 12,500 mm including both bumpers	
Distance between front axles	1,630 mm min				1,950 mm min				1,630 mm min		1,950 mm min	
Distance between rear axles	1,600 min				1,800 mm min				1,600 min		1,800 mm min	
Total width	2,500 mm max, without mirrors and with doors closed				2,600 mm max, without mirrors and with doors closed				2,500 mm max, without mirrors and with doors closed		2,600 mm max, without mirrors and with doors closed	
Distance from ground to floor	960 mm max				1,150 mm mechanical suspension and door behind front axle		960 mm max		360 mm max measured to vehicle weight in area of passenger ascent			
Outer turning radius	10,000 mm max				12,000 mm max				10,000 mm max		12,000 mm max	

* Recommended for medium and steep routes because of the engine type and location.

** Recommended for flat routes because of its engine type and location.

In most countries, there are regulations and conditions that public transportation vehicles must meet pertaining to bus import, assembly, and manufacturing. Identifying all conditions and restrictions thus becomes necessary, along with any required certification and standardization processes. Norms, standards, and regulations that cover the following fields are present in most countries:

- Environmental performance;
- Security standards;
- Physical conditions;
- Country of origin;
- Local manufacturing ratios;
- Import procedures and requirements;
- Tariffs and other import duties;
- Handicap accessibility.

In the absence of laws and regulations governing these issues, setting the vehicle technical specification should take these issues into consideration in any case, following international norms.

As a reference, Table 20.8 is a summary of the vehicle specifications put forward by the public company overseeing Phase I of the Bogotá TransMilenio system in 2000. The actual specifications for any given city will vary depending on local preferences and circumstances.

Table 20.9. Bogotá Vehicle Specifications (Trunk Vehicles)

Vehicle attribute	Specification
Load weights	
GAWR front axle load	7,500 kg
GAWR middle axle load	20,500 kg

GAWR rear axle load	20,500 kg
GVWR total weight	30,000 kg
External dimensions	
Maximum width	2.60 meters
Maximum height	4.10 meters
Overall minimum length	17.50 meters
Overall maximum length	18.50 meters
Maximum front overhang	3000 mm
Maximum rear overhang	3500 mm
Floor height from ground	
Minimum height	870 mm
Maximum height	930 mm
Turning radius	
Minimum between sidewalks	7,400 mm
Maximum between sidewalks	20,100 mm
Minimum between walls	7,400 mm
Maximum between walls	13,400 mm
Chassis and body	
Body type	Integral body or self-supporting body
Modification	Every modification of the chassis must be formally approved by the manufacturer
Certification of static load proof	Can be obtained by physical proof or computational model; Minimum certified roof resistance in 5 minutes: 50% of GMV; Maximum deformation in every point: 70 mm;
Customer space	
Total customer capacity	160 customers
Seating capacity	48 customers
Color of seats	Red
Number of preferential seats	6
Color of preferential seats	Blue
Standing customer area	16 m2
Standing design capacity	7 customers per square meter
Wheelchair capacity	1 space for wheelchair (90 centimeters x 140 centimeters); Located in the first body of the bus in front of the second door
Layout of seats	2-2, 2-1, 1-1, 1-0; Perimeter or front-to-front
Internal dimensions	
Free internal height	2100 mm minimum
Superior visibility height	1850 mm minimum
Inferior visibility height	600 mm minimum; 850 mm maximum
Corridor width	600 mm minimum
Seating characteristics	

Characteristics	Individual seats; Closed in back; Direct anchorage to the vehicle floor; Without upholstery or cushioned; Without sharp edges or rivets;
Materials	Plastic; Washable; Self-extinguishing and flame retardant; No release of toxic gases during combustion;
Seat dimensions	
Distance between seats	700 mm
Distance between seats front to front	1300 mm
Seat depth	350 mm minimum; 430 mm maximum
Seat height (measured from floor)	350 mm minimum; 450 mm maximum
Back height	500 mm minimum; 600 mm maximum
Seat width	400 mm
Handles and handrails	
Characteristics	Surfaces without sharp edges; End finished in a curve; Continuous; Non-slip surface;
Dimensions	Diameter: Between 30 and 45 mm; Horizontal handrail height: 1750 mm minimum and 1800 mm maximum; Distance between vertical balusters: 1500 mm or every two seats;
Windows	
Front window type	Laminated
Type, all other windows	Tempered
Color of window	Green
Transparency level	70%
Advertising	Windows without advertisement
Inferior module	Fixed to the body with adhesive
Superior module height	Minimum: 30% of total height of the window; Maximum: 50% of total height of the window;
Doorways	
Number of customer doorways	4
Position	Left side of vehicle
Minimum free width	1100 mm
Free height	1900 mm
Door opening time	2 seconds
Emergency doors	Type: single door; Number of emergency doorways: 2; Minimum free width: 650 mm; Free height: 1800 mm; With stairs covered and with a pneumatic opening system;
Control and instrumentation	
Logic unit	Communication display in view of driver; GPS and communications antennas; Tachnograph (with register and storage of instant velocity, distance traveled, times of operation and non-operation over 24-hour period);
Control center communications	Voice communication equipment
Instrumentation	Odometer with pulse output connected to the logic unit
	Complete instrumentation with alarms for low pressure of the air brake system and motor oil system
Ventilation	
Air renewal requirement	Minimum 20 times per hour
Noise	
Maximum internal sound level	90 dB(A)

Destination signs	
Number and size of signs	1 in front: 1950 mm x 300 mm; 2 on left side: 450 mm x 250 mm;
Visibility	Visible from a distance of 100 meters
Technical standards	
Vehicle	NTC 4901-1 Mass Transport Passenger Vehicles
Test methods	NTC 4901-2 Mass Transport Passenger Vehicles
Local standards	ICONTEC (Colombian Technical and Standardization Institute)

Source: TransMilenio SA

20.7 Vehicle Aesthetics

"Design is not just what it looks like and feels like. Design is how it works."
— Steve Jobs, co-founder and former CEO of Apple Inc., 1955–2011

The aesthetic nature of the vehicle technology should also be an explicit component of the design and specification process. Vehicle styling, color and aesthetic features figure greatly in the public's perception of the system. The vehicle, along with the stations, are the most visceral and visible elements of the system. The appearance, branding, interior design, and maintenance of these elements will be critical to customer experience of the system and the visual language of the system.

Some manufacturers are now emulating many of the design features from light-rail systems (Figure 20.41). Simply by covering the wheels and rounding the bus body, these manufacturers have greatly increased the aesthetic appeal of their product. These initial vehicle designs are relatively expensive, in part because other features such as optical-guidance systems often accompany them. However, the idea of creating a customer pleasing form is not necessarily a costly endeavor.

Figure 20.41. Despite giving a distinctly light-rail appearance, the Civis vehicle is actually a bus. *US TCRP media library.*

It is important that the external and internal aesthetic design include modern elements that differentiate the system from informal public transportation. Design elements that typically elicit a positive customer reaction include:

- Aerodynamic curvature of body, especially a rounded front;
- Covered wheels (Figure 20.42);
- Panoramic windows;
- Window color and tint;
- Paint-color combination;
- Interior lighting of vehicle;
- High-quality floor and interior materials;
- Interior layout and design (Figure 20.43);
- Information systems for customers (electronic information boards and sound systems).

Figure 20.42. Covered wheels and well-designed interiors are seemingly small details that can have a big impact on the public's perception of the vehicle. *NBRTI*

Figure 20.43. Covered wheels and well-designed interiors are seemingly small details that can have a big impact on the public's perception of the vehicle. *Advanced Public Transport Systems (APTS)*

20.8 Strategic Considerations

"A goal without a plan is just a wish."

— Antoine de Saint-Exupéry, author, 1900–1944

There are a series of considerations that have to be taken into account besides technical, environmental or legal factors. These considerations are important from political and strategic points of view; and although they are not directly related to the system's performance, they are directly associated with its impact and positive contribution to the local transportation service and to users.

20.8.1 Government Policies

Fuel-type selection can also be affected by political considerations, which may influence the system's stability, permanency, and economic viability. In particular, development policies established by administrations must be considered, including factors such as:

- Tariff structure for transportation equipment, depending on their respective technology (it might be possible to obtain preferential tariffs for low emission fuels);
- Policies regarding subsidies;
- Tax incentives for clean vehicles;
- Future plans and investments in clean fuel production initiatives;
- Future fuel supply infrastructure expansion and maintenance plans.

20.8.2 Local Assembly and Production

Renovating vehicle-fleet technology and public transportation creates a great opportunity for developing new industries and implementing technologies that can be groundbreaking in the country in question.

It is desirable that when selecting vehicle technology, one can take into account the real possibility of incorporating local businesses into whatever part of the process is possible. For instance, it may be possible to encourage local fabrication, chassis assembly, body fabrication and mounting (Figure 20.44).

Figure 20.44. Cities such as Bogotá have put in the right incentives to encourage major vehicle manufacturers to set up local manufacturing facilities. *Lloyd Wright*

Choosing more modern and state-of-the-art technology might make it more difficult to obtain parts and equipment locally, as this equipment might not be available. Further, such technology may prove difficult for local manufacturers to deliver. However, this should not mean that the technology chosen for the project has to be obsolete. On the contrary, even if the chosen technologies are advanced, an effort should be made to foment and encourage local industries to develop local capacity. Not being able to incorporate local business into the process might generate an unfavorable public opinion towards the project in some sectors and could also generate political opposition.

20.8.3 Ensuring Competition among Vehicle Suppliers

The vehicle specifications should be developed in part to ensure that the widest number of manufacturers will be able to compete in the market. By maximizing the number of eligible manufacturers, the operating companies will be able to undertake a competing tendering process that will minimize the vehicle costs. Limiting the vehicle type to just one or two manufacturers will quite likely increase the purchase costs.

20.9 Docking Systems

> *"We require from buildings two kinds of goodness: first, the doing their practical duty well: then that they be graceful and pleasing in doing it."*
>
> — Josh Ruskin, author, 1819–1900

The process of aligning the vehicle to the station will affect the speed of customer boarding and alighting, customer safety, and vehicle quality. Vehicle alignment to the station can be critical for both the lateral and longitudinal distances. The lateral distance between the vehicle and the station is important in terms of customers easily and safely crossing. The longitudinal placement of the vehicle can be critical if the station has precise doorways that must match up with the doorways on the vehicle. If the station has an open platform without doorways, then the longitudinal placement is less critical.

Docking precision is also required to avoid damage to the vehicle. If a driver comes too close to the station platform, a collision between the vehicle and the station can easily occur. Rubber padding on the platform sides can mitigate some of the damage, but ultimately, small collisions will damage the vehicle. Boarding bridges that extend from the vehicle to cover the gap between the vehicle and the station are sometimes used by systems, like Curitiba in Brazil. While the docking system will be determined by the system designers, most operators do not like boarding bridges, as they are an extra maintenance cost and can be delicate (i.e., not robust). Chapter 25: BRT Stations, of this Planning Guide expands further on the design of stations and terminals.

20.10 Vehicle Costs

> *"The cost of a thing is the amount of what I will call life which is required to be exchanged for it, immediately or in the long run."*
>
> — Henry David Thoreau, author, 1817–1862

The one variable that often has an overriding impact on vehicle selection is cost. The amortization of the vehicle is one of the principal operating costs that affects both operator profitability as well as the fare level. An exorbitantly high-cost vehicle will reduce system profits and make fares unaffordable. For this reason, attention to vehicle costing must be undertaken jointly with the operational costing model.

Some of the principal determinants of a vehicle's cost are vehicle size (i.e., length) and the type of propulsion system. Other factors, such as interior design, engine size (including if it is a front or rear engine), type of chassis (including high or low floor), air conditioning, and number of doorways, will also play a role. For example, a low-floor vehicle will cost approximately 25 percent more than a higher-floor model.

Economies-of-scale in production is a major factor that affects pricing. For this reason, two 12-meter vehicles often cost less than a single 18-meter vehicle. This result occurs due to the significantly greater number of 12-meter vehicles produced in the world.

Because vehicle cost is not fixed, but a function of the scale of production, some cleaner, new technologies face initial high costs, which create a barrier to entry. However, cleaner vehicles also yield social benefits for beyond just public-transport customers. These factors may in some cases constitute a justification for short-term subsidization of cleaner bus technologies.

Standard diesel vehicles are by far the least expensive vehicle technology. Most new BRT systems, such as the ones in Rio de Janeiro and Belo Horizonte, Brazil, Guadalajara, Mexico, Istanbul, Guatemala City, are now using Euro V diesel technology. Clean diesel technology, in combination with good-quality fuel, can often meet or even exceed the emission standards of supposedly more sophisticated propulsion systems. In Johannesburg, the BRT system was used to introduce Euro V buses for the first time to the country.

After diesel, CNG is perhaps the next most common type of fuel used in road-based public transport today. In India, the capital cost of a CNG bus is about 20 percent higher than that of a diesel bus, and ongoing maintenance costs are about 10 percent higher. The fuel price is another factor that would also increase the cost of running CNG. A typical 900-millimeter, 12-meter AC diesel bus would cost somewhere between US$65,000 and US$85,000 in India. (Figure 20.45). Elsewhere, a CNG vehicle will increase the procurement price by between US$25,000 and US$50,000 US dollars. The cost difference varies widely, depending on how powerful the engine needs to be, which will be a function of vehicle size.

Figure 20.45. In India, fairly cost-effective CNG vehicles are supplied in substantial volumes. *Lloyd Wright*

The electric trolleybus is also a fairly common propulsion type. Electric trolleybuses can be three times the cost of a comparable Euro II diesel vehicle. Further, the added infrastructure costs of the electric conduit and transformers can be significant. These extra costs are somewhat mitigated by the longer life of electric trolleybuses. Due to the lower mechanical demands on the electric trolleybus technology, the life of the vehicles can be twice that of diesel vehicles. Usually electric trolleybuses also have a backup diesel motor in case of a power failure, which accounts for part of the difference in cost.

Quito utilized electric trolleybus technology on its first BRT corridor in 1996 (Figure 20.46). The technology was chosen primarily for its environmental benefits. Quito's historical core is a World Heritage Site, and the municipality wished to reduce the impacts of diesel emissions on the integrity of the built environment. Further, Ecuador's electricity generation is primarily from hydro-electric sources. The price of each vehicle was approximately US$700,000. In total, the added infrastructure for the electric-trolley corridor pushed capital costs to over US$5 million per kilometer. By comparison, a subsequent BRT corridor in Quito using Euro II diesel technology resulted in capital costs of approximately US$585,000 per kilometer.

Figure 20.46. The cost of the electric-trolley vehicles in Quito, along with the cost of the associated infrastructure, resulted in a comparatively expensive system. *Lloyd Wright*

Electric-diesel and electric-CNG hybrids are likely to be the next generation of clean vehicle technology. Currently electric-CNG and electric-diesel hybrids are available at US$100,000 to US$175,000 more than a standard diesel bus. The BRT systems in Cleveland, Ohio, and Eugene, Oregon, USA, both use electric-diesel hybrid articulated vehicles with a low floor.

The BRT business plan outlined in the chapters in Volume IV will determine how much money can reasonably be spent on the vehicle procurement without compromising the financial viability of the entire BRT system. The business plan will indicate the maximum cost of the vehicle procurement (depreciation) and the maximum on-going operating cost (including maintenance) that can be sustained, and how much the system will have to charge per vehicle-kilometer in order to cover these costs. The technical specification can require high levels of environmental protection, high noise standards, high aesthetic standards, and high levels of customer comfort, but only within the parameters that the business plan has determined to be financially viable. In some cases, the system being designed will be profitable, as in the case of TransMilenio Phases 1-3, giving the system designers considerable freedom to set a high technical standard. In other cases, such as in very poor countries, customer demand may be highly sensitive to even modest increases in fare prices, placing tight constraints on the options for the technical specification.

Many local conditions will influence the cost of the vehicle. Vehicle technologies with a longer history and large manufacturing volumes will hold a cost advantage in terms of manufacturing economies of scale. Many traditional Indian buses, for example, are mass-produced using a truck body, and are some of the lowest-cost buses in the world, but they leave much to be desired from the point-of-view of customer comfort. New vehicle technologies will generally have lower manufacturing volumes and may incur additional research and tooling costs (Figure 20.47).

Figure 20.47. Specialized manufacturing of low-volume vehicles can dramatically increase overall costs. *TCRP BRT image library.*

The location of the manufactured vehicle will also be a factor. Production sites in developing countries will often hold an advantage in terms of labor and site costs. Further, locally manufactured vehicles will have lower shipping costs to arrive at the destination city. However, in some instances, locally manufactured vehicles may raise quality issues in comparison to developed-nation production sites.

In some cases, the vehicle manufacturers themselves have determined that certain branches of their own company are responsible for specific regions, even though they may not be the lowest-cost producers. For example, the cost of good-quality name- brand buses in Africa is sometimes more expensive, only because the manufacturers have determined that the African market is to be supplied by the European branch, rather than the Latin American or Asian branch of the company. The following factors are likely to strongly influence local vehicles procurement costs:

- Chassis cost;
- Body Cost;
- Sales tax;
- Licensing and paperwork fees and costs;
- Circulation permit costs;
- Operational insurance costs;
- Financing cost;
- Projected vehicle life;

- Projected resale value;
- Projected repair requirements.

For imported vehicles, there will be the following additional cost considerations:

- CIF costs;
- Shipping costs;
- Shipping insurance costs;
- Local port storage fees;
- Tariffs;
- Value-added tax;
- Local customizing costs;
- Domestic transportation costs from ports to cities.

Table 20.10 breaks down how different elements that go into choosing the best type of vehicle for a public-transport system affect the overall vehicle price.

Table 20.10. Cost of each vehicle element as a percentage of impact to total vehicle cost

	Percent of Total Vehicle Price			Costs as a Percent Additional to Total Vehicle Price	
Passenger Capacity (type of vehicle)	Chassis	Body	Total	Low Floor	Air Conditioning
40 (mini)	50%	50%	100%	4.5	12.5
53 (midi)	50%	50%	100%	4.25	12
75 (conventional)	55%	45%	100%	4	11.5
120 (articulated)	60%	40%	100%	2	11.5

Table 20.11 provides a summary of vehicle-cost estimation based on technology types and location of manufacturer. However, these costs could be significantly underestimated, particularly in the case of Africa, which has limited proximate vehicle-manufacturing capability, high financing costs, and high duties and value-added taxes.

Table 20.11. Vehicle costs for standard 12 meter bus

Vehicle type	Purchase cost (US$)	Percentage
Diesel	Baseline range of $200,000 to $600,000; depends on where the vehicle is manufactured and if it is high-floor or low-floor	-
CNG, LPG buses	$20,000 to $150,000 more than a comparable standard diesel bus	5-50% more than diesel
Hybrid-electric buses	$100,000 to $220,000 more than a comparable standard diesel bus	33-72% more than diesel
Fuel-cell buses	$800,000+ more than a comparable standard diesel bus	400+% more than diesel

Sources: Adapted from IEA, 2002, p. 200; EESI; NBRTI; FTA; EMBARQ; BYD Brazil; and publictransport.about.com

Determining an aggregate cost might be difficult, considering there are several determining factors involved. However, it is advisable for BRT project managers to communicate with local vehicle manufacturers throughout the process, as this will allow for a comparison of all price options pertinent to vehicle choice.

In practical terms, a joint work effort will be required between system operational design and the business plan. An iterative process will help to find an optimal vehicle technology solution that both meets a high-level of customer comfort as well as achieves cost-effectiveness.

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VOLUME VI

Infrastructure

Volume 6 provides detailed guidance on the physical infrastructure that are required of a BRT system as well as their management and costs. Depending on the context of the corridor for the project, the roadway may need to be altered to accommodate dedicated BRT lanes.

Additionally, there are a number of station configurations specific to varying widths and rider demand. Plus the station and terminal designs need consideration in order to provide a comfortable, functional, and easy boarding and alighting process for customers.

At each intersection there are potential conflicts with motor vehicles, cyclists, pedestrians, and other users of the road, and in order for BRT vehicles to maintain a high frequency, the traffic signals will need to be created or retrofitted with transit signal priority to give preference to the BRT.

The vehicles themselves need to be stored, repaired, and deployed from depots, which require careful planning in order to best fit and arrange the vehicles spatially.

Finally, the control center should be planned carefully in order to have oversight and the potential to adapt to changing traffic conditions and respond to a wide variety of emergencies.

21. Infrastructure Management and Costing

The objective of this chapter is to provide an overview of the infrastructure design process required to deliver a BRT corridor and its associated infrastructure components. The chapter first describes the infrastructure components that make up a BRT system, and then describes the infrastructure design process. Finally, the chapter deals with the calculation of design and construction costs for the various infrastructure elements using an infrastructure cost calculator. The cost of maintaining the infrastructure can be assessed by means of an infrastructure maintenance cost calculator (as detailed in Section 21.4.2), whereby life-cycle costing of infrastructure elements or materials can be evaluated.

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21.1 Infrastructure Components

> *"A person should design the way he makes a living around how he wishes to make a life."*
>
> — Charlie Byrd, jazz musician, 1925–1999

The physical design of the BRT system begins to give the project a tangible substance that better allows all stakeholders to properly envision the final product. This process also allows the planning team to better estimate the actual capital costs expected for the project.

Infrastructure consists of not only the roadwork that forms the busway, but also a range of other components, such as:

- Roadway and station configuration;
- Intersection and signal treatments;
- Station and terminal design;
- Depots and intermediate parking areas;
- Control center.

Additionally, thought will need to be given to:

- Multi-modal integration pedestrian and bicycle integration;
- Universal accessibility;
- Urban design and land use.

Connection to public utilities, discussed in Chapter 23: Roadway Design, might also play a part in the infrastructure design process.

The design and engineering of these components is dependent on several key factors including cost, functional attributes, and aesthetics. There is no one correct solution to infrastructure design. However, the elements of *The BRT Standard* indicate an initial starting place for design considerations. The physical design and engineering of the system must be done in concert with the operational design and service plan chosen in Chapters 5: Corridor and Network Development and Chapter 6: Service Planning. The corridor selected, expected capacities, and service options all influence the physical design.

The initial stage in the infrastructure design process is to develop a conceptual design framework for the system. At this point in the process, the physical location and initial designs are completed for the various infrastructure elements, based upon inputs from previous demand modeling and the operational study. An initial cost analysis can then be performed to determine the feasibility of the proposed design. Finally, once the conceptual design has been thoroughly evaluated and approved, preliminary and detailed engineering designs can proceed.

21.2 Infrastructure Design Process

> *"The designer has an obligation to provide an appropriate conceptual model for the way that the device works. It doesn't have to be completely accurate but it has to be sufficiently accurate that it will help in both the learning of the operation and also dealing with novel situations."*
>
> — Don Norman, scientist and psychologist, 1935–

The design of the infrastructure takes place in three basic stages, though in practice it is often more of an evolutionary process. In the first stage, conceptual designs will be developed based on the emerging service plan. The second and third stages—the preliminary and detailed engineering design follow once the conceptual study and the initial cost estimates warrant a commitment toward a particular design. Thus, for each infrastructure component discussed in this section (e.g., bus lanes, stations, terminals, etc.), the planning team will first complete a conceptual study prior to moving towards more detailed engineering plans and specifications. Most of the conceptual design issues are addressed in the operations chapters. This chapter provides additional detail to the physical design process necessary to complete the conceptual design. Preliminary and detailed engineering will follow general engineering practice.

21.2.1 Conceptual Design

The infrastructure conceptual design should provide a sufficient level of detail so that decision makers may properly evaluate the cost, functionality, and aesthetics of the proposed system.

Even for a basic conceptual design, a considerable knowledge of the corridors will be required. A full audit and inspection of each corridor segment will allow the design team to understand the nuances of the corridor as well as identify the most problematic areas. It is also critical to know which services will operate on the corridor, as well as projected target yearly ridership on each route (Chapter 6: Service Planning). This will be a major factor in determining infrastructure sizing and accommodation of routes that may enter and exit the corridor at various locations.

Particular attention should be given to intersections and proposed station locations.

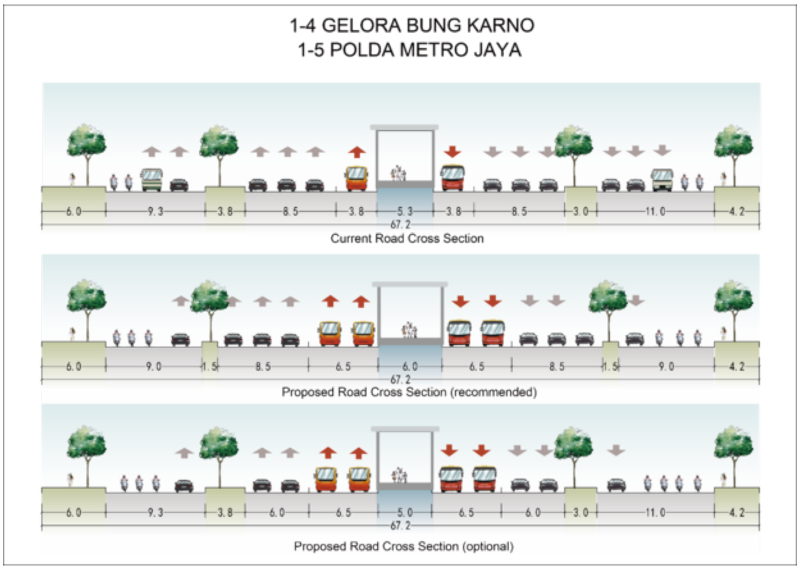

Figure 21.1. Conceptual layout and cross section of a median BRT in Jakarta, Indonesia, to illustrate the insertion of dedicated infrastructure within a corridor. *ITDP.*

Figure 21.2. Early rendering of the proposed Guangzhou, China, BRT system (top), and photo showing the rendering being used for outreach purposes during the BRT construction (middle). The bottom photo shows ITDP's BRT station rendering on display at the Yichang BRT construction site in May 2014. *ITDP*

Figure 21.3. Early rendering of the proposed Guangzhou, China, BRT system (top), and photo showing the rendering being used for outreach purposes during the BRT construction (middle). The bottom photo shows ITDP's BRT station rendering on display at the Yichang BRT construction site in May 2014. *ITDP*

Once the conceptual stage is completed, it will be possible to develop fairly accurate artistic renderings of the system infrastructure. These initial renderings will help decision makers and interested parties begin to visualize the system. Figures 21.2 and 21.3 show an artistic impression for the Guangzhou, China, BRT system.

Renderings can also be an important part of simulation videos that give decision-makers a fairly realistic idea of the proposed system. Renderings for the proposed Johannesburg, South Africa, Rea Vaya system helped secure necessary political support (Figure 21.4).

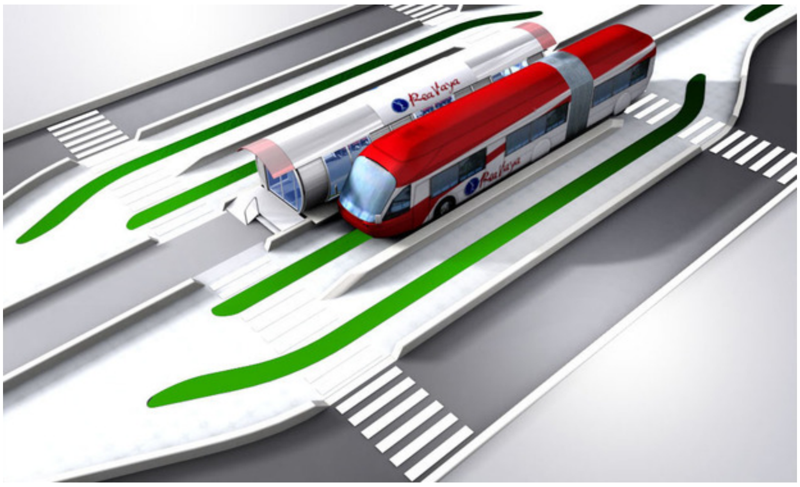

Figure 21.4. Rendering for the proposed Johannesburg Rea Vaya system. *City of Johannesburg.*

Figure 21.5. Photo of the existing federal highway in Kuala Lumpur, Malaysia *ITDP.*

Figure 21.6. Rendering of a proposed BRT station along the same highway *ITDP*

Likewise, early renderings in Bogotá helped communicate the project to a range of stakeholders, including the general public. It is critical, however, that these renderings be presented as accurately as possible.

Figure 21.7. This early rendering of the Bogotá system closely matches the ultimate shape and form of the actual system. *TransMilenio SA.*

The contracting of the design consultants can take on several different forms. In some cases, the design is carried out by one firm while the ultimate construction is to be done by another firm. This option avoids any problems with conflicts of interest between the design and construction work. For example, if the design and construction firm are one and the same, then there could be a tendency to choose designs that minimize construction costs. However, such a design may not be optimal from an operational perspective. If multiple firms are contracted, for example, for design, service planning, and construction, all should be in frequent communication to ensure the alignment of system objectives. Ideally one lead firm should carry out the detailed design as well as guide the actual implementation by all system subcontractors.

Combining the design and construction work into a single contract, though, does hold some advantages. With a single firm undertaking both these tasks, there is a greater degree of continuity between the design and construction. The single contract can also ensure a greater degree of responsibility in delivering the project.

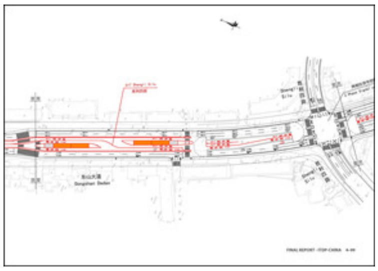

Figure 21.8. ITDP China's preliminary design drawing for a BRT station, intersection, and roadway in Yichang, China. *ITDP and the Guangzhou Municipal Engineering Design & Research Institute.*

21.2.2 Preliminary and Detailed Design

Once a conceptual design is completed and initial cost estimations are within an acceptable range, then a preliminary (followed by a more detailed) design process can begin. The detailed engineering design and specifications will be the basis for the actual construction work. The detailed design will also permit construction firms to make more accurate cost estimates within the construction bid process.

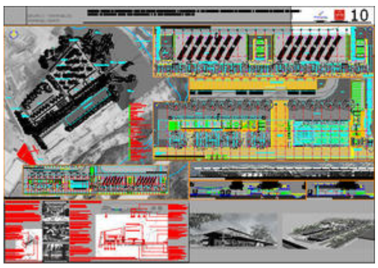

Figure 21.9. An AutoCAD drawing of the North Terminal of the Barranquilla, Colombia, system. *Municipality of Barranquilla.*

It is during the preliminary design phase where public comment is often sought and is useful to the project. At the preliminary design phase, the conceptual design is being tested for robustness and input from the local community and local municipal officials must be sought to refine the layout and design, discussed in detail in Chapter 10: Public Participation. Once the preliminary design phase is complete, changes to the layout and design concept are counterproductive, as this leads to expensive redesign and abortive effort.

Given the topographical changes throughout any corridor, each section of roadway will have its own unique design. Detailed drawings generated from software such as AutoCAD will be required along each segment. Other drawings will begin to provide some of the more precise dimensional and structural details that will later be transformed into highly detailed engineering drawings. Figures 21.8 and 21.9 are examples of these types of drawings.

The bulk of detailed design terminates with the completion of the final construction drawings, project specifications, tender documentation (including conditions of contract), and full bill of quantities (with a complete capital cost estimate). The design firm, if different from the construction firm, should play a leading role during construction to ensure that contractors follow the designs, and to react to myriad contingencies and circumstances arising during construction.

21.3 Project Management of the Design Process

> *"Everyone designs who devises courses of action aimed at changing existing situations into preferred ones."*
>
> — Herbert Simon, political scientist, 1916-2001

21.3.1 Structure of the Design Team

For the roadwork and other predominantly civil-engineering components of the design, the design team is likely to be headed up by a civil-engineering firm with BRT design expertise. The team will require input from geotechnical, pavement, geometric, utility, structural, and traffic engineers, as well as urban designers and landscape architects.

For the building work components of the design, the design team is likely to be led by a project manager. The design team would include architects for station design (see Chapter 25: Stations) and quantity surveyors, who would work in association with geometric, pavement, electrical, mechanical, and structural engineers as required.

Other specialist designers may be required on an ad-hoc basis, such as universal access specialists (see Chapter 30: Universal Access), non-motorized transit specialists (see Chapter 29: Pedestrian Integration and Chapter 31: Bicycle and Pedicab Integration), surveyors, etc., and will need to be brought in at the appropriate time to provide the necessary input into the design.

21.3.2 Design Management Tools and Resources

BRT systems are designed and planned by a team of professionals from different disciplines, each contributing a component of the designs for the final implementation product. It is, therefore, essential to manage the integration of the design input on a regular basis in order to achieve the required implementation deadlines.

Once each member of the professional team has been appointed, it is useful to distribute an organizational chart, or organogram, indicating the various responsibilities and work streams (Figure 21.10). Although each sub-team or work group will focus on the delivery of a specific design, the targeted delivery of all the components of the full system can be coordinated through various tools and resources.

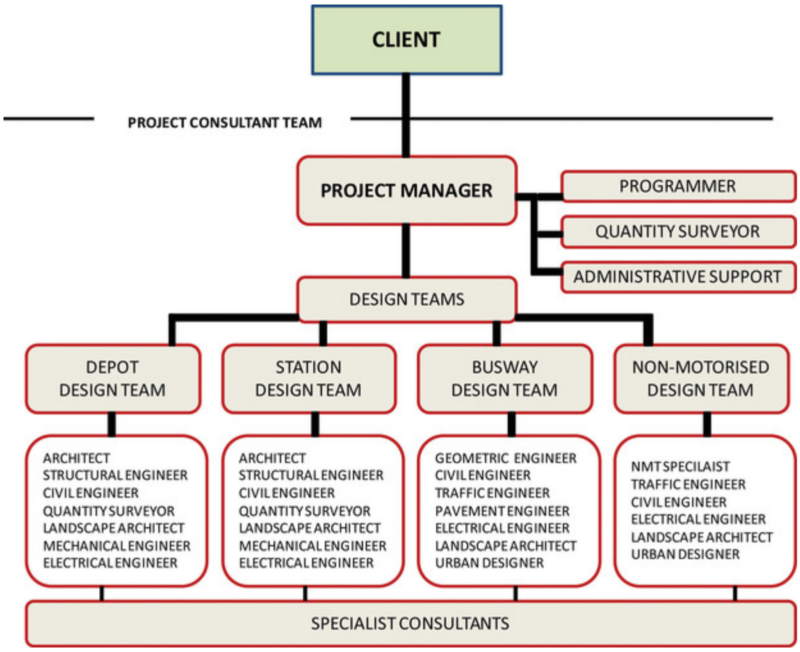

Figure 21.10. Sample organogram of a professional design team. *HHO Africa.*

The appointed project manager will distribute a coordinated schedule of project deliverables for both the individual work streams and the larger design team. This schedule of deliverables will take into consideration the complexity and time required for each design element, thereby managing key deliverables in the context of the infrastructure implementation schedule and the required system start-up dates. Various software options are available to assist in the management of design-project deliverables.

Coordination meetings are also extremely important, particularly if multiple parties are working on the design of distinct elements. Changes in one design element may have significant impacts on other elements. The project manager must be knowledgeable of the overall infrastructure project to be able to foresee impacts across disciplines and to facilitate coordination.

Design review meetings can also be a place where the system manager signs off on designs prepared by the various work streams. These meetings gain value from contributions by the project managers, various infrastructure designers, the system operational team, the systems planning team, the system financial team, and representatives from the various work streams. Once initial decisions have been made, a broader public consultation may be helpful. Such wide representation and contributions are required for the delivery of a coordinated and consistent design product, as well as for public support, for the entire system.

Design audits should occur during the preliminary and detailed design phases to ensure that the final designs are consistent with the original concept, while being flexible to potential evolution and adaptation of the design. The final BRT system will have an optimal design if selective site visits are used to assist in designing local applications with knowledge of international best practice from operational BRT systems. (Refer to ITDP's *BRT Standard*)

21.3.3 Timelines

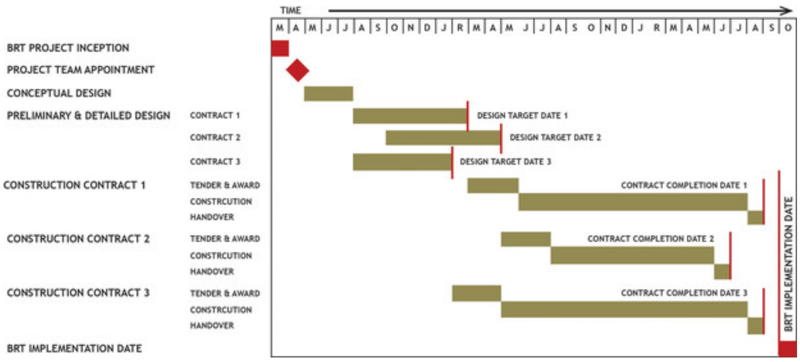

Figure 21.11. Sample timeline for a typical BRT system design and construction. *HHO Africa.*

A timeline for the design process starts with an understanding of the required implementation date of the planned BRT system; the program is calculated from that date, taking into full consideration local procurement legislation and policies that may structure a design and implementation program (Figure 21.11). A matrix of individual design target dates will assist in coordinating the various detailed aspects of the infrastructure design. Several software options are available to draw such a matrix and link it with the required procurement and implementation timelines.

A design program matrix is often used to manage a multiphase process and program, or a design process for an incremental rollout of implementation for a BRT system. This last option may be the most common choice for managing the design program, as it would, in most instances, be unrealistic to build an entire BRT network in a single brief period.

In exceptional examples where the project implementation is linked with a predetermined date, such as the start of a mega-event, the construction-tendering process could occur at preliminary designs only. Detailed designs and construction drawings can then be completed during the statutory infrastructure-procurement period, thereby reducing the project timeline significantly. This, however, is risky. Generally, if construction bidding is happening during the preliminary design phase, a maximum of 25 percent variance between the bid and the actual project budget is permitted. Design and implementation periods can be condensed even more by dividing the required product into separate contracts of similar complexity or construction time, which could be implemented simultaneously. This approach will then require the careful management of several design process timelines, as each serves separate construction procurement and implementation schedules, while still adhering to the final implementation date of the BRT system.

Examples of condensed design timelines may, however, result in cost variations against which the benefits of the shortened implementation program must be weighed.

21.4 Infrastructure Costing

"You and I come by road or rail, but economists travel on infrastructure."

— Margaret Thatcher, former UK Prime Minister, 1925–2013

Infrastructure capital costs can consist of both construction costs and any related land or property acquisition costs. Based on the preferred design characteristics, in conjunction with the size of the initial phase of the project, a city can determine if the capital cost estimates are in line with realistic financial resources. Several iterations of physical designs and service planning are likely before finding a balance between system cost and system performance.

21.4.1 Costing Techniques

The limited number of BRT systems to date, combined with the lack of a shared costing database, makes local estimations of infrastructure costs difficult. However, there are a few options for developing an initial estimate of infrastructure costs. These options include developing estimates based on:

- Costs from BRT systems in other cities, with adjustments based on local design and macroeconomic factors;
- Similar past projects in similar areas of the municipality. Such projects could include road expansion efforts and previous bus-improvement measures;
- Informal discussions with local contractors and engineering trade associations;
- Survey work by consultants, which may incorporate all of the above estimation techniques;
- Comparisons of cost projections against actual costs of other projects.

Yichang BRT Project Investment Cost Estimates

Project Name： Yichang BRT Asian Development Bank loan Project Preparatory Technical Assistance (PPTA)

Sequence	Items	Cost Estimates Unit: ten thousand (CNY)					Techno-Economic Indicator			Proportion(%)	Subtotal
		Municipal Engineering	Equipment	Installation	others	Total	Unit	quantity	Unit Value Index (CNY)		USD
	Part 1: Infrastructure Engineering	**66659.98**	**12796.75**	**6386.25**		**85842.98**	**km**	**13.300**	**50120286**	**57.79**	**$ 136,258,698**
I	Road Engineering	40200.92				40200.92	km	13.300	30226256	27.08	$ 63,810,984
II	Bridge Engineering	2640.00				2640.00	km	13.300	1984962	1.78	$ 4,190,476
III	Drainage Works	9750.00				9750.00	km	13	7500000	6.56	$ 15,476,190
IV	Greenery	1304.50				1304.50				0.88	$ 2,070,635
V	Street lights			2128.00		2128.00	km	13.300	1600000	1.43	$ 3,377,778
VI	Traffic Engineering (Traffic sign, road marking, traffic signals and controllers)	2146.36	1700.00	2300.00		6146.36	km	13.000	3500000	4.14	$ 9,756,127
VII	BRT Station and Architecture Engineering	8040.00				8040.00	station	67	1200000	5.41	$ 12,761,905
VIII	BRT Station power supply and lighting		2278.00	402.00		2680.00	station	67	400000	1.80	$ 4,253,968
IX	BRT Operation and Intelligent Dispatching System		7118.75	1256.25		8375.00	station	67	1250000	5.64	$ 13,293,651
X	BRT Control Centre mechanical and electrical engineering (including display and software and hardware)		1700.00	300.00		2000.00				1.35	$ 3,174,603
XI	Public Bicycle System	500.00				500.00	station	25	200000	0.34	$ 793,651
XII	BRT Corridor Traffic Safety and NMT Improvement work	2078.20				2078.20				1.40	$ 3,298,730

Figure 21.12. A simplified budget for Yichang, China's BRT demonstrates a sample cost breakdown. A complete budget can be found in Appendix B. *ITDP.*

21.4.2 BRT Cost Calculator

Based on cost data from existing developing-nation BRT systems and inputs from BRT experts, a BRT cost calculator has been developed to give cities an initial estimation of infrastructure costs. Actual costing will depend much on local conditions and circumstances. However, the BRT cost calculator is useful in alerting project developers to the costing items that should be considered in planning a system. The BRT cost calculator is based on 2011 costs in U.S. dollars, so construction cost escalation, exchange rate variation, and other financial factors should be taken into account when utilizing this tool. The actual cost calculator can be accessed on the ITDP website and Appendix B at the end of this guide.

In order to demonstrate infrastructure costing, we provide an example of a preliminary budget prepared for a hypothetical BRT system. Using the infrastructure-maintenance section of the cost calculator, costing is estimated for a hypothetical Phase I project of fifty kilometers of trunk infrastructure.

The methodology utilized assesses the anticipated maintenance costs associated with each infrastructure element over a thirty-year period, and then yields an average annual maintenance cost for the system.

Typically, maintenance for the first year after completion of the construction contract is undertaken by the contractor as part of its defects-liability period. Thereafter, the local municipality (or BRT entity) will need to maintain the infrastructure for the duration of the project.

The objective of the cost calculator is to provide designers and decision makers with an idea of maintenance costs that can be expected once a system is built. The calculator can assist with the choice of materials for construction, as it takes into account life-cycle costs.

Table 21.1 summarizes the subtotals from each of the maintenance costing categories. The total infrastructure maintenance budget projected for this hypothetical project for a thirty-year period comes to approximately US$180 million, which equates to approximately US$6 million per annum (or 1.4 percent of total construction costs) and US$120 thousand per kilometer of trunk services. Note that these costs are based on interviews conducted with professionals involved in infrastructure maintenance in the Cape Town, South Africa, municipal area. The percentages utilized are best estimates of the potential maintenance costs of the different infrastructural components of a BRT system. Actual costs may vary widely from region to region.

Table 21.1. Summary of System Infrastructure Maintenance Costs (Phase I Project of 50 kilometers)

BRT Infrastructure Elements	Total Maintenance Costs (US$) for 30 year Period	Average Annual Maintenance Costs (US$)	Average Annual Maintenance Costs (US$)/Busway km	Total Maintenance Costs (US$) for 30 year Period/ Total Construction Cost	Average Annual Maintenance Costs (US$)/ Total Construction Cost
Trunk busway infrastructure	$112,700,115	$3,756,671	$75,133	62%	2.07%
Trunk stations	$32,115,567	$1,070,519	$21,410	40%	1.33%
Integration	$10,208,626	$340,288	$6,806	22%	0.73%
Feeder/kerbside services	$14,850,025	$495,001	$9,900	30%	1.00%
Terminals, depots, and other	$11,280,106	$376,004	$7,520	15%	0.51%
TOTAL	**$181,154,439**	**$6,038,481**	**$120,770**	**42%**	**1.40%**

21.4.3 Value Engineering Process

A value engineering process is in essence an assessment of the design to determine whether there are more cost-effective ways of achieving the operational objectives using lower-cost infrastructure elements or alternative designs.

Value engineering can also take place during the preliminary and detailed design stages. Here the value engineering process takes the assessment deeper to interrogate whether there are more cost-effective materials or elements that can be used to minimize overall cost, with minimal reduction in quality (Figure 21.13). Life-cycle costing of materials form a major part of value engineering.

Once a portion of infrastructure is constructed, a value engineering exercise could be undertaken to input lessons learned from the construction phase into how costs could be reduced in future phases of the BRT project. These could include construction methods, proven new technologies, the use of smaller BRT vehicles to minimize pavement loadings, etc.

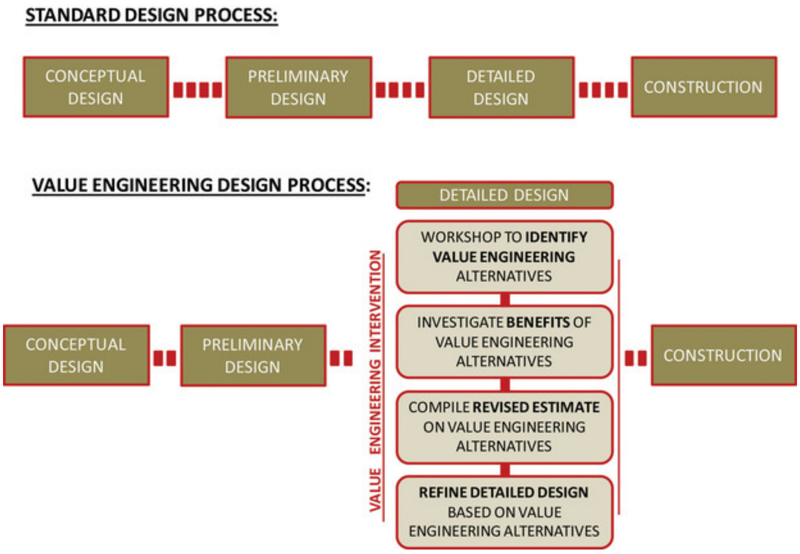

Figure 21.13. Standard- and value-design engineering process flow diagrams. *HHO Africa.*

21.4.4 Capital Cost and Operating Cost Options

In most BRT systems, the distinction between capital costs and operating costs is important from the standpoint of public versus private investment. The public sector generally provides the capital investment just as it typically funds roadways for private automobiles. Many BRT systems utilize private operators to cover operating costs, and thus such operators obtain access to revenues from fare collection. Some costs, such as vehicles and fare collection equipment, do not automatically fall into either category, and thus the assignment of these costs can depend on local circumstances (see also Chapter 17: Finance Plan).

There are circumstances when some elements of the BRT system may be strategically moved between capital and operational cost categories (Figure 21.13). Some systems have room for higher fare levels and may prefer to reduce their capital borrowing for the initial system infrastructure. In such instances, putting some elements of equipment into the operating cost category can make sense. For example, Bogotá required the private firm with the fare collection concession to include the electronic turnstiles and smart cards as part of the operational bid. The private fare collection firm thus reduces the cost of this infrastructure through its share of the fare revenue. In effect, the concessioned firm is acting as a financing agent for the particular piece of infrastructure.

Figure 21.14. Fare gates in Quito, Ecuador. Cost items like vehicles and fare equipment could be listed as either capital or operating costs. Shifting all or part of these expenses to one category or another will impact the affordability of fares and the amount of infrastructure investment required. *Lloyd Wright.*

There are instances when some elements of the BRT system may be strategically moved between capital and operational cost categories. Typically, this situation arises when fare affordability in lower-income countries becomes a significant issue. Since the cost of vehicles and fare collection equipment will likely not be appreciably different between a low-income and middle-income nation, the costs of such equipment can put significant pressure on total operating costs in low-income nations. Thus, moving some of these costs to the capital cost category can help permit reasonable fare levels without the need for operating subsidies. However, all aspects of this decision must be weighed carefully, because placing bus procurement with the public sector sometimes results in higher vehicle costs. In most cases, vehicles will cost less if they are procured by the private sector. A more detailed description of this can be found in Chapter 16: Vehicle Operator Contracting.

Moving equipment purchases to the capital cost category can bring with it some unintended consequences. In general, it is best to have the companies utilizing the equipment to pay for it and to maintain it. Companies operating buses that they do not own will tend to not maintain the vehicles properly. Public procurement of equipment can result in many misplaced incentives. A compromise is for the public sector to share costs with the private sector. For example, the public sector may provide 50 percent of the vehicle cost while the private firm must pay off the other 50 percent through fare revenues. In this way, the private firm still has an incentive to properly maintain the vehicle, but the reduced cost means that pressure on cost recovery is lessened.

In general, it is always best for the private sector to purchase its own vehicles, based on the well-defined specifications developed by the public sector. However, in some instances with low-income nations, it may be necessary to transfer some of the vehicle purchase costs to the capital cost category in order to achieve an affordable customer fare (as was done in Mexico City, along the Insurgentes corridor). It is feasible to transfer the burden of the initial investment from private to public hands and to maintain the efficiency of the private sector. As an alternative to direct public investment in equipment, such as vehicles and fare equipment, the public sector could provide special-condition loans or tax incentives that will reduce the impact of the investment on cash flow and will not get the public sector involved in the actual purchasing process. The key element is to select financial options that will allow the city to achieve affordable fares, maximizing the respective resources and capabilities of both the public and private actors.

21.4.5 Land and Property Acquisition

One of the most variable cost items when comparing different BRT systems is the level of land and property acquisition required, especially along the road at stations and terminals due to the greater land requirement.

In instances where property purchases are necessary, infrastructure costs can quickly skyrocket. Infrastructure costs on Bogotá's TransMilenio system jumped from approximately US$5.3 million per kilometer in Phase I to as high as US$15.9 million per kilometer in Phase II. Much of this increase was due to the much greater need for land purchases in the second phase. In Phase I of TransMilenio, approximately 600 plots were purchased. In Phase II, the municipality purchased approximately 4,000 plots (Figure 21.13).

Figure 21.15. Land and property expropriation in Phase II of TransMilenio greatly increased the overall capital investment. *Carlos Pardo.*

Resettlement can have major impacts on livelihoods. While the homes of residents may be able to be replaced elsewhere—ideally nearby—the livelihoods of residents may be much harder to directly replace due to their reliance on a particular location.

Some characteristics of a well-designed property-purchase program include:

- Clarity in the procedures;
- Transparency and openness of the process;
- Timeliness in processing and timeliness in resolving conflicts;
- An overriding sense of fairness in the process.

The World Bank has developed a set of recommended procedures for compulsory purchase programs in infrastructure projects. Likewise, Bogotá has developed a similar process to fairly deal with property purchases required by the expanding TransMilenio system.

21.5 Appendix A: Bogotá's Land Acquisition Process

The following steps outline the process Bogotá developed for land acquisition:

1. Design adjustments should be undertaken to minimize land acquisition, even if this implies reducing the number of mixed traffic lanes.
2. Determine the property-ownership history of any required properties.
3. Survey the actual activities and socioeconomic conditions of existing occupants, in order to define a baseline for potential financial compensation.
4. Assess the property value through independent appraisers to compensate the commercial value of the plots. If only the property tax registrar is used, properties may be significantly undervalued, which may prompt litigation and delays in the purchase process.
5. Estimate the required compensation based on the current property conditions. Also include a value for potential impacts on sales during the relocation process.
6. Offer assistance in searching for relocation options. This assistance should be particularly directed toward any low-income families and other vulnerable groups that are being displaced.

7. Provide a complete and well-documented compensation offer for the displaced inhabitants. It is helpful to include a down payment at this stage to help move the transaction toward completion.
8. Provide a fast-track process to complete the transaction documents and issue the down payment. Failure to promptly deliver promised documentation and payments will undermine public confidence in the process and lead to less cooperation in future acquisitions.
9. If the offer is declined due to the amount of the proposed compensation, then both parties can agree to an arbitration process to determine the correct value. If the parties do not agree to arbitration, then eminent domain law will be applied. A subsequent legal proceeding will take place in which the property owner(s) can present the case against expropriation or argue for a different compensation value.

The key to any land-expropriation process is the quality of the property appraisal and the clarity of the procedures to be undertaken. The entire process should be designed to account for all eventualities and to provide timely actions at each step. Delays due to legal proceedings not only increase the project-implementation speed, but also increase construction costs dramatically.

21.6 Appendix B: BRT Infrastructure Maintenance Cost Calculator

Table 21.2. BRT Infrastructure Maintenance Cost Calculator

BRT Infrastructure Maintenance Cost Calculator (DRAFT)			
Number of dedicated trunk busway	50		
Item	**Capex Investment**	**% of Capex Investment to Maintain for 30 yrs**	**Cost (for 30 yr period)**
Trunk busway infrastructure			
Busway construction (assumes 1 lane in each direction)			
Asphalt busway / concrete at stations - very heavy (ES 100)	$ -	30%	$ -
Asphalt busway / concrete at stations - heavy (ES 30)	$ 60 000 000	30%	$ 18 000 000
CRC, busways and station areas - Very heavy (280mm)	$ -	10%	$ -
CRC, busways and station areas - Heavy (200 mm)	$ -	10%	$ -
Virtual lanes (asphalt) (one lane)	$ -	30%	$ -
Queue jump lanes (asphalt) (one lane)	$ -	30%	$ -
Passing lanes at stations for express services (assumes 1 lane in each direction)			
Asphalt - very heavy (ES 100)	$ -	30%	$ -
Asphalt - heavy (ES 30)	$ -	30%	$ -
CRC - Very heavy (280mm)	$ -	10%	$ -
CRC - Heavy (200 mm)	$ -	10%	$ -
Accommodation of Construction Traffic (Per busway km)			
Accommodation of construction traffic - Separate busway	$ -		$ -
Accommodation of construction traffic - Median Busway	$ 4 750 000		$ -
Roadway reconfiguration			
Widen to Replace General Traffic Lanes (per 3.5m lane)	$ -		$ -
Widen to Replace General Traffic Lanes (per 4.5m lane)	$ -		$ -
Intersection Strengthening & Colourisation			
Extra Over Cost for Strengthening Asphalt - Small Int	$ 9 000 000	30%	$ 2 700 000
Extra Over Cost for Strengthening Asphalt - Large Int	$ 5 500 000	30%	$ 1 650 000
Colourised at intersections only - Tyregrip	$ -	600%	$ -
Colourised at intersections only - UTFC	$ -	600%	$ -
Intersection Signalisation			
Signalisation of Single Carriageway Intersections	$ 4 875 000	100%	$ 4 875 000
Signalisation of Dual Carriageway Intersections	$ 2 250 000	100%	$ 2 250 000
Audio/Tactile Push Buttons	$ -	100%	$ -
Intersection Over/Underpasses			
Over/ underpasses (2 lanes)	$ 7 500 000	10%	$ 750 000
Lane separators (assumes in each direction)			
Painted line	$ -	1500%	$ -
10 cm wide asphalt Rumble strip	$ -	30%	$ -
10 cm wide delineator kerbs	$ 3 250 000	15%	$ 487 500
50 cm separator wall	$ -	15%	$ -
Busway colouration (assumes a lane in each direction)			
No colourisation	$ -	0%	$ -
Busway with fully colourised lanes - CRC Very Heavy	$ -	0%	$ -
Busway with fully colourised lanes - CRC Heavy	$ -	0%	$ -
Busway with fully colourised lanes - Tyregrip on Asphalt	$ -	600%	$ -
Busway with fully colourised lanes - UTFC on Asphalt	$ 7 500 000	600%	$ 45 000 000
Virtual lane - Tyregrip on Asphalt (one lane)	$ -	600%	$ -
Virtual Lane - UTFC on Asphalt (one lane)	$ -	600%	$ -
Queue Jump lane - Tyregrip on Asphalt (one lane)	$ -	600%	$ -
Queue Jump Lane - UTFC on Asphalt (one lane)	$ -	600%	$ -
Landscaping			
None	$ -	0%	$ -
Small Areas plus irrigation	$ 1 875 000	30%	$ 562 500
Large Areas with trees plus irrigation	$ 4 375 000	30%	$ 1 312 500
Property acquisition for buslanes			
No property acquisition	$ -	0%	$ -
Property acquisition for buslanes	$ -	0%	$ -
Services			
No services impacts	$ -	0%	$ -
Services protection /relocation plus ducting	$ 3 750 000	0%	$ -
Street Lights	$ -	25%	$ -
Telecommunication Ducts and manholes	$ 3 750 000	5%	$ 187 500
Electronic Surveilance (Poles, busway cameras and fibre)	$ 7 500 000	5%	$ 375 000
Bikeway			
Bikeway: one each side (asphalt - 2.5m wide)	$ -	20%	$ -
Bikeway: on one side only (asphalt - 3m wide)	$ -	20%	$ -
		Sub-total	**$ 78 150 000**
Contingency Sum	15%		**$ 11 722 500**
		Trunk busway sub-total	**$ 89 872 500**
Design and Supervision Fees	10%		**$ 8 987 250**
		Trunk busway sub-total	**$ 98 859 750**
Value Added Taxes	14%		**$ 13 840 365**
		Trunk busway sub-total	**$ 112 700 115**
Busway km's	**50**	**Trunk busway per busway km**	**$ 2 254 002**

Table 21.3. BRT Infrastructure Maintenance Cost Calculator

BRT Infrastructure Maintenance Cost Calculator (DRAFT)			
Number of dedicated trunk busway	50		
Item	**Capex Investment**	**% of Capex Investment to Maintain for 30 yrs**	**Cost (for 30 yr period)**
Trunk busway infrastructure			
Busway construction (assumes 1 lane in each direction)			
Asphalt busway / concrete at stations - very heavy (ES 100)	$ -	30%	$ -
Asphalt busway / concrete at stations - heavy (ES 30)	$ 60 000 000	30%	$ 18 000 000
CRC, busways and station areas - Very heavy (280mm)	$ -	10%	$ -
CRC, busways and station areas - Heavy (200 mm)	$ -	10%	$ -
Virtual lanes (asphalt) (one lane)	$ -	30%	$ -
Queue jump lanes (asphalt) (one lane)	$ -	30%	$ -
Passing lanes at stations for express services (assumes 1 lane in each direction)			
Asphalt - very heavy (ES 100)	$ -	30%	$ -
Asphalt - heavy (ES 30)	$ -	30%	$ -
CRC - Very heavy (280mm)	$ -	10%	$ -
CRC - Heavy (200 mm)	$ -	10%	$ -
Accommodation of Construction Traffic (Per busway km)			
Accommodation of construction traffic - Separate busway	$ -		$ -
Accommodation of construction traffic - Median Busway	$ 4 750 000		$ -
Roadway reconfiguration			
Widen to Replace General Traffic Lanes (per 3.5m lane)	$ -		$ -
Widen to Replace General Traffic Lanes (per 4.5m lane)	$ -		$ -
Intersection Strengthening & Colourisation			
Extra Over Cost for Strengthening Asphalt - Small Int	$ 9 000 000	30%	$ 2 700 000
Extra Over Cost for Strengthening Asphalt - Large Int	$ 5 500 000	30%	$ 1 650 000
Colourised at intersections only - Tyregrip	$ -	600%	$ -
Colourised at intersections only - UTFC	$ -	600%	$ -
Intersection Signalisation			
Signalisation of Single Carriageway Intersections	$ 4 875 000	100%	$ 4 875 000
Signalisation of Dual Carriageway Intersections	$ 2 250 000	100%	$ 2 250 000
Audio/Tactile Push Buttons	$ -	100%	$ -
Intersection Over/Underpasses			
Over/ underpasses (2 lanes)	$ 7 500 000	10%	$ 750 000
Lane separators (assumes in each direction)			
Painted line	$ -	1500%	$ -
10 cm wide asphalt Rumble strip	$ -	30%	$ -
10 cm wide delineator kerbs	$ 3 250 000	15%	$ 487 500
50 cm separator wall	$ -	15%	$ -
Busway colouration (assumes a lane in each direction)			
No colourisation	$ -	0%	$ -
Busway with fully colourised lanes - CRC Very Heavy	$ -	0%	$ -
Busway with fully colourised lanes - CRC Heavy	$ -	0%	$ -
Busway with fully colourised lanes - Tyregrip on Asphalt	$ -	600%	$ -
Busway with fully colourised lanes - UTFC on Asphalt	$ 7 500 000	600%	$ 45 000 000
Virtual lane - Tyregrip on Asphalt (one lane)	$ -	600%	$ -
Virtual Lane - UTFC on Asphalt (one lane)	$ -	600%	$ -
Queue Jump lane - Tyregrip on Asphalt (one lane)	$ -	600%	$ -
Queue Jump Lane - UTFC on Asphalt (one lane)	$ -	600%	$ -
Landscaping			
None	$ -	0%	$ -
Small Areas plus irrigation	$ 1 875 000	30%	$ 562 500
Large Areas with trees plus irrigation	$ 4 375 000	30%	$ 1 312 500
Property acquisition for buslanes			
No property acquisition	$ -	0%	$ -
Property acquisition for buslanes	$ -	0%	$ -
Services			
No services impacts	$ -	0%	$ -
Services protection /relocation plus ducting	$ 3 750 000	0%	$ -
Street Lights	$ -	25%	$ -
Telecommunication Ducts and manholes	$ 3 750 000	5%	$ 187 500
Electronic Surveilance (Poles, busway cameras and fibre)	$ 7 500 000	5%	$ 375 000
Bikeway			
Bikeway: one each side (asphalt - 2.5m wide)	$ -	20%	$ -
Bikeway: on one side only (asphalt - 3m wide)	$ -	20%	$ -
		Sub-total	**$ 78 150 000**
Contingency Sum	15%		**$ 11 722 500**
		Trunk busway sub-total	**$ 89 872 500**
Design and Supervision Fees	10%		**$ 8 987 250**
		Trunk busway sub-total	**$ 98 859 750**
Value Added Taxes	14%		**$ 13 840 365**
		Trunk busway sub-total	**$ 112 700 115**
Busway km's	50	**Trunk busway per busway km**	**$ 2 254 002**

Table 21.4. BRT Infrastructure Maintenance Cost Calculator

Trunk stations					
Station/Stop construction					
Stop with full shelter (one in each direction)	$	-	30%	$	-
3.5 metre wide median platforms	$	45 000 000	30%	$	13 500 000
5 metre wide median platfoms	$	-	30%	$	-
Intermediate transfer stations/Interchange Stations					
No intermediate transfer stations	$	-	30%	$	-
Intermediate transfer station trunk platforms	$	4 000 000	30%	$	1 200 000
Interchange station trunk platforms	$	-	30%	$	-
Linking building between median platfoms	$	500 000	30%	$	150 000
Closed feeder platform in median	$	-	30%	$	-
Operator buildings/facilities	$	250 000	30%	$	75 000
Property acquisition for stations					
No property acquisition	$	-	0%	$	-
Property acquistion for station	$	-	0%	$	-
Station air conditioning					
No air conditioning	$	-	0%	$	-
Full air conditioning	$	-	150%	$	-
Heating	$	-	75%	$	-
Mist generators	$	500 000	150%	$	750 000
Automatic sliding doors at boarding interface					
No sliding doors	$	-	0%	$	-
Sliding doors	$	4 000 000	150%	$	6 000 000
Toilet facilities					
No toilet facilities	$	-	0%	$	-
Toilet facilities at stations	$	-	20%	$	-
Maps and information					
No maps or information	$	-		$	-
Maps at trunk stations	$	-		$	-
Maps at stations and in vehicles	$	600 000		$	-
Information kiosks	$	150 000	30%	$	45 000
Recycling receptacles at stations					
None	$	-	0%	$	-
Receptacles at station	$	100 000	150%	$	150 000
Station Security					
No security measures	$	-		$	-
Security call box	$	-		$	-
Security cameras	$	800 000	50%	$	400 000
			Sub-total	**$**	**22 270 000**
Contingency Sum		15%		**$**	**3 340 500**
			Trunk Station sub-total	**$**	**25 610 500**
Design and Supervision Fees		10%		**$**	**2 561 050**
			Trunk Station sub-total	**$**	**28 171 550**
Value Added Taxes		14%		**$**	**3 944 017**
			Trunk Station sub-total	**$**	**32 115 567**
Busway km's		**50**	**Trunk Station per busway km**	**$**	**642 311**

Integration					
Pedestrian crossings					
Pedestrian crosswalk with midblock signal	$	2 560 000	100%	$	2 560 000
Pedestrian bridge	$	12 500 000	10%	$	1 250 000
Pedestrian access ways					
No upgrades to station access for pedestrians	$	-	0%	$	-
Improvements to pedestrian access ways	$	11 500 000	20%	$	2 300 000
Bicycle integration					
No bicycle integration	$	-	0%	$	-
Bicycle parking at stations	$	400 000	10%	$	40 000
Metered taxi integration					
No taxi integration	$	-	0%	$	-
Formal metered taxi stands at stations	$	1 200 000	10%	$	120 000
Park-and-ride facilities					
No park-and-ride facilities	$	-	0%	$	-
Kiss-and-ride facilities only	$	90 000	10%	$	9 000
Park-and-ride facility (open lot parking per 100 bays)	$	4 000 000	20%	$	800 000
Park-and-ride facility (multi-level parking per 100 bays)	$	-	15%	$	-
Property acquisition for park-and-ride facilities					
No property acquisition	$	-		$	-
Acquisition of property for park-and-ride site	$	-		$	-
			Sub-total	**$**	**7 079 000**
Contingency Sum		15%		**$**	**1 061 850**
			Integration sub-total	**$**	**8 140 850**
Design and Supervision Fees		10%		**$**	**814 085**
			Integration sub-total	**$**	**8 954 935**
Value Added Taxes		14%		**$**	**1 253 691**
			Integration sub-total	**$**	**10 208 626**
Busway km's		**50**	**Integration per busway km**	**$**	**204 173**

Table 21.5. BRT Infrastructure Maintenance Cost Calculator

Trunk stations					
Station/Stop construction					
Stop with full shelter (one in each direction)	$	-	30%	$	-
3.5 metre wide median platforms	$	45 000 000	30%	$	13 500 000
5 metre wide median platfoms	$	-	30%	$	-
Intermediate transfer stations/Interchange Stations					
No intermediate transfer stations	$	-	30%	$	-
Intermediate transfer station trunk platforms	$	4 000 000	30%	$	1 200 000
Interchange station trunk platforms	$	-	30%	$	-
Linking building between median platfoms	$	500 000	30%	$	150 000
Closed feeder platform in median	$	-	30%	$	-
Operator buildings/facilities	$	250 000	30%	$	75 000
Property acquisition for stations					
No property acquisition	$	-	0%	$	-
Property acquistion for station	$	-	0%	$	-
Station air conditioning					
No air conditioning	$	-	0%	$	-
Full air conditioning	$	-	150%	$	-
Heating	$	-	75%	$	-
Mist generators	$	500 000	150%	$	750 000
Automatic sliding doors at boarding interface					
No sliding doors	$	-	0%	$	-
Sliding doors	$	4 000 000	150%	$	6 000 000
Toilet facilities					
No toilet facilities	$	-	0%	$	-
Toilet facilities at stations	$	-	20%	$	-
Maps and information					
No maps or information	$	-		$	-
Maps at trunk stations	$	-		$	-
Maps at stations and in vehicles	$	600 000		$	-
Information kiosks	$	150 000	30%	$	45 000
Recycling receptacles at stations					
None	$	-	0%	$	-
Receptacles at station	$	100 000	150%	$	150 000
Station Security					
No security measures	$	-		$	-
Security call box	$	-		$	-
Security cameras	$	800 000	50%	$	400 000
			Sub-total	**$**	**22 270 000**
Contingency Sum		15%		**$**	**3 340 500**
			Trunk Station sub-total	**$**	**25 610 500**
Design and Supervision Fees		10%		**$**	**2 561 050**
			Trunk Station sub-total	**$**	**28 171 550**
Value Added Taxes		14%		**$**	**3 944 017**
			Trunk Station sub-total	**$**	**32 115 567**
Busway km's		**50**	**Trunk Station per busway km**	**$**	**642 311**
Integration					
Pedestrian crossings					
Pedestrian crosswalk with midblock signal	$	2 560 000	100%	$	2 560 000
Pedestrian bridge	$	12 500 000	10%	$	1 250 000
Pedestrian access ways					
No upgrades to station access for pedestrians	$	-	0%	$	-
Improvements to pedestrian access ways	$	11 500 000	20%	$	2 300 000
Bicycle integration					
No bicycle integration	$	-	0%	$	-
Bicycle parking at stations	$	400 000	10%	$	40 000
Metered taxi integration					
No taxi integration	$	-	0%	$	-
Formal metered taxi stands at stations	$	1 200 000	10%	$	120 000
Park-and-ride facilities					
No park-and-ride facilities	$	-	0%	$	-
Kiss-and-ride facilities only	$	90 000	10%	$	9 000
Park-and-ride facility (open lot parking per 100 bays)	$	4 000 000	20%	$	800 000
Park-and-ride facility (multi-level parking per 100 bays)	$	-	15%	$	-
Property acquisition for park-and-ride facilities					
No property acquisition	$	-		$	-
Acquisition of property for park-and-ride site	$	-		$	-
			Sub-total	**$**	**7 079 000**
Contingency Sum		15%		**$**	**1 061 850**
			Integration sub-total	**$**	**8 140 850**
Design and Supervision Fees		10%		**$**	**814 085**
			Integration sub-total	**$**	**8 954 935**
Value Added Taxes		14%		**$**	**1 253 691**
			Integration sub-total	**$**	**10 208 626**
Busway km's		**50**	**Integration per busway km**	**$**	**204 173**

Table 21.6. BRT Infrastructure Maintenance Cost Calculator

Feeder / kerbside services					
Feeder system road infrastructure					
No feeder improvements	$	-		$	-
Platform & Associated Roadworks	$	3 600 000	30%	$	1 080 000
Provision of virtual lanes (asphalt)(per lane)	$	10 400 000	30%	$	3 120 000
Provision of queue jump lanes (asphalt)(per lane)	$	10 400 000	30%	$	3 120 000
Colourisation of virtual/queue jump lanes (per lane) - Tyregrip	$	-	30%	$	-
Colourisation of virtual/queue jump lanes (per lane) -UTFC	$	3 000 000	30%	$	900 000
Lane separators					
Painted line	$	18 000	1500%	$	270 000
10 cm wide asphalt Rumble strip	$	-	30%	$	-
10 cm wide delineator kerbs	$	1 300 000	15%	$	195 000
Feeder stations					
Station sign post only	$	-	30%	$	-
Totem only	$	375 000	30%	$	112 500
Cantilever shelter	$	1 500 000	30%	$	450 000
Full Shelter	$	2 250 000	30%	$	675 000
Double full shelter	$	1 250 000	30%	$	375 000
Closed feeder station	$	-	30%	$	-
Station maps					
No maps or information	$	-		$	-
Maps at feeder stops	$	400 000		$	-
			Sub-total	**$**	**10 297 500**
Contingency Sum		15%		**$**	**1 544 625**
			Feeder Facilities sub-total	**$**	**11 842 125**
Design and Supervision Fees		10%		**$**	**1 184 213**
			Feeder Facilities sub-total	**$**	**13 026 338**
Value Added Taxes		14%		**$**	**1 823 687**
			Feeder Facilities sub-total	**$**	**14 850 025**
Busway km's		**50**	**Feeder Facilities per busway km**	**$**	**297 000**
Terminals, depots, and other					
Construction of terminals					
No terminal facilities	$	-		$	-
Terminal facility	$	8 000 000	30%	$	2 400 000
Toilet facilities at terminals					
No toilet facilities	$	-		$	-
Toilet facilities	$	50 000	20%	$	10 000
Construction of depots					
No public depots	$	-		$	-
Depot (200 buses)	$	18 000 000	30%	$	5 400 000
Information kiosks					
No information kiosks	$	-		$	-
Information kiosks	$	60 000	20%	$	12 000
Property acquisition					
No property acquistion	$	-		$	-
Terminal sites	$	12 500 000		$	-
Depot (200 buses)	$	12 500 000		$	-
			Sub-total	**$**	**7 822 000**
Contingency Sum		15%		**$**	**1 173 300**
			Terminals/Depots sub-total	**$**	**8 995 300**
Design and Supervision Fees		10%		**$**	**899 530**
			Terminals/Depots sub-total	**$**	**9 894 830**
Value Added Taxes		14%		**$**	**1 385 276**
			Terminals/Depots sub-total	**$**	**11 280 106**
Busway km's		**50**	**Terminals/Depots per busway km**	**$**	**225 602**

21.7 Appendix C: Yichang BRT Project Investment Cost Estimates

Table 21.7. Yichangs BRT Preliminary Design, ITDP, January 2013

Yichang BRT Project Investment Cost Estimates

Project Name： Yichang BRT Asian Development Bank loan Project Preparatory Technical Assistance (PPTA)

Sequence	Items	Cost Estimates Unit: ten thousand (CNY)）					Techno-Economic Indicator			Proportion(%)	Subtotal
		Municipal Engineering	Euipment	Installation	others	Total	Unit	quantity	Unit Value Index（CNY）		USD
	Part 1: Infrastructure Engineering	**66659.98**	**12796.75**	**6386.25**		**85842.98**	**km**	**13.300**	**50120286**	**57.79**	**$ 13,625,870**
I	**Road Engineering**	40200.92				40200.92	km	13.300	30226256	27.06	$ 6,381,098
1	Earth and Rock	329.03				329.03	km	13.300	247391	0.22	$ 52,227
1.1	Excavation	125.94				125.94	m^3	35983	35	0.08	
1.2	Fill	203.09				203.09	m^3	47231	43	0.14	
2	Mix Traffic Lanes	19184.10				19184.10	km	13.300	14424135	12.91	$ 3,045,095
2.1	AC-13C Asphalt(4cm)	3095.54				3095.54	m^2	325846	95	2.08	
2.2	AC-20C Asphalt(6cm）	3584.31				3584.31	m^2	325846	110	2.41	
2.3	TAB-25 Asphalt Macadam(8cm)	5351.05				5351.05	m^2	290818	184	3.60	
2.4	5% Graded Broken Stone(35cm)	2544.07				2544.07	m^2	314083	81	1.71	
2.5	4% Graded Broken Stone(15cm)	1005.07				1005.07	m^2	314083	32	0.68	
2.6	Graded Broken Stone(15cm)	1036.26				1036.26	m^2	398563	26	0.70	
2.7	Geogrid	105.08				105.08	m^2	35028	30	0.07	
2.8	C25 Black Color Reinforced Concrete(25cm)	1689.60				1689.60	m^2	84480	200	1.14	
2.9	C25 Concrete(25cm)	55.04				55.04	m^2	3336	165	0.04	
2.10	4% Graded Broken Stone(40cm)	718.08				718.08	m^2	84480	85	0.48	
3	Bike Lane	2786.43				2786.43	km	13.300	2095060	1.88	$ 442,290
3.1	6-8mm C25 Red Color Concrete(3cm)	1888.40				1888.40	m^2	83929	225	1.27	
3.2	10mm C25 Concrete(7cm)	562.32				562.32	m^2	83929	67	0.38	
3.3	Sand Filter(3cm)	41.96				41.96	m^2	83929	5	0.03	
3.4	5% Cement Stabilized Macadam (15cm)	293.75				293.75	m^2	83929	35	0.20	
4	Sidewalk and Curb	8895.84				8895.84	km	13.300	6688602	5.99	$ 1,412,038
4.1	Green Flag Brick (5cm)	4354.50				4354.50	m^2	136078	320	2.93	
4.2	C20 Concrete(15cm)	925.33				925.33	m^2	136078	68	0.62	
4.3	Graded Broken Stone(10cm)	231.33				231.33	m^2	136078	17	0.16	
4.4	Artificial Granite Curbs for Central Greenery(100*20*60cm)	957.65				957.65	m	53203	180	0.64	
4.5	Artificial Granite Curbs(100*18*35cm)	957.65				957.65	m	79804	120	0.64	
4.6	Concrete Gutter Apron Curb(100*25*12cm)	718.24				718.24	m	79804	90	0.48	
4.7	Sidewalk Gutter Apron(100*15*15cm)	269.02				269.02	m	38432	70	0.18	
4.8	Gutter apron around Plant pit(120*10*16cm)	338.20				338.20	m	30745	110	0.23	
4.9	C20 Concrete Backstand	89.78				89.78	m^3	1995	450	0.06	
4.10	Artificial Granite Bollard	54.14				54.14	个	1867	290	0.04	
5	Retaining Wall	423.57				423.57	km	13.300	318474	0.29	$ 67,233
5.1	Stone Masonry Wall	423.57				423.57	m^3	12102	350	0.29	
6	Demolition	2199.76				2199.76	km	13.300	1653955	1.48	$ 349,168
6.1	Demolition Exsiting Concrete Road Pavement	2160.27				2160.27	m^2	288036	75	1.45	
6.2	Demolition Exsiting Asphalt Road Pavement	39.49				39.49	m^2	43879	9	0.03	

Table 21.8. Yichangs BRT Preliminary Design, ITDP, January 2013

Yichang BRT Project Investment Cost Estimates

Project Name： Yichang BRT Asian Development Bank loan Project Preparatory Technical Assistance (PPTA)

Sequence	Items	Cost Estimates Unit: ten thousand (CNY)）					Techno-Economic Indicator			Proportion(%)	Subtotal
		Municipal Engineering	Euipment	Installation	others	Total	Unit	quantity	Unit Value Index（CNY）		USD
7	BRT Station Area Road Engineering in Yemingzhu Road	4841.60				4841.60				3.26	$ 768,508
8	BRT Station Area Road Engineering in Yixing Av.	1540.59				1540.59				1.04	$ 244,538
II	**Bridge Engineering**	2640.00				2640.00	km	13.300	1984962	1.78	$ 419,048
1	One Small Bridge on Road	392.00				392.00	m^2	800	4900	0.26	
2	Mideum Bridge on Road	848.00				848.00	m^2	1600	5300	0.57	
3	Footbridge	1400.00				1400.00	pic	4	3500000	0.94	
III	**Drainage Works**	9750.00				9750.00	km	13	7500000	6.56	$ 1,547,619
IV	**Greenery**	1304.50				1304.50				0.88	$ 207,063
1	Remove the Exsiting Trees	355.96				355.96	m^2	29663	120	0.24	
2	Newly Planted Greenery and Trees	283.14				283.14	m^2	7451	380	0.19	
3	Trees on BRT Lane Greenery Divider Belts	665.40				665.40	pic	4436	1500	0.45	
V	**Street lights**			2128.00		2128.00	km	13.300	1600000	1.43	$ 337,778
VI	**Traffic Engineering(Traffic sign, road marking, traffic signals and controllers)**	2146.36	1700.00	2300.00		6146.36	km	13.000	3500000	4.14	$ 975,613
1	Traffic Engineering			2000.00		2000.00				1.35	
2	Signal, Controller, Traffic vilation system etc.		1700.00	300.00		2000.00				1.35	
3	Temporary Traffic Engineering During Construction	1000.00				1000.00				0.67	
4	Optical Fiber (10 years rental from Operators)	1146.36				1146.36				0.77	
VII	**BRT Station and Architecture Engineering**	8040.00				8040.00	station	67	1200000	5.41	$ 1,276,190
VIII	**BRT Station power supply and lighting**		2278.00	402.00		2680.00	station	67	400000	1.80	$ 425,397
IX	**BRT Operation and Interlligent Dispatching System**		7118.75	1256.25		8375.00	station	67	1250000	5.64	$ 1,329,365
1	Operation and Dispatching System		2278.00	402.00		2680.00	station	67	400000	1.80	
2	AFC system		1993.25	351.75		2345.00	station	67	350000	1.58	
3	Automatic door		2847.50	502.50		3350.00	station	67	500000	2.26	
X	**BRT Control Center mechanical and electrical engineering （Including display and software and hardware)**		1700.00	300.00		2000.00				1.35	$ 317,460
XI	**Public Bicycle System**	500.00				500.00	station	25	200000	0.34	$ 79,365
XII	**BRT Corridor Traffic Safety and NMT Improvement work**	2078.20				2078.20				1.40	$ 329,873
1	Pedestrian Safe Crossing and Island	64.00				64.00	location	32	20000	0.04	
2	Bollard	2014.20				2014.20				1.36	
2.1	Bollard on Walkway to Keep Car out	1887.96				1887.96	pic	31466	600	1.27	
2.2	Bollard in Pedstrian Island	15.36				15.36	pic	256	600	0.01	
2.3	Bollard on Station Entrance Access Island	54.72				54.72	pic	912	600	0.04	
2.4	Bollard on Traffic Canalization Island	56.16				56.16	pic	936	600	0.04	
	Part 2: Associated cost				**8308.65**	**8308.65**	**km**	**13.300**	**6247105.00**	**5.59**	**$ 1,318,833**
1	Construction land Use Fee				2838.29	2838.29				1.91	
①	Resettlement				2838.29	2838.29				1.91	
2	Construction Management Fee				2012.19	2012.19				1.35	

Table 21.9. Yichangs BRT Preliminary Design, ITDP, January 2013

Yichang BRT Project Investment Cost Estimates

Project Name: Yichang BRT Asian Development Bank loan Project Preparatory Technical Assistance (PPTA)

Sequence	Items	Cost Estimates Unit: ten thousand (CNY))					Techno-Economic Indicator			Proportion(%)	Subtotal USD
		Municipal Engineering	Euipment	Installation	others	Total	Unit	quantity	Unit Value Index（CNY）		
①	Implementation Management Fee				683.00	683.00				0.46	
②	Project Supervision Fee				1329.19	1329.19				0.89	
3	Preparation Phase Research and Study				115.16	115.16				0.08	
①	Project Proposal Report				40.78	40.78				0.03	
②	Project Feasibility Study				74.38	74.38				0.05	
4	EIA Report				25.20	25.20				0.02	
5	Engineering Geological Exploration,Survey and Design				3149.04	3149.04				2.12	
①	Engineering Design				2086.69	2086.69				1.40	
②	Project Investment and Budget Calculation for Detailed Engineering Design Phase				208.67	208.67				0.14	
③	As-built Drawings				166.94	166.94				0.11	
④	Geological Exploration,Survey				686.74	686.74				0.46	
6	Project Insurance				0.00	0.00				0.00	
7	Detailed Engineering Design Examination				2.30	2.30				0.00	
8	Bidding agent service charge				85.65	85.65				0.06	
9	Bidding center service charge				3.22	3.22				0.00	
10	Labor Safety and Health Evaluation Fee				0.00	0.00				0.00	
11	Site preparation and temporary facility fee				0.00	0.00				0.00	
12	Underground pipeline detection fee				0.00	0.00				0.00	
13	Construction engineering cost consultation service charge				62.60	62.60				0.04	
①	Project Bill of quantities or examination				18.30	18.30				0.01	
②	Control price (standard base price) compilation				9.30	9.30				0.01	
③	The whole process of construction project cost control				35.00	35.00				0.02	
④	The final accounts of the completed project establishment or examination				0.00	0.00				0.00	
14	Soil and Water conservation facilities compensation				15.00	15.00				0.01	1.5 /m^2
	Subtotal 1 (Part 1 and Part 2)	**66659.98**	**12796.75**	**6386.25**	**8308.65**	**94151.63**				63.38	$ 14,944,703
Associated Project or Cost											
1	**Preparation cost**				**9415.16**	**9415.16**	**km**	**13.300**	**7079068.00**	**6.34**	$ 1,494,470
①	Basic Preparation cost				9415.16	9415.16	km	13.300	7079068.00	6.34	
2	**Vehicle Purchase**		**16000.00**			**16000.00**	**vehicle**	**200.000**	**800000.00**	**10.77**	$ 2,539,683
①	12m bus with doors on both sides		16000.00			16000.00	vehicle	200.00	800000.00	10.77	
3	Access Road Traffic Safety and NMT Improvement Work	**256.00**	**869.60**	**118.72**		**1244.32**					$ 197,511
①	Intersection Canalization and Traffic Signals		800.00	100.00		900.00		9.000			

Table 21.10. Yichangs BRT Preliminary Design, ITDP, January 2013

Yichang BRT Project Investment Cost Estimates

Project Name: Yichang BRT Asian Development Bank loan Project Preparatory Technical Assistance (PPTA)

Sequence	Items	Cost Estimates Unit: ten thousand (CNY))					Techno-Economic Indicator			Proportion(%)	Subtotal USD
		Municipal Engineering	Euipment	Installation	others	Total	Unit	quantity	Unit Value Index（CNY）		
②	Mid block Pedestrain Crossing	256.00				256.00	location	128.000			
③	Bollard on Mid block Pedestrain Island		60.00	18.72		78.72	pic	1312.000			
④	Passenger Signage(Wayfinding)		9.60			9.60	pic	64.000			
4	Greenway	2262.00				2262.00	Km	17.400			$ 359,048
5	Bridge(overpass channel) Reconstruciton on Yixing Av.	1317.60				1317.60	m^2	2160			$ 209,143
6	Footbridge Overpass Railway Reconstruciton on Yemingzhu Rd.	700.00				700.00	pic	1			$ 111,111
7	Road Engineering between station area, on Yemingzhu Road	11322.38				11322.38	km	4.345			$ 1,797,203
8	Road Engineering between station area, on Yixing AV.	5996.53				5996.53	km	3.600			$ 951,830
9	Road Engineering between station area, on Xiazhou Road	558.83				558.83	km	0.231			$ 88,703
10	Road Engineering between station area, on Sanxia Road	3213.94				3213.94	km	1.328			$ 510,149
11	Road Engineering between station area, on Ganghong Road	2369.55				2369.55	km	0.744			$ 376,119
	Total	**94656.81**	**29666.35**	**6504.97**	**17723.81**	**148551.94**				**100.00**	$ 23,579,673

Note: Upon the request from Yichang IA, the cost for Vehicle Purchase, Access Road Traffic Safety and NMT Improvement Work, Greenway, Road Engineering between station area on Yemingzhu Road, Sanxia, Ganghong, Xiazhou, and Yixing Road are not including into the BRT project budget, which we listed separately in Associated Project cost item. But the related road engineering around BRT station area are included in the part 1 cost.
Upon the request from IA, the budget doesn't include the pipeline works resettlement cost, the fiber cable communication system considering rental from operator for 10 years, or the resettlement cost provided by the Yichang IA.

22. Roadway and Station Configurations

"We will either find a way, or make one."

— Hannibal, military commander and politician, 247 BC–183 BC

Overview

Figure 22.1. Guangzhou, China, is a median-aligned busway configuration with split stations located along the outside of the busway. *ITDP.*

Creating optimal use of the available road reserve, or right-of-way, within a defined BRT corridor is the chief purpose of the design engineer (Figure 22.1). The first step to doing that is to create a conceptual design that is based on the sustainable transport hierarchy. First allocate space for walking trips, then cycling trips, then public transport trips, next service and freight trips, then taxi, then HOV, and finally the private car/motorcycle. While the rest of the chapter is about possible busway configurations, it is grounded upon the idea that pedestrian and cyclist access is paramount to a successful system. For more information about pedestrian and cyclist infrastructure design and integration, see Chapter 29: Pedestrian Integration and Chapter 31: Bicycle and Pedicab Integration.

To create the conceptual design, three frameworks need to be decided on:

1. Cross-section design and integration: Will there be parallel bike lanes along the corridor? What is the minimum walkway width that is to be used in the design? Here you may decide upon typologies based on existing right-of-way;
2. Busway configurations: Will the corridor be median aligned or run in one-way pairs? Different sections of the corridor may require different configurations. What type of separation will be used to protect the busway?
3. Station and terminal configurations: Will the stations in the corridor be center stations or split? This decision will affect or be a result of the decision about the bus. Center stations require doors on the opposite side from the curb. Will there be passing lanes at the stations? This is a function of availability of space on the road and the needs of the service plan.

Other things to consider include the placement and design of the depot(s) (see Chapter 26), intermediate parking terminals, where buses can park during the times when frequency is not as high, the control center (Chapter 27), and the intersection and signal control (Chapter 24).

This chapter begins with a discussion of cross-section components and the creation of conceptual design assumptions. It then discusses the roadway configurations that can be applied in various design environments. Thereafter, the station placement considerations and options are reviewed.

The objective of this chapter is to equip the design engineer with the tools required to optimally locate and lay out the BRT infrastructure for the proposed BRT system within a given road corridor.

Terminology

- Busway: also known as runway or running ways, this is the segregated lane in which the BRT vehicles operate.
- Sub-stop: also known as module, a sub-stop is the basic unit of the station where BRT vehicles dock and customers get on and off, consisting of one or more docking bays.
- Docking bay: also known as stopping bay, this is the area in a sub-stop where the BRT vehicles pull up to allow customers to board or alight.
- Transfer station: also can be known as an interchange station, this is a station where customers can transfer from one service or route to another within the BRT system.
- Platform: the raised area where customers board or alight the buses after they pull up to the docking bay at the sub-stop. It is also the place where customers wait for the next bus.

22.1 Cross-Section Design

> *"All architecture is shelter, all great architecture is the design of space that contains, cuddles, exalts, or stimulates the persons in that space."*
>
> — Philip Johnson, architect, 1906–2005

In the conceptual-design phase, the right-of-way is the first consideration as that is the boundary of where the BRT corridor will be designed. Once the boundaries of that are understood, you can start creating design assumptions to see where decisions need to be made due to space constraints.

Box 22.1. Standard Widths for Conceptual Design

Busway lane: 3.5 meters

Busway passing lane: 3.5 meters

Busway lane at station: 3 meters

Station: 5 meters

Barrier/curb separator: 0.5 meter

Mixed-traffic lanes: 3 meters

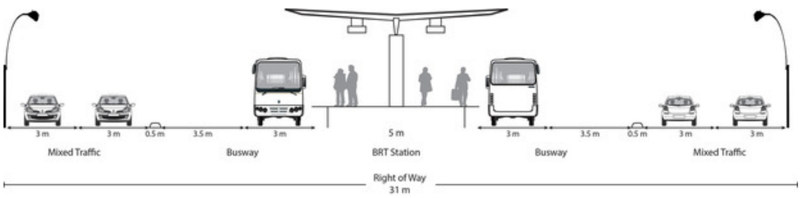

Figure 22.2. A conceptual design of a BRT corridor. *ITDP.*

The best BRT systems have used the opportunity of reconstructing the corridor for exclusive busways to invest in upgrading the environment for pedestrians and cyclists. This is partly to support sustainable transportation options, but it is also less of a cost burden to the system to have people arrive at the station by foot or bicycle than by a feeder bus. The easier it is for these customers to arrive at the stations, the more customers and the more revenue. Finally these improvements have been shown to help leverage economic development around the corridor.

Figure 22.3. Guangzhou BRT, China, with bike sharing, walkways, and segregated bike lanes along the BRT corridor. *ITDP.*

Customers need sidewalks to gain access to the system, and will gravitate toward the corridor and then walk along the route to access the nearest station. A minimum sidewalk width of 2 meters unobstructed (by trees, vendors, lighting poles, street furniture) should be considered, but where moderate to high pedestrian flows are predicted the width of the sidewalk should be increased to 2.5 to 3 meters (or wider), if the road reserve width exists. Where the pedestrian flows can be predicted along a sidewalk, the level of service of the sidewalk should be evaluated to ensure that the sidewalk is wide enough to accommodate the predicted flow.

Some of the best BRT systems in the world have included bicycle infrastructure along the corridor. Bogotá is home to Latin America's largest bicycle network, with some 376 kilometers of dedicated bike lanes. The new Orange Line BRT system in Los Angeles, the BRT corridor in Guangzhou, China, and many other new BRT corridors under development also have parallel bicycle facilities along the entire corridor.

Cyclists, like all travelers, seek the most direct and fastest way to reach their destination. If no cycling facilities are provided, the likelihood of bicyclists using the busway as a bikeway is fairly high, and very difficult to control. Finally, the inclusion of a bike lane can help mitigate the loss of a mixed-traffic lane, as some private automobile traffic could potentially shift to bicycle.

For all of these reasons, a plan to build segregated busways should also consider adding cycling facilities—this should be part of the cross-section conceptual design assumptions. *The BRT Standard* awards full points for bicycle lanes that are directly on the corridor, or parallel (but close) to the corridor.

The type of infrastructure depends on:

- The speed and intensity of the general traffic lanes;
- The type of cyclist activity anticipated within the corridor—i.e., recreation, commute, sport, or for student travel;
- The availability of road reserve width to accommodate bicycle lanes;
- The intensity of pedestrian traffic anticipated on the sidewalks.

The design assumptions for cycle lanes depends on the type:

- 2.0 meters for separate one-way bikeways, including space for a buffer area or separator;
- 3.0 meters for shared bikeways/sidewalks;
- 1.5 meters for marked, one-way bicycle lanes in the roadway or bike lanes;
- 1.5 meters for unmarked, one-way bicycle lanes in the roadway, indicated using signage.

If the bike lanes will be used by non-motorized three wheelers, 2.5 meters is recommended. For more detailed information see Chapter 31: Bicycle and Pedicab Integration. *The BRT Standard* awards more points for bike lanes that span the entirety of the corridor, and fewer points for bike lanes that exist in parts, but not all, of the system.

Figure 22.4. Separate bike lane and sidewalk along Bogota's Usme Corridor. *ITDP.*

Figure 22.5. Separate bike lane and sidewalk along Bogota's Usme Corridor. *Andre Frieslaar.*

Figure 22.6. Bike lanes along new BRT corridor in Bogotá, passing under the station. Image *ITDP.*

Figure 22.7. Bike lane alongside separate alignment busway in Hangzhou, China. Image *ITDP.*

In the conceptual design phase a decision about the type of separation between the busway and the mixed-traffic lanes needs to be taken. Key considerations include space, enforcement needs (i.e., where enforcement is strong, a less overtly physical separation is needed).

Rouen, France, has a semipermeable barrier between the busway and the mixed-traffic lane that allows private vehicles to encroach temporarily onto the busway in case of lane obstruction. This solution assumes a corridor has available right-of-way of at least 14 meters for vehicles, plus an appropriate amount of space for pedestrians. Additional space is also required in areas with stations, which likely require at least another 3 meters of width. This solution works in places where enforcement is strong.

Where enforcement is weak and encroachment of the busway is likely, impermeable barriers may be necessary between the general traffic lanes and the busway. This is especially needed when there is only one moving traffic lane adjacent to the busway since the temptation to encroach can be significant. Guayaquil, Ecuador, has done this successfully using an impermeable barrier or a raised curb to separate the bus lane from the mixed-traffic lanes. In Nantes, France, where encroachment is less of a problem, a permeable barrier (rumble strip) separates a single mixed-traffic lane from a busway.

In places where there is snow, a buffer around the busway may be needed for snow storage after plowing.

22.2 Roadway Configurations

> *"Many roads lead to the path, but basically there are only two: reason and practice."*
>
> — Bodhidharma, Buddhist monk, 6th century

The location of the segregated busway within a specific roadway is a design decision that offers more options than might be immediately apparent. Busway configuration, also known as alignment, is critical to achieving fast and efficient operations by minimizing the potential conflicts with turning cars, stopping taxis, and unloading delivery trucks. Because of this, *The BRT Standard* awards the highest points to those configurations that minimize those conflicts that happen at the curb the most: two-way busways in the central verge of the roadway, two-way busways that run adjacent to an edge condition like a waterfront, and bus-only corridors, like a transit mall. A two-way busway that runs on the side of a one-way street is awarded fewer points. The reason for the point drop is a concern for safety as pedestrians are unlikely to expect traffic to come from the opposite direction. One-way busways in the median of a one-way street are awarded even fewer points and one-way busways that run alongside the curb of a one-way street fewer still. Virtual lanes are awarded the least points.

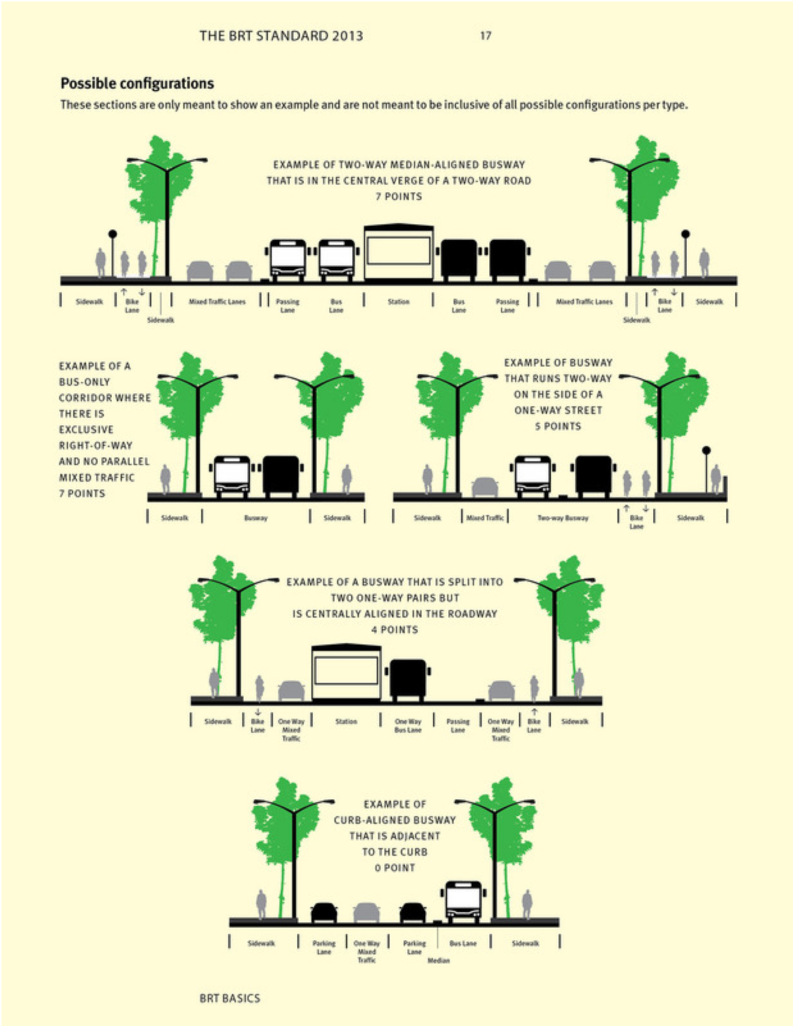

Figure 22.8. Examples of different BRT roadway configurations from The BRT Standard. *ITDP.*

A corridor may have multiple configurations over its length. Like many other design decisions associated with BRT, there is no one correct solution to roadway configuration. Much depends on the local circumstances. Johannesburg, South Africa, has a two-way median-aligned busway until it gets into the downtown where it splits into one-way, median-aligned busways running on one-way streets. Curitiba, Brazil, uses center lanes, both lanes on the side, and streets exclusively for BRT (Figures 22.9, 22.10, and 22.11). Curitiba essentially tailors the roadway configuration to the particular situation on the given road segment.

Figure 22.9. Curitiba utilizes a variety of roadway configurations. Each street's design depends on the local circumstances. *Lloyd Wright.*

Figure 22.12. TransJakarta utilizes buses with doorways on both sides of the vehicle in order to service both median and curbside stations. *ITDP.*

Figure 22.10. Curitiba utilizes a variety of roadway configurations. Each street's design depends on the local circumstances. *URBS and the Municipality of Curitiba.*

Figure 22.11. Curitiba utilizes a variety of roadway configurations. Each street's design depends on the local circumstances. *Lloyd Wright.*

Box 22.2. The Example of Dar es Salaam, Tanzania

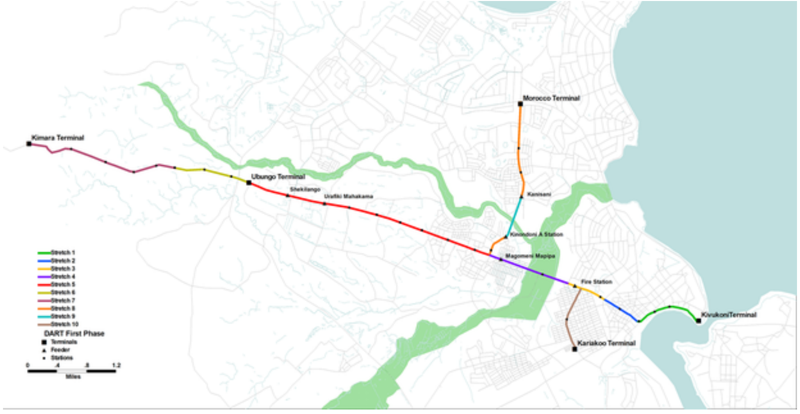

Figure 22.13. In the conceptual design for Dar es Salaam, the corridor was broken up into ten main typologies with different configurations based on unique conditions. *Logit.*

Stretch 1 is located along the waterfront and its typical cross sections varies from 25.5 meters at station locations to 21.5 meters in between stations. Its design characteristics include:

- Two 3.5-meter wide BRT lanes, one per direction;
- A 3.5-meter wide mixed-traffic lane in the southeast bound direction only;
- A 3.5-meter wide bikeway lane on the ocean side on the same road way level, separated from the vehicle lanes by concrete separators;
- A 3-meter pedestrian's boulevard will be provided on the ocean side;
- Retaining walls will be required in some parts where there is a steep slope of more than 2 meters and fills will be required along the coastline.

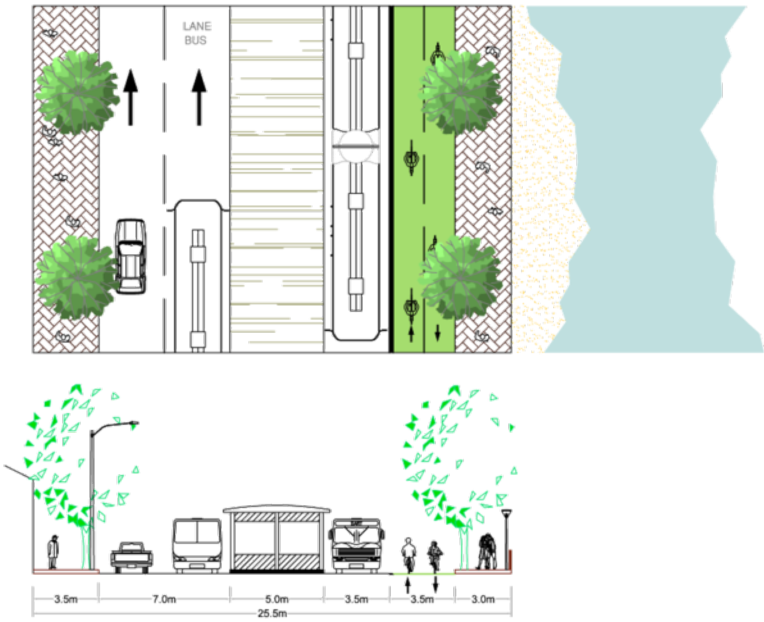

Figure 22.14. Plan and section view of Stretch 1 at a width of 25.5 meters. *Logit.*

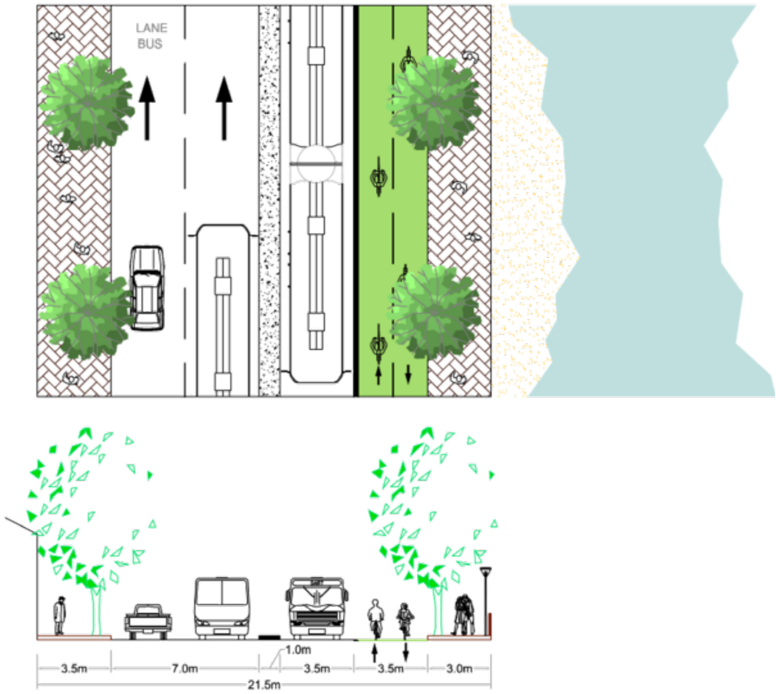

Figure 22.15. Plan and section view of Stretch 1 at a width of 21.5 meters. *Logit.*

In Stretch 5 (Figure 22.16 below), the cross section design varies from 49 meters at stations to 38.5 meters in between stations. The section characteristics include:

- 2.5-meter wide bikeway on both sides of the road;
- 4-meter sidewalks on both sides;
- 6.5-meter lanes per direction for mixed traffic on both sides;
- 7-meter lanes per direction for BRT vehicles at stations;
- 3.5-meter lane per direction for BRT vehicles between stations;
- 1-meter wide median separating the BRT vehicles;
- 1.5-meter wide planting strip between bikeway and mixed-traffic lanes.

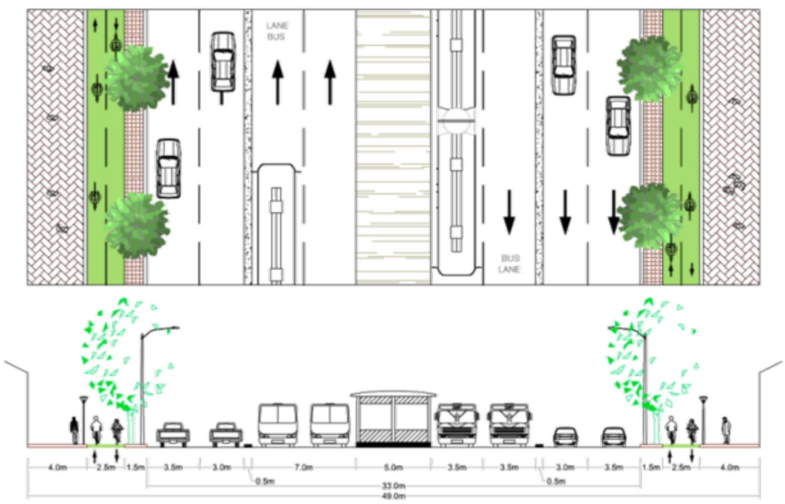

Figure 22.16. Plan and section view of Stretch 5 at a width of 49 meters. *Logit.*

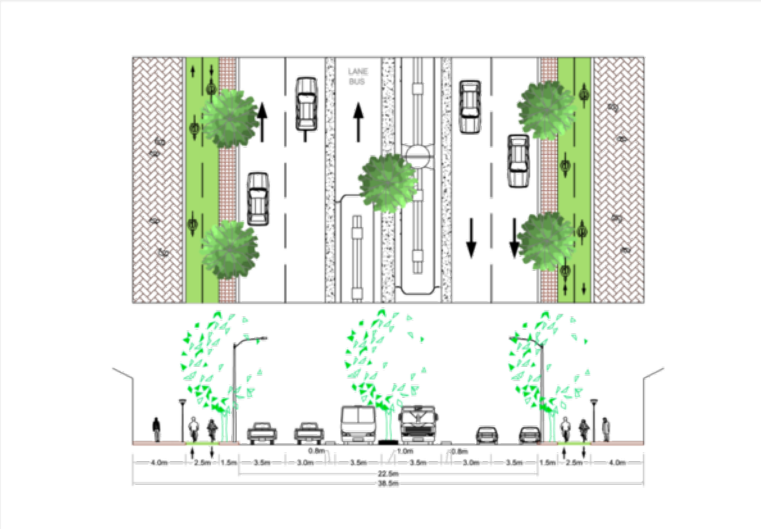

Figure 22.17. Plan and section view of Stretch 5 at a width of 38.5 meters. *Logit.*

Following are the typical configurations for BRT corridor design to consider in the conceptual design phase and that should become the basis for the detailed engineering.

Figure 22.18. Insertion of bus lane and station in a narrow space in Quito. *Andre Frieslaar.*

Box 22.3. Options for Narrow Roadways

Areas with narrow road widths, such as central business districts (CBDs) and historic centers, present many challenges to BRT developers (Figure 22.50). The density of activity and architectural nature of these areas may mean that less road space is available for a surface-based public transport system. At the same time, CBDs and historic centers are prime destinations for customers, and thus such areas should be included in the system's network. Without access to central destinations, the entire system becomes considerably less useful to the potential customer base.

In general, there are at least ten different solutions to designing BRT systems through an area with extremely narrow road widths:

1. Median busway and single mixed-traffic lane (e.g., Rouen, France);
2. Transit malls and transit-only corridors;
3. Split routes (two one-way services on parallel roads);
4. Virtual lanes;
5. Use of median space;
6. Road widening;
7. Grade separation;
8. Fixed guideway;
9. Single-lane operation or virtual lanes;
10. Staggered stations/elongated stations.

22.2.1 Median Busways

The most common option is to locate the busway in the center median or in the center two lanes (Figure 22.7). *The BRT Standard* awards full points for a median busway alignment. This is because the central verge of a roadway encounters fewer conflicts with turning vehicles than those closer to the curb, due to alleys, parking lots, etc. Additionally, while delivery vehicles and taxis generally require access to the curb, the central verge of the road usually remains free of such obstructions.

The median location also permits a central station to serve both busway directions. *The BRT Standard* awards full points under the "Center Stations" metric for a single station serving both directions of travel, allowing for easier transferring between directions or routes. A median station permits customers to select multiple routing options from a single station platform. A single station reduces infrastructure costs in comparison to the construction of separate stations for each direction. For more information about station configurations, see the next section.

Figure 22.19. A median busway in Bogotá with a single median station has become the standard for high-quality BRT systems. *ITDP.*

22.2.2 Curbside Busways

While it is typical to find conventional bus lanes at the curbside, it is rare for BRT to place the busway on the sides of the roadway. *The BRT Standard* awards no points for this configuration under the "Busway Alignment" metric, as curb lanes rarely function as intended. Curb lanes have conflicts with turning traffic, stopping taxis, delivery vehicles, and non-motorized traffic, greatly reducing the system's capacity. Achieving capacities of more than five thousand customers per hour per direction is quite difficult if turning vehicles frequently interfere with busway operations. Curbside busways create the potential for the entire busway to be stopped due to a single taxi picking up a customer, a policeman temporarily parking, an accident, or a turning vehicle trapped behind high pedestrian-crossing volumes (Figure 22.17).

Figure 22.20. One section of Lima, Peru's BRT, with a single lane for mixed traffic in one direction, and two lanes in the other direction. *ITDP.*

Figure 22.21. Curbside bus lanes often fail due to traffic congestion and poor enforcement (Hangzhou, China). *ITDP.*

Figure 22.22. Curbside bus lanes often fail due to traffic congestion and poor enforcement (New York City). *ITDP.*

Figure 22.23. In this image from Quito, Ecuador, the Trolé BRT vehicle operates in an "exclusive" curbside lane, but is blocked by merging traffic from a side street. A median busway would largely avoid these types of conflicts. *Lloyd Wright.*

22.2.3 Side-Aligned, Two-Way Busway Configuration

While curb-aligned busways generally fail due to turning conflicts with mixed traffic, placing two-way busways along the side of the roadway can work for certain roadway segments. If a roadway is bordered by green space (e.g., a large park), water (e.g., ocean, bay, lake, or river frontage), or open space, then there may be no turning conflicts for long distances, in which case side alignment may actually be preferable to median alignment. *The BRT Standard* awards the highest points under the "Busway Alignment" metric for side-aligned busways that are adjacent to such an edge condition. A key to choosing this type of alignment is the absence of access to development along a particular corridor edge, i.e., a park, an airport boundary wall, etc.

Where such an edge condition does not exist, it is still possible to consider other side-aligned options. Lima has implemented a two-lane, two-way busway adjacent to a two-lane, two-way general-traffic roadway (Figure 22.19). Intersections along a side-aligned busway can be problematic, but can be dealt with by using traffic signals and roundabouts.

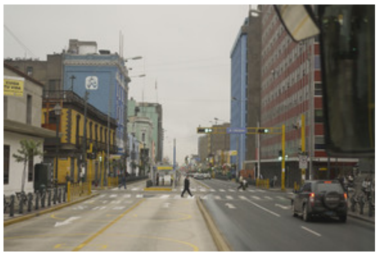

Figure 22.24. In this city-center location, Lima, Peru is able to segregate the busway to the side of an existing roadway. *ITDP.*

22.2.4 Fixed Guided Busways

Since a BRT vehicle is typically 2.6 meters wide, it is possible that a lane just slightly wider than this amount could suffice. Under normal operating conditions, a driver will require a road width of approximately 3.5 meters to safely maintain position within the lane, and 3 meters at the station, since the driver will slow down to pull adjacent to the boarding platform. However, if a vehicle is physically restrained by a guidance mechanism, then a lane width of 3 meters is possible.

Physical guidance systems are employed on BRT systems in Adelaide, Australia; Bradford, United Kingdom; Essen, Germany; Leeds, United Kingdom; and Nagoya, Japan. A side-mounted guidance wheel maintains the vehicle's position within the lane (Figures 22.21 and 22.22). A slight trench in the roadbed has also been used reasonably successfully in the Netherlands for short sections. Likewise, optical or magnetic guidance systems are also possible.

Figure 22.25. In this city-center location Curitiba, Brazil, is able to segregate the busway to the side of an existing railway. *ITDP.*

In instances when reducing lane width by approximately 0.9 meter is of great value, then a fixed-guideway system can be an option to consider. Guidance systems also provide other advantages, such as safer vehicle operation and higher operating speeds. The chief disadvantage is the added infrastructure cost associated with the side wheel and the guidance track. Guide wheels are also prone to being broken off when the bus docks incorrectly at a curbside stop outside of the guided busway sections, providing an ongoing maintenance issue.

Figure 22.26. Nagoya, Japan's elevated BRT line utilizes a mechanical guidance system to reduce the required roadway width. *Lloyd Wright.*

Figure 22.27. Nagoya, Japan's elevated BRT line utilizes a mechanical guidance system to reduce the required roadway width. *Lloyd Wright.*

Table 22.1. Advantages and Disadvantages of Guided Busway Systems

Advantages	Disadvantages
Higher speeds (reduced travel times) are achievable within safety standards	Increases busway construction costs considerably
Permits construction of narrower busway lanes	Increases vehicle costs
Contributes to a more permanent image of the busway	Reduces flexibility with regard to the type of vehicles that may utilize the busway
Allows construction of lanes without paving the center strip, which can be grassed to give "green" and softer appearance.	Speed advantages of guided busways are only realized when the distances between stations are quite significant
Self-enforcing as general traffic is unable to utilize the busway	Difficult for recovery vehicle to remove stranded bus from the guideway
Permanence of busway, as roadway cannot easily be opened to mixed-traffic operations	Ongoing maintenance of bus guidance wheels on bus front axle

Additionally, since busways do not require vehicle lane changes, some system developers have elected to not pave the center of the lane (Figure 22.23). The existence of earth or grass beneath the bus can help absorb engine noise; noise reductions of up to 40 percent have been reported using this technique.

Not paving the center of the lane is also an option that other busway developers are considering, even when roller guides are not being utilized. The paved strips for non-guided buses will likely be wider than the strips for guided buses, since non-guided buses will be subject to more variation in lateral movement. The feasibility of this approach and cost savings associated with not paving the center-lane area will depend on local construction costs and practices. In some instances, local contractors may not be well-versed in utilizing this construction technique. However, given that the paving of the busway represents perhaps the single-highest cost item in system infrastructure, any potential cost savings should be considered.

Figure 22.28. Not paving the center of the busway, like this example in Eugene, USA, may produce infrastructure cost savings as well as reduce operational noise. *Lane District Transit.*

In operating a vehicle along a guided busway, the driver does not actually have to steer the vehicle. The guideways prevent any turning movements, and thus the vehicle can technically be operated "hands-free" (Figure 22.24). In some systems, such as Nagoya, Japan, there are safety concerns at the point the BRT vehicle leaves the guideway. If for some reason the driver does not re-engage physical steering, a mishap may occur. Thus, in the case of Nagoya, a forced stop is made at the exit from the guideway in order to remind the driver to use physical steering once again (Figure 22.25).

Figure 22.29. The guideway allows for hands-free driving on the Nagoya-Yutorito Line. *Lloyd Wright.*

22.2.5 Grade-Separated Busways

Grade separation, where the BRT corridor either runs on an elevated roadway or underground, is an option within narrow right-of-way configurations, as well as an option at very busy intersections and roundabouts. Grade separation can also be an option to consider bypassing difficult terrain or water (Figure 22.26). Because it is so expensive to build grade separations, it is usually done in strategic locations where the separation greatly improves operations. Grade-separated busways, however, can

Figure 22.30. A stopping device at the end of the guideway ensures that the driver re-engages physical steering. *Lloyd Wright.*

also be the length of a corridor, like Expresso Tiradentes in São Paulo, which runs on an elevated roadway. A grade-separated busway receives maximum points under the "Busway Alignment" metric of *The BRT Standard,* since it is a fully exclusive right-of-way, completely separated from mixed traffic.

In all cases, the physical terrain and base materials must be considered for their engineering appropriateness for tunnels or elevated structures. High water tables or hard bedrock can make underpasses and tunnels impractical from a cost and engineering standpoint. Likewise, soft soils can significantly increase the cost of securely siting pillars for elevated structures. Thus, an engineering and cost-feasibility analysis should be conducted whenever grade separation is being considered as an option along certain BRT corridor segments.

In addition to being highly costly (up to five times the cost of at-grade infrastructure), elevated busways can cause visual impacts in a community, and can also serve to split up an urban area.

Figure 22.31. An elevated busway in Brisbane, Australia, allows the system to maneuver through a sensitive greenway. *Queensland Transport.*

22.2.6 Transit Malls and Transit-Only Configurations

"Bus-only" or "transit-mall" corridors are effective options in giving complete priority to public transport. Such corridor segments are typically employed in central areas where space restrictions limit the ability to share space between both public transport and private vehicles, but can exist along an entire corridor, such as the Orange Line in Los Angeles, USA. Transit mall configurations receive maximum points under the "Busway Alignment" metric of *The BRT Standard*, since they constitute a fully exclusive right-of-way, completely separated from mixed traffic.

Transit malls are frequently an effective solution when a key corridor only has two lanes of road space available. Thus, segments with only seven meters of road space could be appropriate for a transit mall. Private cars, motorcycles, and trucks are banned either entirely from the corridor segment or during public transport operating hours. However, a one-way transit mall can operate on as little as three meters of space, as is the case with the Plaza del Teatro segment of the Quito Trolebús.

Figure 22.32. The elevated track of São Paolo's Expresso Tiradentes. *ITDP.*

Transit malls are particularly appropriate when the public transport service enhances commercial activity and integrates well into the existing land-use patterns. In such cases, the transit mall creates a calmed street environment void of traffic congestion. Transit malls permit a maximum number of customers to access shops and street amenities. Thus, transit malls typically reside in locations where shop sales are quite robust. The lack of mixed traffic encourages an environment friendly to pedestrians and street activity.

The open interaction between pedestrians and the public-transport service on a typical commercial transit mall requires that buses usually travel at slower speeds in these areas. Otherwise, accidents can occur, or the system will dampen the usefulness of the public space. However, the Plaza del Teatro segment of the Quito Trolebús avoids this problem by physically separating the pedestrian area from the busway. While this separation reduces the risk of accidents, it also makes the streetscape less socially inviting to pedestrians. Bogotá's TransMilenio restricts maximum speed in its transit mall to 13 kph, while the rest of the system has a higher speed.

In instances where pedestrian movement along a transit mall is quite high, the presence of public-transport vehicles can become detrimental to the overall quality of the street. Conditions on the Oxford Street corridor in London have become difficult due to the fact that pedestrian volume exceeds the provided footpath space. In this case, the space given to public-transport vehicles (and taxis) may be better allocated entirely to pedestrians. Thus, at certain pedestrian volumes a street may be better utilized as a "pedestrian mall" rather than a "transit mall."

Cities such as Bogotá and Quito, employ bus-only corridors in selected locations. Likewise, Brisbane, Australia; Ottawa, Canada; and Pittsburgh, Pennsylvania, USA, also have developed bus-only corridors over certain roadway segments (Figure 22.28).

Figure 22.33. An exclusive busway runs under the Mater Hill Hospital in Brisbane. *Queensland Transport.*

Figure 22.38. Transit mall in Utrecht, Netherlands. Deliveries are made very early in the morning, or via side streets. *ITDP.*

Transit-only corridors, though, are not just restricted to central business and shopping districts. For example, some busways are essentially limited-access roadways restricted to bus use. The West Busway in Pittsburgh, Pennsylvania, USA, moves through a bus-only corridor in largely residential areas (Figure 22.34). In the cases of Pittsburgh and Brisbane, the busways run along corridors with significant green space. Thus, there are no residential driveways entering directly onto the corridor. Otherwise, these schemes would likely be less viable.

Perhaps the greatest challenge in making transit malls and other transit-only corridors work is access for delivery vehicles and local residents. Some merchants desire round-the-clock delivery access, which is both a political and technical obstacle to implementing a transit mall. The loss of on-street parking and direct customer access by private vehicles may also be a worry for some merchants. In general, the experience to date has indicated that transit malls and pedestrian malls tend to both improve shop sales and property values. Thus, merchants sometimes object to vehicle restrictions at the outset

> *"...they virtually never campaign for the abandonment of a scheme once it has come into operation. It is notable that, once a scheme has been put in place, traders are often the main people to voice a desire to extend its*

Figure 22.34. Examples of successful transit malls include central Zurich, where the tram system provides easy access to shops, offices, and restaurants. *Lloyd Wright.*

Figure 22.35. The Avenida Jiménez corridor of Bogotá's TransMilenio system represents a high-quality example of merging urban regeneration with a BRT system. *Lloyd Wright.*

Figure 22.36. A transit mall in the central district of Pereira, Colombia. *Municipality of Pereira.*

Figure 22.37. Painted information employing a bus-only approach is also an option, as shown here from an example in Jakarta, Indonesia. *Lloyd Wright.*

boundaries or period of operation."

— Hass-Klau 1992, 30

A common solution is to establish delivery access for shops during non-transit hours. Thus, merchants are able to move large goods during the late evening and early morning hours. Smaller goods can typically be delivered at any time by carts and delivery services operating from the pedestrian area (Figure 22.35). This may, however, pose a safety challenge for nighttime freight deliveries in some areas and should be addressed properly.

Figure 22.40. Non-motorized delivery systems, as shown here in Santiago, Chile, can help make transit malls viable for local shop owners. *Lloyd Wright.*

Figure 22.39. In Pittsburgh, Pennsylvania, USA, entire roadways are devoted exclusively to BRT operation. *Lloyd Wright.*

If the area is largely residential, then conflicts are usually with individuals seeking private-vehicle access to their properties and parking. Such conflicts can sometimes be resolved with the establishment of nearby parking garages and access during non-operating hours of the public transport system. In both the case of residential access and shop deliveries, the successful achievement of a transit mall is likely to require careful political negotiation.

22.2.7 One-Way Pairs Configuration

As an alternative to the transit mall, cities frequently consider splitting each direction of public transport service between two different (typically parallel) roads. The public transport system thus operates as two one-way pairs. This is sometimes called a couplet configuration. In this case, at least one lane of mixed traffic can typically be retained.

The chief advantage of splitting the route is the impact on mixed traffic, parking, and truck deliveries. Private vehicles retain some form of direct access to corridor properties. Also, this type of configuration often mirrors the existing bus routes, and thus is potentially more acceptable to existing operators. Guayaquil, Ecuador, has successfully utilized a split-route configuration in the central areas of the city (Figure 22.36) with the one-way pairs running in the center of the street. Johannesburg, South Africa, also has a similar configuration of median-aligned, one-way pairs in the downtown. Outside the denser city center, both directions of the BRT system are recombined in a more conventional two-directional configuration.

Figure 22.41. Through the denser city center area, the Guayaquil Metrovía system utilizes a split-route configuration, with each direction of travel being provided on parallel streets. *Carlos González.*

However, this configuration receives only half the amount of points under the "Busway Alignment" metric of *The BRT Standard*, because of the transfer penalty faced by customers if they need to transfer to a different line or go in a different direction and the potential for customer confusion in determining which station to board for which direction.

22.2.8 Bi-directional One-Lane Configuration

In some special cases of lower demand and good technology, a short stretch of narrow busway could be operated with a single lane. Thus, a single lane would provide service to both directions on an alternating basis. To ensure that two vehicles do not try to use the one-lane segment at the same time, a special traffic control system is usually employed.

Single-lane operation is used most notably in Eugene, Oregon, USA (Figure 22.37). This option works because it is limited to short road segments and bus frequencies are low. An advanced signaling system holds oncoming buses and the busway breaks into two directions at key points for passing. Because of these low frequencies, Eugene's Lane Transit District has been able to avoid most conflicts simply through scheduling.

Figure 22.42. Eugene, Oregon, USA, employs single lane operation for portions of its corridor. *ITDP.*

Under such a design, as the length of the one-lane operation is increased, the greater the possible disruption to operation of the overall system. This option is also not likely to be viable in systems with high vehicle frequencies and high customer demand.

However, in some circumstances, single-lane operation can be used to overcome obstacles spanning short road segments. A single-lane tunnel or bridge or a narrow historic street may appear as insurmountable obstacles, and therefore cause planners to forgo an otherwise ideal corridor. Single-lane operation can be an option to consider in such situations.

22.2.9 Virtual Busways

Similar to the bi-directional, one-lane configuration, a virtual busway is a single bus lane in the middle of a roadway used by both directions of travel. The difference is that the buses take turns in using the lane by direction and set by the need for queue jumping within the corridor. As the bus approaches the intersection, it will move into the virtual lane. The traffic light will have a separate public-transport vehicle phase allowing the BRT vehicles to leave the virtual lane, move into the general traffic lane, but before the rest of the traffic is allowed to go, so that the lane is relatively free-flowing. The bus proceeds in the general traffic lane until the virtual lane is once again dedicated to its direction of travel, usually upon approaching the intersection.

Rouen, France, has successfully implemented a virtual busway. The route has a three-lane cross section with on-street parking, catering to a general-traffic lane in each direction, and the virtual lane in the median. On the approach to each signalized intersection, the virtual lane is dedicated toward the intersection, thereby allowing the public-transport vehicle unimpeded access to the signalized intersection and a bypass or queue-jump lane. The stops are located prior to the signalized intersection stop line, by locating an island stop in the vicinity of the intersection (refer to Figure 22.37).

Figure 22.43. The virtual lane concept in Rouen, France, where a single centrally located bus lane is used to provide bus priority in both directions of travel. *Andre Frieslaar.*

Figure 22.44. A virtual busway stop located in the middle of the roadway. *Andre Frieslaar.*

The degree to which the direction of dedication is allocated to each direction of travel along the corridor will be dependent on the levels of congestion (and queue backup) in the general traffic lanes during the peak periods of operation of the corridor.

Due to the location of these lanes in the median, as well as the limited width of roadway corridors, it may not be possible to protect these virtual lanes with delineators to ensure self-enforcement. The success of these lanes will therefore depend on a high degree of manual enforcement, which may increase operational costs. Additionally, virtual busways are generally most successful in relatively low-demand systems.

22.2.10 Contra-Flow Busway

In addition to the different roadway configurations, system designers can opt for either “with flow” or “counter-flow” bus movements. “With flow” means that the vehicles operate in the same direction as the mixed traffic in the adjoining lanes. “Counter-flow” means that the vehicles operate in the opposite direction of mixed traffic. “Counter-flow” is sometimes used if the doorways on the existing buses require the bus to drive on a certain side. Counter-flow bus lanes are used in various conventional bus systems around the world (Figure 22.40). Often, counter-flow designs are employed to discourage private vehicles from entering the bus lane. However, the counter-flow lane may simply result in busway congestion if private vehicles nevertheless decide to enter the area.

“Counter-flow” set-ups do have a potentially serious problem with increased pedestrian accidents. Pedestrians can be unaccustomed to looking in the direction of the counter-flow lane, and thus cross unknowingly into a dangerous situation.

Counter-flow systems are generally not employed in BRT systems, particularly due to concerns over pedestrian safety. Quito briefly utilized counter-flow movements for its Ecovía corridor since its only available vehicles possessed doorways on the wrong side. However, once the new vehicles arrived from the manufacturer, Quito converted the corridor back to “with flow” movements.

Figure 22.45. Bangkok employs contra-flow design. *ITDP.*

22.2.11 Mixed-Traffic Operation

A BRT system can operate in mixed traffic for certain segments of a corridor. If the corridor is not congested and future congestion can be controlled, it may make sense not to have dedicated infrastructure at that point. Many cities are also designing “direct service” systems where services, by design, travel both on the trunk infrastructure in dedicated lanes and off the trunk corridor, often in mixed traffic. Direct-service systems can be found in Pittsburgh, Pennsylvania, USA; Guangzhou, Lanzhou, and Changzhou, China; Ottawa, Canada; Cleveland, Ohio, USA; and a growing number of cities around the world.

Many systems, however, operate in mixed traffic at precisely the areas where dedicated infrastructure is needed, that is, downtowns where there may be a lot of congestion. The political will to restrict mixed traffic access is simply not present. If the link is congested, then this choice will have a detrimental impact on travel times, system control, and the overall system image. Therefore, mixed-traffic operation is awarded 0 points under the “Busway Alignment” metric in *The BRT Standard*.

Near the Usme terminal of the Bogotá TransMilenio system, the BRT vehicles operate in mixed-traffic lanes. This design choice is due to two factors: (1) Limited road space (two lanes in each direction) and limited right of way; (2) Relatively light mixed-traffic levels. Since the Usme terminal area does not see high congestion levels, the BRT system co-exists with the mixed traffic in a way that does little to affect public transport operations. In this case, the mixed-traffic operation has a negligible impact on system performance. However, mixed traffic may result in higher bus conflicts with other road users, and experience has indicated that, in particular, bus-motorcycle accidents are more prevalent.

By contrast in Changzhou, China the BRT corridor passes through a mixed-traffic section in the city center. This, combined with multiple four-phase intersections, has a major negative impact on BRT speeds.

Figure 22.46. Changzhou, China, operates its BRT system along mixed-traffic lanes at a crucial segment of the corridor, and thus travel times and system control are negatively affected. *ITDP.*

Mixed-traffic operation can also become necessary when a BRT vehicle must traverse around a flyover or other obstacle. As the BRT vehicle moves to the center median, it must temporarily mix with cars descending from the flyover. While this set of circumstances is undesirable from a travel-time and system-control standpoint, the congestion usually does not occur at the bottleneck or flyover, but prior to it. Providing public transport vehicles with separated facilities up to the flyover will allow them to jump the queue with little detriment to overall travel time.

Thus, short and selected points of mixed-traffic operation can likely be tolerated without undermining the functionality of the entire system. However, longer periods of mixed-traffic operation can render the BRT system indistinguishable from a standard bus system. The impact of such a design is not just on the performance and operational control, but also on the psychological image of the system. The exclusive, priority lane given to a BRT vehicle is the principal physical feature that sets it apart as a higher-quality form of transport. The segregated lane is what allows customers to develop a “mental map” of the system in their minds. Removing this segregation from significant portions of the system greatly diminishes the metro-like nature of BRT, and makes it far less attractive to discretionary riders.

An option for mixed-traffic operations is to include queue-jump lanes, which help give some form of priority during peak periods to avoid vehicles being trapped in congestion.

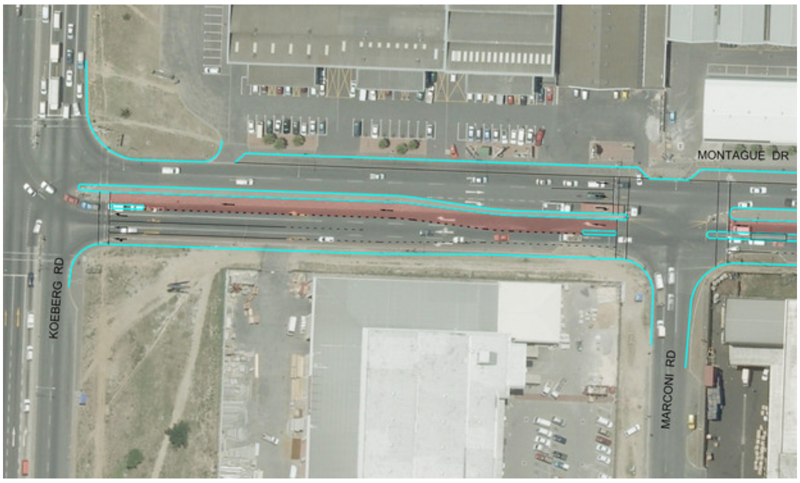

Figure 22.47. A section of median queue-jump lane in Cape Town, South Africa. *Andre Frieslaar.*

Queue-jump lanes can be located on the curbside or in the middle of the corridor (Figures 22.42 and 22.43). Issues that affect the location of these lanes are: driveway spacing and frequency, the presence of a median, median break, turn lanes, etc. Issues associated with queue-jump lanes are the difficulty with encroachment by general traffic vehicles, and difficulty with enforcement due to the need to cross the dedicated lane to access driveways, turn lanes, and median breaks.

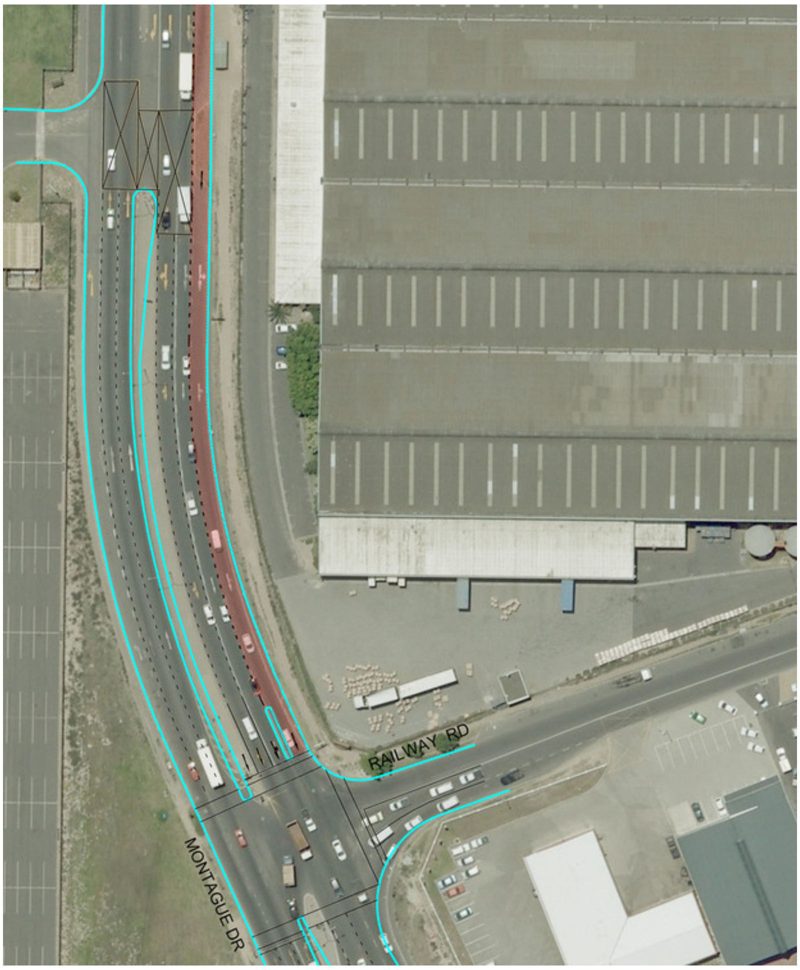

Figure 22.48. A section of curbside queue-jump lane in Cape Town, South Africa. *Andre Frieslaar.*

In some instances, access to the queue-jump lanes by general traffic is only restricted during peak periods, that is, general traffic may utilize these lanes during the out-of–peak periods. This weakens the exclusivity of the road space, which in turn leads to higher rates of peak-period violations, and hence should not be encouraged.

22.3 Station Configurations

> *"Design is directed toward human beings. To design is to solve human problems by identifying them and executing the best solution."*
>
> — Ivan Chermayeff, graphic designer, 1932–

Stations are the critical linchpin between the customer and the system. Some of the attributes of BRT systems that distinguish them from conventional bus systems include pre-boarding fare collection and rapid and at-level boarding and alighting via multiple station doors into multiple doorway vehicles. The station design makes that happen.

When a busway approaches a station area, more roadway space is required due to the need for a station platform in addition to the busway lanes. A standard BRT station should be at least three meters wide (*The BRT Standard* awards 3 out of 3 points for appropriately wide stations). There are many possible ways of fitting a station into limited right-of-way.

- Building stations within medians: Sometimes a median already exists in the corridor. A median that is of a similar width as a proposed station is ideal since it represents unused space in the roadway. Some new roads, as in Dar es Salaam, Tanzania, are being constructed with wide medians, serving as placeholders for potential future BRT lines;
- Removing on-street parking spaces: If on-street parking has been retained, even after the dedication of bus lanes, it may be possible to remove some spaces in order to accommodate a station. This has the benefit of allowing removal of exactly the number of spaces that are needed to accommodate the station and the only result is a direct loss of parking spaces. Removing additional space from mixed traffic, on the other hand, even if in a very specific location, means a reduction in mixed-traffic throughput, which extends beyond that location;
- Removing left turn bays: Often, roadways widen at intersections in order to make room for dedicated left turning bays. It is thus possible to remove the left turning bays and replace them with a station. Removing left turns has the added benefit of eliminating a mixed-traffic phase at intersections, with the result of increased bus throughput at the intersection (*The BRT Standard* rewards removal of left turns across the intersection with maximum points).
- Building stations where there is land readily available: While it is always recommended to build stations where the highest demand exists, within that framework it can be reasonable to select an exact location in which there is open land available. At that place, the road can be widened to make way for a station. Ideally, the land that is taken will have been of marginal use to the community. For example, it may be possible to acquire off-street surface parking lots and widen for stations there. This option is less desirable when it is viable businesses or residences that must be acquired. However, this is sometimes done as well, provided it is accompanied by careful and responsible outreach to the affected community (see Chapter 10: Participation and Outreach);
- Creatively configuring stations: There are a variety of station configurations that may fit better into particularly constrained roadways. These are described in the following section.

It is not recommended, however, to reduce the width of sidewalks in order to accommodate stations, since pedestrian volumes will only grow, not shrink, with the introduction of a BRT station.

If passing lanes are included in the design, there is an even greater need for additional roadway space. In some cases, such as on 80th Street (Calle 80) in Bogotá, passing lanes are provided throughout the entire corridor since the road was wide and space was not constrained. However, this is very rarely the case. Where constraints exist, most of the same principles bulleted above for accommodating stations may apply. However, because passing lanes are an additional draw on roadway space, a combination of these techniques may be needed.

Additionally, it is possible to include passing lanes only at critical passing points rather than along the entire length of the corridor if right-of-way is constrained. *The BRT Standard* awards 4 out of 4 points for providing passing lanes at BRT stations, and does not further incentivize full-corridor passing lanes. On the TransOeste corridor in Rio de Janeiro (Figure 22.44) a passing lane is provided only at station areas. Outside the station areas, only a single lane of busway is provided for each direction of travel.

Figure 22.49. The TransOeste in Rio de Janeiro provides passing lanes at stations. *Clarisse Linke.*

Figure 22.50. In Guangzhou, the passing lane is provided through a widening of the roadway at this midblock station area. *ITDP.*

22.3.1 Station Types

There are three main station types that are based on the function or role they play in the system:

1. Standard: the configuration and structure of a standard station depends on the capacity needed for both customer and vehicle volumes expected at that station;
2. Transfer: a structure that fulfills the role of a standard station and facilities transfers either within the system to another trunk route or a feeder route or to another system, like metro. Ideally this happens without leaving the structure—physical integration—but may not be possible due to space constraints;
3. Terminal: a structure that represents the endpoint of a corridor. Usually space is available for a larger facility that can easily accommodate physical integration of feeder and trunk lines. With direct services becoming more popular, large terminal structures may not be as necessary.

Stops, which are usually defined as having a totem and/or a bus shelter, but no real infrastructure, can occur as well, but usually when the direct services buses are operating off the trunk corridor or when the stations on a trunk route need to integrate into dense downtowns, like on Line Four in Mexico City. It is important to ensure that these are branded as part of the system and can be distinguished from regular bus services. Stops are not usually recommended for BRT systems.

When designing the roadway, the design team should take into consideration the role a particular station will perform upon opening and potentially in the future as the system expands. Upon the opening of line 1, a station may function as a standard station but line 3 will intersect line 1 at that station. Having the space and flexibility to adjust the role of the stations as the system expands will be key. Planning for the infrastructure required for that standard station to become a transfer station can be incorporated into the design process for the roadway. Key aspects of service planning, such as the frequency of the services that coincide at the station and customer transfers, should lead the design of the facility. Ideally services are designed to minimize the number of transfers, which is beneficial to the customer, but can also help reduce the need for large transfer stations.

Standard Stations

The role of a standard station is to be the interface between the customer and the system, through fare collection and allowing access, providing at-level boarding, information about the services. A station should be safe and weather protected. A station can serve as a community focal point. In Ahmedabad, India, when Janmarg opened, its stations were called the city's best public spaces.

A station typically has the following components:

1. Transition areas: the areas that are not directly spaces for boarding and alighting but can include kiosks for buying tickets, seating areas, etc. These are areas where customers can find information about the system;
2. Docking bays: this is where the bus pulls up in order to let customers on and off.
3. Sub-stops: also known as modules, stations may contain multiple sub-stops that can connect to one another but should be separated by a walkway long enough to allow buses to pass one sub-stop to dock at another. A station may be composed of only one sub-stop.
4. Platform: this is the main area where customers wait to board and where they alight. For conceptual design, an average width of five meters is used to estimate the cross section of a center-aligned station. If split, each station is about 3 meters. Platform height will depend on the type of bus being procured or used, which is usually a function of the financial model;
5. Passing lanes.

As a baseline, every station has one sub-stop with two docking bays. Above that, sizing the station should be a function of the operational plan and projected peak customer volume. The peak number of boarding and alighting customers will determine how much station floor space will comfortably accommodate all customers. The operational plan for a particular BRT corridor will dictate whether a single sub-stop will be able to accommodate the planned number of vehicles using the station during a peak period, or whether multiple sub-stops will be required due to high vehicle frequencies or multiple vehicle routes (Figure 22.46).

In order for multiple stopping bays to function properly, and for services to be split between various local and limited-stop routes, vehicles must be able to pass one another at the stations. Passing lanes allow buses approaching the station to pull around docked buses to available docking bays and not sit in queue. Therefore, sub-stops need to be spaced at least 1.7 times the vehicle length from each other in order to allow for buses to bus in or out of the sub-stops. These details of station design are described in more detail in Chapter 25: Stations and Terminals.

Figure 22.51. The existence of a passing lane makes the high customer capacities achieved in the Bogotá system possible. *Carlos Pardo.*

The passing lane may exist as just a second lane in the station area, or the additional lane may be extended all along the corridor (Figure 22.47). Whether the second lane is needed beyond the station area depends on the saturation levels along the corridor, and especially depends on the level of congestion at intersections.

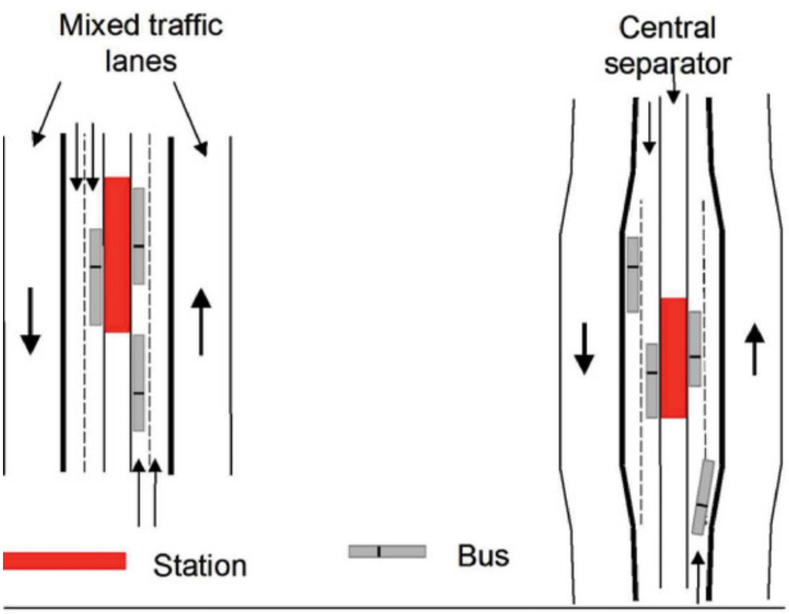

Figure 22.52. Options for provision of a passing lane. *ITDP.*

The principal difficulty in including a passing lane is the impact on road space. The additional lane in each direction would seem to require a road width few developing cities can reasonably provide. However, a staggered station design can help permit passing lanes, even in relatively tight corridors. In this case, the sub-stops for each direction of travel are offset. The preferred median station design is retained, but its shape is elongated to help accommodate the passing lane. Customers can still change directions within the closed station area by crossing a connecting platform. In this case, the higher customer flows within the stations are achieved by lengthening the stations instead of widening them.

Other options for accommodating passing lanes in relatively narrow roadways include reducing mixed-traffic lanes as well as making property purchases for widening. In some BRT cities, such as Barranquilla, Colombia, plans call for the purchase of properties near station areas. The road infrastructure is widened in these areas in order to accommodate the passing lane. This same strategy is being proposed for some stations in the Dar es Salaam, Tanzania, system. The viability of property purchases for this purpose depends on local property costs as well as the existence of a well-designed compensation program for property owners.

Transfer Stations

These stations have to meet the needs of a standard station, but also address transfers, whether between feeder and trunk routes, between other trunk routes, or between other modes. The space requirements may be greater, or the connecting infrastructure may be additional and more costly.

Feeder connections to the trunk lines do not necessarily occur only at major terminal facilities. When feeders intersect the trunk corridors outside of terminals, due to space constraints, it may be difficult to have a seamless integration where the customer remains in a paid-fare area and does not have to re-enter the system between feeder and trunk due to space constraints. Thus, a bit of creativity is required to design and control the transfer process.

In addition to feeder connections, transfer stations can also link two different trunk lines. As a system expands across a wider network, more opportunities to link different corridors of the BRT system will occur. There are several options for facilitating transfers between corridors. These options include:

- Platform transfers;
- Underground tunnels/overhead pedestrian bridges;
- Interchange facility (multi-bay or multi-story facility).

A system may use a combination of these interchange options, depending on the local circumstances at the interchange point.

U-turn facilities may be needed as these stations are often the termination points of either trunk or feeder routes. The U-turn movement of vehicles requires additional road reserve width, a consideration when locating these facilities. In addition, an area is required in close proximity to these stations for the holding of off-duty buses, or buses waiting for their departure time on their schedule. Staff facilities may also be required for drivers changing shift, ablution facilities, and accommodation for a localized dispatch.

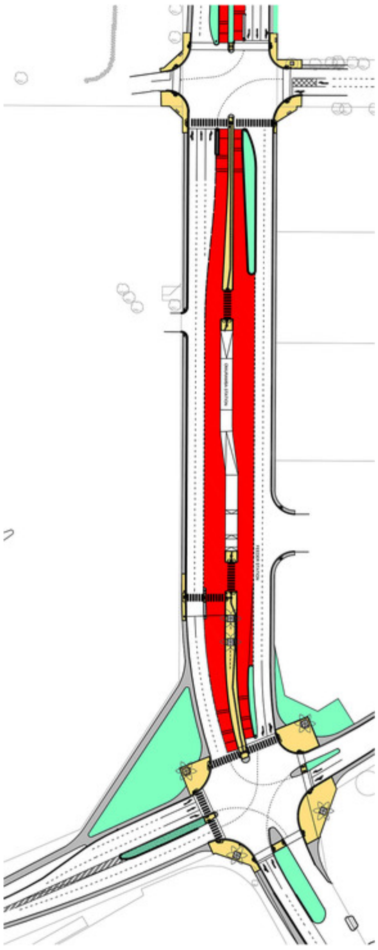

Figure 22.53. An intermediate transfer station on Cape Town's MyCITI system, with a closed environment between the trunk platform on the left and the feeder platform on the right. *Planning Partners.*

Figure 22.54. An interchange station in Bogotá, with a closed environment between the two trunk platforms. *ITDP.*

22.3.2 Station Configurations

There are two main ways of configuring BRT stations: either as center or as split, side-aligned stations. Within those, there are options to address roadway availability and/or constraints.

Center

Center stations are located in the middle of the busway and typically require buses with doors on the opposite side from conventional buses that normally have doors on the curbside. While requiring a somewhat wider floor area and buses with doors on the opposite side, the single station in the median is by far the most useful in terms of customer convenience and system design. With a single station serving both directions, customers are able to change directions by simply crossing the station platform.

Where road width is a constraint, there are two main options with center configurations: elongated and offset. Width is harder to add, while length is easier.

Elongated

One way to address the need for width, which is based on the peak customer demand, is to elongate the station so that the docking bays for the buses from each direction are not directly across from each other. If the station doors for each direction are situated directly opposite one another, then when two buses dock at the same time, the competition for that space increases and it may become too congested, in which case, the station size must be increased to meet the capacity demand.

Alternatively, the station itself can be elongated to offset the placement of the station doors for each service direction. Thus, instead of the station doorways being directly opposite one another for each corridor direction, the doorways are staggered somewhat (Figure 22.49). In order to accommodate this doorway configuration, the stations must be somewhat longer than a station with doorways directly opposite one another (Figure 22.49). However, the advantage is a reduction in the required station width. Quito's Ecovía corridor makes use of this technique in order to fit the system into a relatively narrow roadway (Figure 22.50). Thus, an elongated station configuration allows a fairly narrow station with the favored median station location. On the other hand, it is generally agreed that a narrower station is less comfortable for customers.

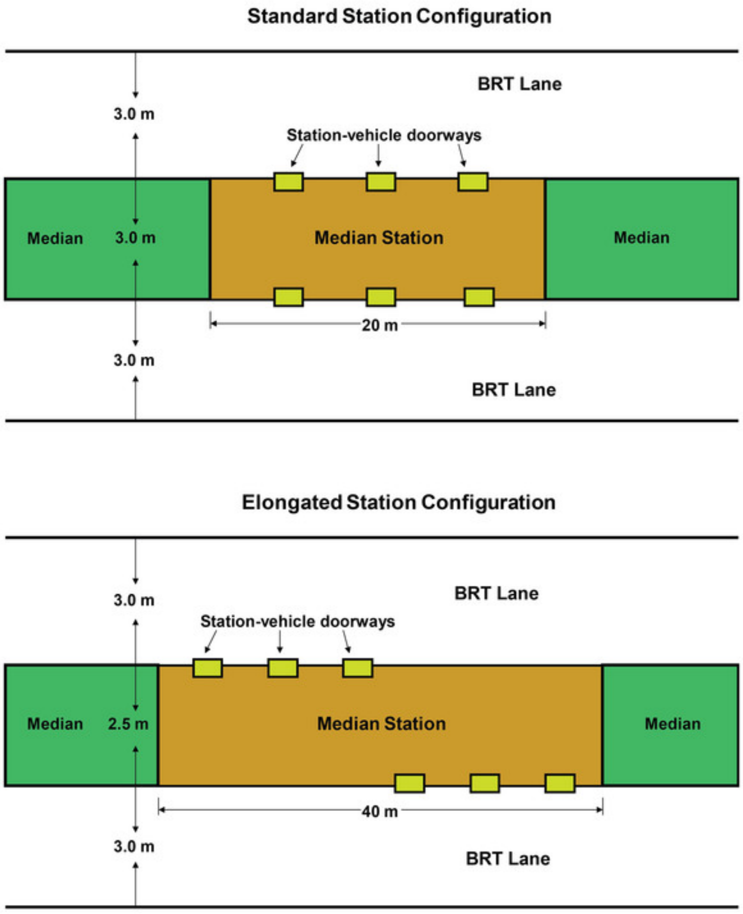

Figure 22.55. Comparison of a standard and elongated station configuration. *HHO Africa.*

Off-Set Stations

Another way to address constraints in road width with a center-aligned configuration is to off-set the directions of travel into two separate sub-stops, so that each sub-stop only allows for docking in one direction of travel. This still allows buses to dock and transfer customers in both directions of travel, including passing lanes. However, each sub-stop only allows for docking in one direction of travel. This configuration reduces the required road width by one lane and still delivers full passing capabilities at the station. Of course, this configuration does elongate the station footprint and also introduces a slight turn at the station area. Nevertheless, in cities with restricted road widths, this design can be effective in allowing passing lanes at stations. Cape Town, South Africa, has applied this concept on its Atlantis corridor (Figure 22.53).

Figure 22.56. An off-set station in Cape Town, South Africa. The platforms are arranged a distance apart to allow for a passing lane on each side at the station docking area. *ITDP.*

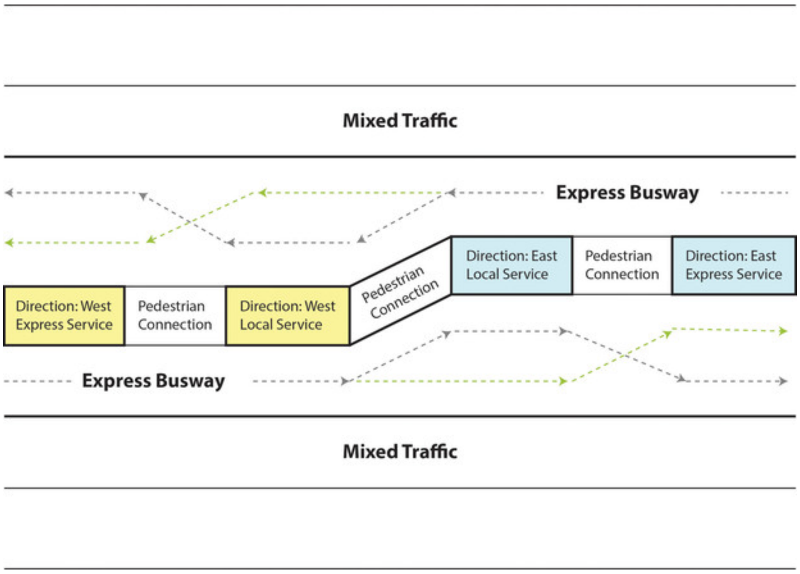

Figure 22.57. By offsetting the sub-stops and elongating the platform, passing lanes can fit into relatively narrow road widths. *Lloyd Wright.*

Figure 22.58. An offset station in Cape Town, South Africa. *Pierre Smit.*

Figure 22.60. A multiple sub-stop, split, side-aligned station in Guangzhou, China. *ITDP.*

Figure 22.59. An offset station in Bogotá, Colombia. *ITDP.*

Split, Side-Aligned Station Configuration

Split stations are located adjacent to the busway along the side, with each station serving just one direction. This type of configuration allows the use of existing bus fleets with doors on the curb-side boarding, and a new fleet with left-side doors may not be required. The benefit is then that all existing bus services already on or near the corridor may continue to use the corridor since existing bus fleets can be used for each service. In the United States, this is often the selected course since most cities already own large bus fleets with right-side doors. However, some cities are beginning to consider procuring left-side or dual-side boarding buses as a standard practice whenever new buses are required anywhere in their systems.

Split stations will require either complicated connecting infrastructure (underground pedestrian tunnels or overhead pedestrian bridges) or a more costly fare system to recognize customers leaving and reentering the system from nearby stations. It may also cause confusion to users new to the system (they may get lost or lose their paid fare). Additionally, building two stations instead of a single median station will tend to increase overall construction costs and may require more road space. To address space constraints, split stations can be staggered.

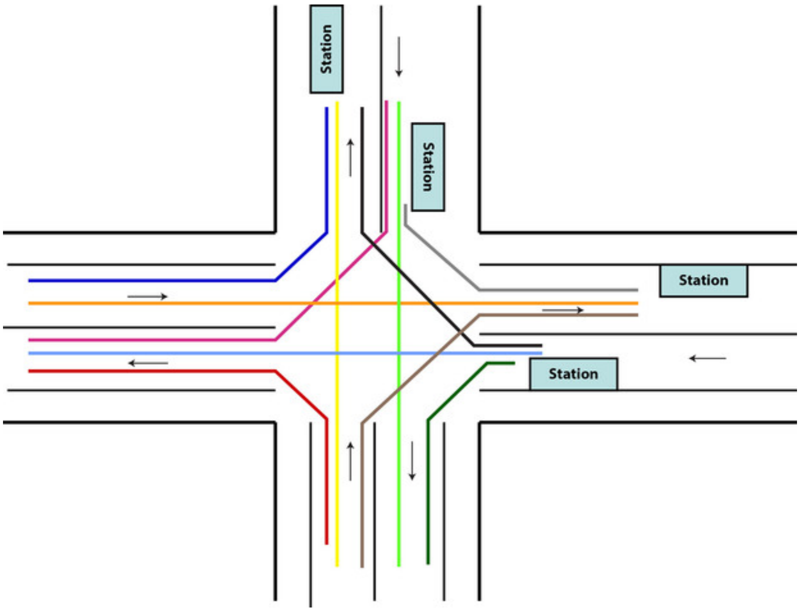

Figure 22.61. An alternative means of connecting split and side-aligned stations is to provide a full set of route permutations. *HHO Africa.*

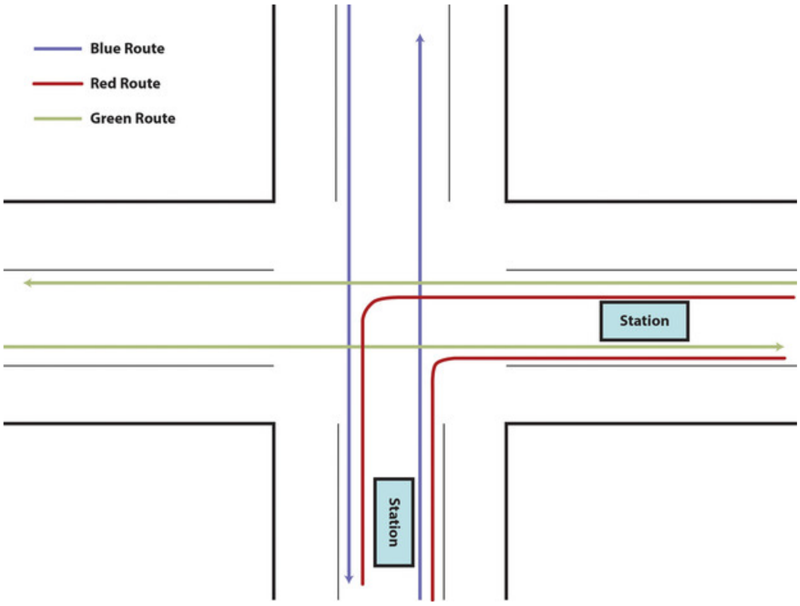

Figure 22.62. However, the required number of permutations becomes excessive, even for just a single intersection. Median stations permit easier platform transfers and multiple route permutations. *HHO Africa.*

Staggered

The staggering of split stations for each direction may provide marginal space savings in terms of road width. The station will have to accommodate approximately half as many customers for a single direction, and thus a reduction in width is possible (though a reduced width can feel uncomfortable for customers). The marginal width gained from a staggered configuration, estimated at 0.5 meters, is not significant, and given the operational advantages of center-aligned stations, they are recommended over split stations. For those reasons, split stations receive no points in *The BRT Standard*.

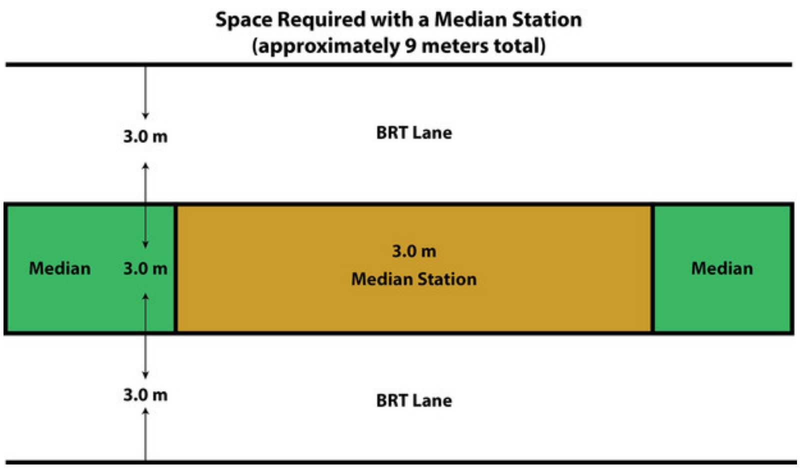

Figure 22.63. Relative space requirements for roadway configurations with median stations. *HHO Africa.*

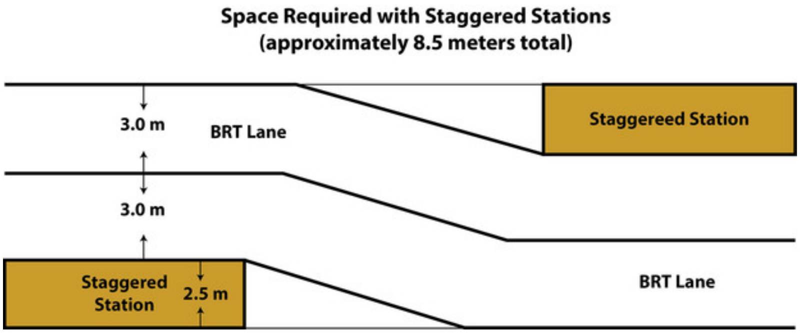

Figure 22.64. Relative space requirements for roadway configurations with staggered stations. *HHO Africa.*

22.4 Bibliography

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23. Roadway Design

> *"The excellence of a road consists chiefly in its being protected from the reigning winds, and the swell of the sea; in having a good anchoring-ground, and being at a competent distance from the shore."*
>
> — William Falconer, poet, 1732–1769

When it comes to the design of the BRT corridor infrastructure, a thorough design process is required to ensure that once built, the infrastructure will deliver incident-free services for an extensive period of time. Once a BRT system becomes operational, any downtime to undertake corrective maintenance and modifications will result in severe delays to the system, operation-cost penalties associated with the delay, and embarrassment to all involved in the design process.

This chapter discusses the various stages of the design process, namely the conceptual design stage, the preliminary design stage, and the detailed design stage. Thereafter, various elements of the design process are discussed, namely data collection, geometric design, pavement design, busway colorization and delineation, busway road marking and signage, and the treatment of utilities. Finally, the design of cycle and pedestrian facilities, as well as the urban design and landscaping design are discussed.

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23.1 Overview of Design Process

> *"Always design a thing by considering it in its next larger context—a chair in a room, a room in a house, a house in an environment, and environment in a city plan."*
>
> — Eliel Saarinen, architect, 1873–1950

As discussed above, the design process can be summarized into three sequential stages— namely the conceptual design stage, the preliminary design stage, and the detailed design stage. Once the detailed design stage is completed, construction drawings can be issued to a contractor to undertake the construction of the roadway.

23.1.1 Conceptual Design

Aerial photography and cadastral information of the corridor provide important basic information about the available road reserve widths, current roadway geometrics, and the location of existing structures like bridges and tunnels along the route. The aerial photos also indicate the location of intersections along the route and median breaks on dual roadway arterials. (As-built surveys, if available, are also a good source of roadway data.)

Figure 23.1. Typical aerial photograph of a proposed corridor, showing the lot lines and road reserve information. *HHO Africa*

Typically, designers will try to keep the proposed cross sections to within the available road-reserve width, unless the required road reserve is totally inadequate. The introduction of dedicated public transport lanes within a corridor must be seen as a travel demand management tool, which will result in a shift of commuters from private to public transport. Hence, it is important to first assess whether existing general traffic lanes can be converted into exclusive bus lanes without reducing the general traffic capacity. A conceptual layout of the preferred cross section should be drawn out to show the different options for roadway configuration, discussed in more detail throughout this chapter. The conceptual layout should include all station layouts and intersection treatments. An analysis of the proposed intersection layouts should be undertaken to assess the impact on general traffic performance, as well as the ability of the intersection to accommodate the public transport vehicles at a high level of service. Conceptual design is important because it helps build political will and support for the project.

At this stage, a rough cost estimate of the roadworks can be prepared. This is a further opportunity for the design team to assess whether the proposed layout is within the project budget or whether more cost-effective alternatives need to be pursued.

Figure 23.2. Typical conceptual layout of a BRT corridor showing dedicated lanes, intersections, stations, and station access, for a proposed BRT corridor in Ulaanbaatar, Mongolia. *ITDP*

23.1.2 Preliminary Design

The objective of the preliminary design process is to prove the feasibility of the conceptual design layout, and to prepare a three-dimensional layout of the project.

Once the preferred conceptual layout has been determined, the design can proceed to the preliminary design stage, where the following tasks should be undertaken:

- Horizontal and vertical alignment indicating busways, delineation of busways (specialized curbs located between busway and mixed-traffic lanes to assist enforcement), mixed-traffic lanes, bike lanes, sidewalks, and landscaped areas/medians;
- Busway station location and layout, including the provision of passing lanes at stations and any vehicle-docking infrastructure. Interaction is required here with the operational-planning team to determine number and width of platforms. The width of the platform must be able to accommodate the fare system gates, as well as the peak demand for customer holding and circulation, with architectural station-design specifications;
- Intersection design, including closure of medians, banning of turns across the busway, introduction of special bus phases at intersections, etc. (See Chapter 2: Mode Selection: Why BRT?);
- Busway pavement design, where various pavement surfaces should be considered, namely asphalt, concrete (full-width pavement or pavement strips), continuously reinforced concrete, and ultrathin concrete. Colorization of the bus lanes should be considered. Existing pavements must be tested to determine residual life and extent of mixed-traffic lane upgrades required;
- Station services, including stormwater design, relocation and/or protection of existing services, irrigation, street lighting, electrical reticulation, traffic-signal electrical connections, and irrigation electrical connections. If treated, effluent will be available for landscape irrigation, then the design of the effluent reticulation should also be undertaken;
- Structural design of proposed bridge or culvert widening, busway over- or underpasses. Geotechnical investigations should be conducted for all foundations, to determine founding conditions;
- Fiber-optic reticulation, including sleeves and manholes, as well as surveillance mast locations to be coordinated with ITS consultant;
- Layouts of all NMT facilities to be provided alongside the busways, giving access to stations and within 500-meter radius of busway stations, to be planned in conjunction with NMT Specialist (see Chapter 28: Multi-Modal Integration);
- Universal access designs incorporating dropped curbs at intersections, ramps, audio and tactile push buttons at intersections, tactile paving, etc., to be planned in conjunction with Universal Access Specialist (see Chapter 30: Universal Access);
- Land acquisition to be determined and undertaken;

- Urban design and landscaping design should be undertaken. The urban design treatments at stations require more detailed attention via specialists (see Chapter 33: TOD Station Area Planning and Regulation);
- Traffic accommodation during construction needs to be assessed to determine whether it is feasible to construct the route while maintaining reasonable traffic operations, and how this may impact the construction period;
- The identification of listed activities requiring environmental authorization needs to be assessed and any environmental authorization applied for. Stakeholder coordination and consultation meetings should be held to assist with the optimization and finalization of the preliminary design;
- Preparation of a detailed schedule of quantities to provide an updated cost estimate. A contingency sum of at least 15 percent should be used at the preliminary design stage to allow for design development.

Once the above design processes have been concluded, the preliminary design of the route can be finalized. Tender documentation could be prepared at the preliminary design stage, should project delivery schedules require an early start to construction.

23.1.3 Detailed Design

The objective of the detailed design process is to refine and communicate the preliminary design in a set of drawings and specifications, in order for a contractor to build the planned infrastructure. At the detailed design stage, the following tasks should be performed:

- Changes to the preliminary design layout should be minimized, as this could result in time delays and could impact other elements of the design;
- The detailed design of each element of the preliminary design needs to be undertaken to ensure that all design procedures have been undertaken, design calculations completed and documented, and any design approvals have been sought with utility and other relevant authorities;
- A complete and detailed set of construction drawings needs to be prepared, indicating layout, levels, and setting out details of all infrastructure;
- If not already done as part of the preliminary design process, a full set of detailed specifications should be provided that identifies construction methodology, tolerances, etc.;
- Tender documentation, including detailed schedule of quantities, tender procedures, and conditions of contact;
- Provisional construction, indicating construction activities, critical path analysis, interface with associated contracts (i.e., station construction if not part of roadwork contract), and overall contract duration;
- Overall construction cost estimate.

It should be noted that a thorough, detailed design process is critical to the successful rollout of a roadworks project. Design omissions and errors can be very costly both in time and economics once a contractor has been appointed to undertake the construction. A significant number of variations can increase the overall cost of the project to beyond the project budget.

23.2 Data and Studies Required to Do Preliminary and Detailed Design

"The details are not the details. They make the design."

— Charles Ormond Eames, Jr, architect, 1907–1978

23.2.1 Topographical Surveys

Figure 23.3. Typical output from a topographical survey *HHO Africa*.

In order to undertake a preliminary electronic design of a roadway project, a high-quality topographical survey is required. The objective of the topographical survey is to provide a digital terrain model of the roadway corridor, with all the roadway features that exist in the corridor, recorded in three dimensions, that is coordinated and with levels. Relevant features that should be recorded in the topographical survey include:

- Roadway edges and road markings along the corridor and at least one hundred meters along all intersecting roads;
- Property-line boundaries and road-reserve boundaries;
- All stormwater catch pits or channels along the route with invert levels on all pipe work;
- Street-light poles, traffic-signal poles, traffic-signal controllers, and any other street furniture;
- Trees, both by location and girth;
- Bridges, culverts, overpasses, and underpasses;
- Underground services, like electricity, drainage, water, and sanitation. These may have to be verified through hand excavation to get spot heights and locations.

The quality of the topographical survey can have a significant impact on the ability of design engineers to design accurately, and inaccurate survey work can lead to design errors and potential construction claims. A high-quality specification for the topographical survey would be prepared to ensure that all tendering survey firms are aware of the quality required. The tender process should ensure that only those surveyors with the relevant qualifications can be awarded this task.

23.2.2 Pavement Assessment

An assessment of the existing roadbed founding conditions and existing general traffic lane pavements is required in the corridor. The quality of the founding material on which road layer works is placed can have dramatic effects on the design of the pavement layers. The road pavement design is critical in the overall design process, as it can constitute a third of the cost of the roadwork contract.

Pavement assessments start with the collection of road-design data from the road authority responsible for the corridor. What is of importance is the age of the pavement, its founding material, and the thickness and specification of each layer of the pavement. Where this information does not exist, pavement data can be collected on-site by means of trial holes. Each trial hole provides a profile of the road pavement, indicating layer thickness and material classification. This information can be used to assess the residual life of the pavement and its ability to accommodate the proposed BRT vehicle loading.

Other less-invasive means of pavement testing can be undertaken using a pavement deflectometer device, but the quality of the information is not as detailed as with the trial-hole procedure.

23.2.3 Foundational Assessment for Structures

Structures have point loads that require specialized investigation and design. For any bridge, tunnel, overpass, underpass, or elevated busway support, a foundation assessment needs to be undertaken at the location of the structural foundation. The bearing pressure of the in situ material needs to be investigated to determine what type of footing is required to support the structure. Where the material has a poor bearing pressure, piling may be required to provide the required stability.

The quality of the founding material has a major impact on the structural design, and hence should be undertaken early in the design process. Failure to adequately assess founding conditions and hence design adequate foundations, could lead to structures settling, cracking, and ultimately failing.

23.3 Roadway Geometric Design

"A common mistake that people make when trying to design something completely foolproof is to underestimate the ingenuity of complete fools."

— Douglas Adams, novelist, 1952–2001

There are various ways of configuring the roadway to accommodate a BRT system. Depending on features such as station location, non-motorized transit infrastructure, intersection treatment, etc., the road cross section will have a different configuration. Cross-section design is covered in depth in Chapter 22: Roadway and Station Configuration. This section will focus on changes in the design of the right-of-way that implementing a BRT system might require.

23.3.1 Road Widening

Road widening often involves appropriating land surrounding the roadway. The expropriation of land and buildings can be logistically complex and incur political and community opposition. Therefore, the process of land appropriation for the BRT system should be transparent, with extensive community outreach throughout. Land appropriation should be done carefully, taking into consideration the surrounding context and community.

Road widening and land appropriation can also dramatically drive up the costs of the BRT system. Phase II of the Bogotá TransMilenio system has seen extensive road widening and property acquisition along its Norte-Quito-Sur corridor (Figure 23.4). While the existing roadway was actually sufficiently wide for both BRT and mixed traffic lanes, the municipality wished to retain the same number of mixed-traffic lanes after the BRT system went into operation. However, the amount of expenditure on land acquisition has pushed up the corridor's cost considerably. Phase II of TransMilenio represents a near tripling of costs over the system's Phase I.

Figure 23.4. Road widening along the Norte-Quito-Sur corridor in Bogotá increased the total infrastructure cost. *Carlosfelipe Pardo*

Selective land purchases in bottleneck points away from the central districts are more affordable and there are likely to be fewer conflicts with historical buildings and infrastructure. In particular, areas with undeveloped land, parking lots, derelict buildings, and/or illegal encroachments are clearly more cost-effective acquisition targets than other areas.

However, land cost should not be the only criteria when making land acquisition decisions. If land value is the only deciding factor, then road widening will tend to impact lower-income groups more adversely than others. While it may be economically optimal to widen roads through a poor neighborhood when building a BRT system, mechanisms for compensating poor families with only informal claims to their land will often be weak. The forced relocation of such families will cause severe hardships that should be avoided. Thus, some social criteria should also be included in any decision making on land acquisition or property expropriation.

23.3.2 Horizontal and Vertical Alignment

Once the cross section for each section of the route has been fixed, the horizontal alignment of the roadway can be prepared. The horizontal alignment is essentially the layout of the roadway, including general traffic lanes, BRT lanes, BRT stations, intersections, NMT facilities, and landscaping zones.

Once finalized, the vertical alignment can be designed. Vertical alignment is both the slope and the shape of the roadbed and the matching of the station platform to the vehicle's height to allow for at-level boarding. The vertical alignment depends on the roadway-design speed, the need for superelevation, and the minimum crest and sag curves. Superelevation is usually required on roads with high speeds and tight corners. This rarely occurs on BRT corridors and those type of conditions are usually discouraged for BRT operations.

At median stations, where vehicles dock on either side of the platforms, care needs to be taken to have the busway lanes at similar heights to avoid steps or sloping floors in the station. BRT corridors are often well-developed urban corridors, and hence the vertical alignment design need to ensure that the proposed roadworks tie in with the surrounding urban environment, that is, driveways from properties adjacent to the corridor must tie into the general traffic lanes at acceptable gradients. The drainage of the roadway is endured horizontally through the provision of a cross fall on the roadway, toward stormwater inlets and pipes or a surface channel system. Longitudinally, the route should also be designed to drain surface water to low spots along the route where this water can be collected and introduced to the stormwater system.

23.3.3 Stormwater and Drainage

The street environment is often far more complicated than the surface would indicate. The street is the principal conduit of many critical city services, including water supply, drainage, sewer lines, gas lines, and electricity lines. Since BRT systems typically operate on the principal corridors of a city, there is likely to be a concentration of city infrastructure alongside and beneath the busways.

Consultation of city infrastructure maps can determine the extent to which the new BRT system may affect these other services. The construction process must take care to not disrupt or harm the water and drainage lines. If a new surface material is applied for the BRT lane, then water drainage should be explicitly considered in the design process. Concrete busways and painted busways may be less permeable than the previous surface materials. Worst-case storm scenarios should be tested in terms of water buildup. If possible, green stormwater infrastructure should be integrated into the busway, adjoining medians, and sidewalks as both transportation and water management infrastructure are interconnected. If designed properly, green stormwater infrastructure such as permeable pavement, infiltration basins, and rain gardens among others, can mitigate local flooding (Figure 23.5) where there are depressions in the road by allowing water to infiltrate into the ground, rather than collect and puddle on impervious pavement.

Figure 23.5. Without adequate drainage, a heavy storm in Quito puts the operation of the Trolé line at risk. *El Comercio*

23.3.4 Impact on Existing Utilities

It is highly likely that the proposed BRT corridor layout will have some impact on existing utilities. The impacted utilities need to be identified and consultation needs to be held with the relevant utility authorities to establish whether the utilities can either be left and protected or need to be moved (and at what cost). Any utilities falling under the busway lanes should be moved, especially if a concrete pavement is being considered. This is also a chance to upgrade these services.

The mitigation of utility impacts can often be the largest contributor to construction delays and construction cost variations. The detailed design of the underground utility mitigations should be done using the best information, which may involve engaging a services contractor prior to the main roadworks contract who can identify the exact location of underground utilities and move or protect them as required.

23.3.5 Intersection Design Considerations

The optimum layout and traffic control of intersections is discussed in detail in Chapter 24: Intersections and Signal Control. From a roadway-design perspective, the intersection poses a few interesting design considerations as follows:

- At intersections, major utility runs from side roads converge on the main route and cross it. Rather than have these services buried under concrete BRT lanes, it may be more appropriate to utilize a flexible pavement such as an asphalt surface in the intersection area (area bounded by the pedestrian crossing lines), which can be more easily dug up should utility repairs be required;
- The travel path of the BRT vehicles through the intersection area may need to be strengthened to accommodate the higher-axle loads;
- Pedestrians and cyclists will need to cross the route at intersections, and care must be taken when designing the intersection to ensure that sight lines are not obscured. Sight lines to traffic signals at signalized intersections should be assessed, especially at overpasses.

23.3.6 Station Design Considerations

Station placement and design should be a key consideration in the roadway design. Passengers need to feel safe in stations, especially those placed on the median of busy arterials with large public transport vehicles moving past them at high speeds and great frequency. The optimum design will be the one that addresses this issue the best, and where customer convenience is maximized. For details on the different possibilities for station design and placement, see Chapter 25: Stations and Terminals.

23.4 Roadway Pavement Design

> *"You know more of a road by having travelled it than by all the conjectures and descriptions in the world."*
>
> — William Hazlitt, literary critic, 1778–1830

The construction of the busway will typically represent approximately 50 percent of the total infrastructure costs. Thus, savings through efficient design and material choice can produce significant dividends. Cost savings, though, must be viewed both from the perspective of initial construction costs and long-term maintenance costs. Lower-quality road materials may reduce capital costs, but will dramatically increase maintenance costs if roadways need repaving or reconstruction after just a few years.

23.4.1 Alternative Pavement Treatments

The principal determinant in choice of roadway materials is the axle weight of the BRT vehicles selected for operation and the number of projected BRT vehicles likely to use the infrastructure over the projected service life of the road. The roads must be built to a standard able to withstand the projected usage by vehicles with the specified axle weight. One pavement treatment that works well in temperate climates may degrade in tropical climates. Local pavement engineers should thus be a part of the decision-making team.

If the BRT vehicles are standard 18.5-meter articulated vehicles, they may require reconstruction of the entire roadbed with materials able to withstand these heavy axle loads. The total vehicle weight of the articulated vehicle utilized by the Bogotá TransMilenio system is approximately 30,000 kilos, and the maximum axle load is approximately 12,500 kilos. The vehicle volumes are also extremely high, so busways must thus be constructed to withstand this axle load on a frequent basis.

The weight of the vehicle is most acutely experienced at stations, where the vehicle's acceleration and deceleration increases the amount of force on the roadbed. The degradation of the roadbed from the weight and force of the vehicles is also a more serious problem at stations, where it can effectively render a station boarding area inoperable. As the roadbed level lowers, the station-to-vehicle interface will no longer align evenly and a step will form between the vehicle floor and the platform.

There are several options for the pavement structure with advantages and disadvantages for each. The following are three of these options:

1. Asphalt: Properly designed and constructed, asphalt pavement can last more than thirty years with surface replacement every ten to twelve years. This can be done without interrupting service, resulting in a smooth, quiet ride. For stations, rigid pavement is important to use to accommodate the axle loadings due to loaded buses and resist the potential pavement damage due to braking;
2. Jointed Plain Concrete Pavement (JPCP): This type of pavement design can have a life of thirty or more years. To ensure this life the pavement must have round dowel bars at the transverse joints, tied lanes by the use of reinforcing steel, and adequate thickness;
3. Continuously Reinforced Concrete Pavement (CRCR): Continuous slab reinforcement can add additional pavement strength and might be considered under certain design conditions. It is the most expensive option.

Asphalt pavement that is correctly designed can be a cost-effective alternative that provides the quietest and smoothest surface for BRT. The top layer (two inches) can be ground off after ten years and repaved. This can be done while service is maintained by doing the work in hours when the facility is closed. It can be ground down and still be used while the new paving takes place late at night. The asphalt alternative will still need concrete pads at the stations.

Other building materials can also be used, though they tend to be more expensive. Particularly in the city center, brick and other paving stones are frequently chosen for aesthetic reasons (Figure 23.8). These surface materials also send a useful visual signal to bus drivers that they are in a public space and must operate at safe speeds. Such materials are often able to withstand very heavy axle loads with regular maintenance.

The surface material will only endure as long as the base materials are intact. If water drainage is insufficient or if the base structure is inherently weak, then the surface material will quickly fail. A poor base design in Bogotá led to the premature failure of the concrete surface on the system's Avenida Caracas corridor. Bogotá has largely relied on a technique known as "white topping" for its concrete busways. The white topping method utilizes the existing asphalt lane as the base material for the

Figure 23.6. Damaged pavements along a TransMilenio corridor. *Karl Fjellstrom, Far East BRT*

Figure 23.7. Reinforced concrete, as in this example from the construction of the Quito Central Norte line, has much greater longevity than asphalt. *Lloyd Wright*

Figure 23.8. Bogotá's TransMilenio resurfaced the entire corridor in concrete and used brick in the city center for aesthetic reasons. *Carlosfelipe Pardo*

Figure 23.9. TransJakarta, in Jakarta, Indonesia, initially used only asphalt and suffered from major problems of the roadway sinking and deteriorating at the stations, so the roadbed at the stations was repaved using concrete. *ITDP*

Figure 23.10. For its first two corridors, Quito utilized asphalt on the runways, but used concrete at the stations. The latest corridor to be constructed in Quito, the Central Norte corridor, was built with concrete throughout the system. However, Quito's use of high-quality concrete on the runways of the Central Norte line contrasts with the relatively lower quality of the station infrastructure. *Lloyd Wright*

concrete surface material. White topping is thus a fairly economic option since it does not rely upon reconstruction of the busway base. However, the successful application of white topping depends on the strength of the base core, the integrity of the asphalt layer, and the level of cohesiveness between the asphalt and concrete layers.

23.4.2 Pavement Design

Pavement design must be preceded by investigations and assessments of the route through a center-line soil survey and an analysis of the existing ground conditions on-site. Further information is required on the prevailing climate, environmental implications, and geology. The availability and cost of materials such as bitumen and pigments for colorization may guide or influence the more detailed design elements. Once the design procedures for each type of pavement have been considered, a number of designs, excluding any potential variables, may result. Cost considerations may now be used to further the decision-making process.

The above process leads to a basic design of the layers for each pavement option, and this can be described as a virtual catalogue of the details of each pavement option. This product is essentially a series of drawings of how the layer works for each pavement option with a detailed description of each layer.

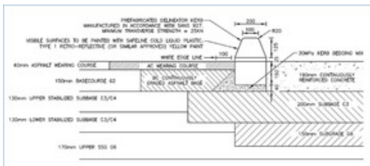

Figure 23.11. Typical pavement design for a moderately loaded concrete busway (on RHS of delineator curb), with general traffic lane (LHS of delineator curb). *HHO Africa*

Pavement joints are usually associated with concrete rather than asphalt pavements. This distinction is relevant when the layer design has progressed to the level of layout adaption. The type of jointing employed on the rigid concrete pavements is determined by the layout design.

Asphalt pavements or interlocking pavers do not require jointing, as they interact with various obstacles in a more flexible manner than rigid concrete. Flexible asphalt flows around corners and curves and does not expand or shrink, while concrete will cause difficulties if not designed with joints. Joints may be designed in a variety of ways to suit the local requirements.

The only viable options for flexible pavements are asphalt or interlocking pavers, while rigid pavement designs offer a wide range of variations to accommodate different design philosophies. Jointed concrete pavers or continuously reinforced concrete are only two of the examples of rigid pavement, but jointed concrete pavers are not ideally suited to the long straight lengths of roadway usually associated with BRT systems.

Color or texture differentiations can be applied to any type of design. The colorization of asphalt may occur through the application of a color layer or the final surface itself may be colored. The MyCITI system in Cape Town, South Africa, has experimented with limited sections of colored friction course applied over the asphalt layer on certain routes (Figure 23.12). The longevity of this type of surface treatment will be evident only through future evaluation.

Figure 23.12. Section of colored friction course with ultrathin asphalt on Cape Town's MyCITI system. *Aimee Gauthier*

Although concrete block pavers are not recommended for BRT routes, this type of surface treatment is usually colored and can then be used very effectively in demarcating non-motorized routes or intersection details.

Concrete is colored through the addition of pigmentation. The selection of a specific color and the level of pigmentation should be based on a certain level of performance record.

The design and function of continuously reinforced concrete (CRC) pavements is based on the placement of high-tensile steel predominantly in the longitudinal direction of a concrete pavement with minimum transverse steel. The main steel is placed in the center of the concrete thickness and is sized and spaced during design, along with the concrete thickness, strength, and pavement supporting layers, to limit the occurrence of distress in the forty-year design period under the specific loading to national distress standards that are contained in the software.

In the case of the BRT, the loading is the combination of approximately 12.5-ton main axles from both the 18-meter and 12-meter vehicles, as well as the approximate 7.5 tons from the steering axles. The pavement distress that is both limited and controlled during the design procedure is mainly the shattering of slabs (to around 2 percent) and the controlling of the transverse-shrinkage cracks to between 1- and 2-meter spacing over the entire pavement length.

Because of the lack of constructed-transverse joints over the pavement-lane length of concrete, which is approximately 3.7-meters wide, the concrete shrinks after placement. With the controlling influence of the longitudinal main steel, the transverse cracks (which are expected) form at approximately 1- to 2-meter spacing. These cracks are through the concrete full depth, but are kept tight by the longitudinal steel, which holds the entire system together. These cracks are not typically sealed by design.

At intersections where the CRC pavement lengths end, a series of end beams and floating slab panels are constructed to add friction to the support and to absorb small movements in the panel joints, which are dowelled and sealed.

23.5 Busway Colorization and Delineators

"Just as one can compose colors, or forms, so can one compose motions."

— William Calder, sculptor, 1898-1976

Overview

Enforcing the exclusive right-of-way of the busway is critical to achieving high vehicle speeds, but the means by which it is enforced are multiple and somewhat context specific. The infringement of the busway by private vehicles can do much to harm BRT speeds and overall performance (Figures 23.13 and 23.14). Even just a few vehicles can cause delays to the BRT vehicles. Further, once a few vehicles enter the system, then a breakdown in the appearance of enforcement can lead to mass violations of the exclusive space. The BRT Standard deducts points if there is any lack of enforcement of the exclusive right-of-way.

Enforcement that is self-enforcing is of great benefit to a BRT system, as it removes the burden of ongoing traffic enforcement, which has an associated additional operational cost. Delineation of busways together with colorization, will provide the greatest opportunity for self-enforcement, and the capital cost of these interventions will need to be weighed against ongoing traffic-enforcement costs along the entire corridor and ultimately the entire BRT network.

23.5.1 Busway Colorization

The aesthetic appearance of the lanes will have an impact on the public's image of the system. A smartly colored busway not only raises the image of the system but also creates a greater sense of permanence to the existence of the system. Colored lanes also create a psychological advantage over motorists, who may potentially block the busway when the lane must cross mixed traffic. Motorists are more likely to recognize that they are committing a traffic infraction by blocking a highly visible busway, especially when compared to the crossing of a lane that is indistinguishable from a normal mixed traffic lane.

Colorization of busway lanes can be accomplished by at least three techniques. First, a road surface paint can be applied to the busway. The advantage of simply painting the lane is that coloration can be accomplished when just the existing street infrastructure is being converted to a busway. The disadvantage of paint-based techniques is the duration of the color and the long-term maintenance costs. A second option is to utilize a colored emulsion within the asphalt or a pigment within the concrete mix. In this case the coloration is a permanent part of the surface material. As the surface begins to wear down, the color is retained. Thirdly, a colored epoxy

Figure 23.13. A significant number of private vehicles entering the Nagoya, Japan, busway. *Lloyd Wright*

Figure 23.14. Motorcycle illegally entering the busway in Pune, India. *Sujit Patwardhan and the Pune Traffic & Transportation Forum (PTTF)*

Figure 23.15. The coloration of busways does much to enhance the image and permanence of a BRT system. This photo shows a colorized busway in Nagoya, Japan. *City of Nagoya*

Figure 23.16. Colorized busway in Seoul, South Korea *Municipality of Seoul*

can be applied to the roadway surface and similar colored aggregate rolled into the epoxy surface. The epoxy surfacing will require regular maintenance (every two to five years), depending on the pavement loading, and has a relatively high application cost relative to the other options.

However, in general, the color finish of an emulsified and pigmented colored surface is less bright than a painted surface or epoxy. Thus, the aesthetic and marketing impact of an emulsified or pigmented surface will tend to be inferior to that of a painted or epoxy-coated surface.

Pigments can be used that produce a luminescent effect. A busway that is luminescent in the evening can be another way of attracting positive attention to the system. In Jakarta, the application of a red luminescent paint to the busway gives the system a majestic red-carpet appearance in the evenings.

The choice of color is highly specific to local preferences and local conditions. Further, a citywide color coding scheme should be considered as a mechanism to differentiate between various infrastructure purposes. For example, it might be useful to use a color for the busway that is different from the color utilized for the city's bike lanes. In this way, each set of sustainable-transport infrastructure has its own unique visual identity. In general, darker colored shades should be selected over lighter colors. With time, tire marks will tend to stain busways with light colors, while such wear marks will be less pronounced with dark colors.

It is important that when assessing the colorization technique, be it paint, emulsion, epoxy, or pigment, the full life-cycle costs be assessed. Initial costs of paints and epoxy coating are relatively high when compared to pigmentation and asphalt emulsions. Pigmented concrete should last for the full forty-year lifespan of the slab, whereas the application on an asphalt surface will need to be replaced every time an asphalt surface is replaced, that is, every two to seven years depending on the pavement loading.

Figure 23.17. Colorized concrete adjacent to epoxy-coated asphalt on Cape Town's MyCITI system. *Andre Frieslaar*

Figure 23.18. In Cape Town, South Africa, the separator between the busway and the mixed-traffic vehicles acts as a two-way bike lane and an island for pedestrians. *ITDP*

Figure 23.19. In Beijing, metal fencing is utilized at the separator. *Karl Fjellstrom, Far East BRT*

Figure 23.20. In Bogotá, the separator blocks are high enough to discourage intrusions by private vehicles but low enough to allow a BRT vehicle to leave the busway in case of emergency. *Carlosfelipe Pardo*

23.5.2 Busway Delineation

While some busways are not at a different grade than mixed traffic, most are separated by a physical barrier. This barrier can range from a fully landscaped median to simple blocks, bollards, curbing, permanent traffic cones, walls, metal fencing, or other types of barrier devices. The design of the separator should be sufficient to physically prohibit mixed-traffic vehicles from entering the busway.

A wall or large landscaped median will provide the most complete protection for the busway, but will make it difficult for vehicles to escape the busway in case of an obstruction (Figure 23.18). Likewise, metal fencing, as utilized in Beijing, makes it impossible for the BRT vehicles to leave the corridor in case of emergency (Figure 23.19). However, the Beijing fencing does have an advantage as a movable barrier. If the system developers later widen the Beijing busway, then the fencing is relatively easy to relocate.

It may be useful to design the separator to permit buses to leave the busway in case of an obstruction. For example, if a bus breaks down on the busway, it can be useful to allow other buses to leave the lane to avoid being blocked. Thus, a curbing separator that is high enough to dissuade private vehicles from entering but low enough to allow buses to safely leave the busway can be appropriate (Figure 23.20). One option is to employ a curbing material that is rounded on the busway side but forms a sharp edge on the private vehicle side.

If it is likely that at times buses will need to cross the separator, the divider should be built strong enough so as not to break under the wheels of the bus, and low enough so as not to damage the bottom of the bus. In Quito, for example, the stone blocks used as separators are frequently damaged and dislocated, creating hazardous obstacles in the roadway and undermining the barrier function (Figure 23.21). The breakdown of the barrier can then subsequently lead to private vehicles infringing upon the busway, creating safety hazards to both the private vehicles and the BRT customers (Figure 23.22).

Pedestrian safety and aesthetics are other considerations. There are several advantages to using a meter-wide median to separate the busway from mixed traffic if the right-of-way allows. A meter-wide median allows the median to also serve as a refuge for pedestrians crossing the road. A larger median tends to also provide the most aesthetically pleasing and complete demarcation of the busway. Curitiba's BRT system is separated by a low curb filled with decorative Portuguese stone, creating an aesthetically pleasing median that provides some pedestrian refuge (Figure 23.23). It was designed to facilitate crossing of the road anywhere along the corridor. In some places, motor-vehicle parking in Curitiba is also adjacent to this median divider rather than adjacent to the curb, so the parking lane becomes part of the barrier protecting the integrity of the busway.

Walls were originally used in the Santo Amaro/Nove de Julho corridor in São Paulo, which is not considered a BRT. The walls provided complete protection from encroachments. They were intended to make it impossible for pedestrians to cross the busway except at designated locations; however, the walls were not aesthetically pleasing and were impossible to escape if a vehicle broke down (Figure 23.24). They also created visibility problems for crossing pedestrians. The walls were eventually completely removed. This significantly improved the aesthetics of the corridor, but the busway now suffers from encroachments from motor vehicles.

In pedestrian areas, the use of a separator medium will depend on the volume of BRT vehicles and pedestrians. In some instances, successful pedestrian malls have been created with no discernible separation between the busway and the pedestrian walkway. Instead, vehicle speeds are reduced to allow drivers to react to any pedestrians straying into the busway. However, in high-volume operations, partial or even full separation may be appropriate. Along the Bogotá Alameda Jiménez route (also known as the "Environmental Axis") nicely designed bollards act to separate the busways from the pedestrian zone (Figure 23.25).

Busway Markings and Signage

Several mechanisms can be utilized to discourage private-vehicle use of the busway:

- Clear signage noting busway-use only (Figures 23.26 and 23.27);
- "Busway only" message imprinted on the busway surface (Figure 23.28);
- Distinctive coloration of the lanes;
- Median differentiation between the mixed traffic lanes and the busway.

Without such measures, there may be instances of inadvertent use of the busway. However, these measures may not be sufficient to deter intentional violations of busway usage, and CCTV tracking and fining of offenders may have to be considered to protect the integrity of the dedicated bus lanes. Thus, cooperation with the traffic police in monitoring and enforcing the exclusivity of the busway is also essential.

23.6 Utilities

> *"The hero is the one who kindles a great light in the world, who sets up blazing torches in the dark streets of life for men to see by. The saint is the man who walks through the dark paths of the world, himself a light."*
>
> — Felix Adler, professor, 1851-1933

Figure 23.21. In Quito, the separator blocks have been susceptible to damage and deterioration. *Lloyd Wright*

Figure 23.22. As more separator blocks erode, an increasing number of private vehicles intrude upon the busway, which can lead to serious accidents. *Lloyd Wright*

Figure 23.23. Curitiba's low-curb medians with Portuguese-style designs in the stones have enhanced the local urban environment. *ITDP*

Figure 23.24. Prior to its removal, the wall barriers on the São Paulo Nove de Julho corridor undermined the urban qualities of the corridor. *ITDP*

Figure 23.25. Along Bogotá's Alameda Jiménez, bollards separate the busway from the pedestrian walkway. *Diego Velazquez*

23.6.1 Electricity and Street Lighting

Relocation and Protection of Existing Electrical Services

The inclusion of BRT into an existing roadway corridor will often necessitate the relocation and/or protection of bulk electrical reticulation cables, and may require the relocation of existing streetlights. It is therefore important to appoint electrical engineering consultants within the design team to undertake this element of the infrastructure design. Establishing communication with electricity authorities at the preliminary design stage is also important, to foresee potential relocation.

Great care must be exercised in locating these underground bulk electrical cables at an early stage in the design process, as it may be too costly to relocate these cables, and this may impact the adopted route for the corridor. Experienced and certified electrical engineering subcontractors should undertake any unavoidable relocation of electrical cables. The relocation of electrical cables will add considerable cost to the installation of BRT lanes within a corridor, and allowance must be made for this in the overall cost estimate.

New Electrical Services

An electrical reticulation system is required along the corridor to provide electrical supply to stations, traffic signals, automated irrigation equipment, surveillance cameras, and streetlights.

Streetlights should be located within the corridor to ensure that they provide the required degree of lighting for safe traffic operations in all vehicle lanes, as well as sufficient lighting levels on all pedestrian sidewalks and bike lanes. The degree to which safe lighting levels are achieved will have a bearing on the perception of personal safety, and a direct bearing on nighttime patronage of the BRT corridor.

Street lighting with decorative poles and light fixtures can give the BRT corridors a distinctive signature, which can assist customers with system legibility.

The location of the bulk electrical-reticulation cables should be under the sidewalks or bike lanes, to minimize the cost and impact of works associated with rectifying damage to cables, cable servicing, or future cable connections.

Other electrical connections required are signalized intersections and automatic irrigation systems.

Figure 23.26. Signage is a basic mechanism to designate an exclusive busway. This example is from León, Mexico. *Karl Fjellstrom*

Figure 23.27. Signage in Jakarta, Indonesia *Karl Fjellstrom*

Figure 23.28. Painted information on the busway surface is also an option, as shown here in an example in León, Mexico *Karl Fjellstrom*

23.6.2 Water and Sewer Connections

Each station along the corridor will require connections to the closest water and sewer lines. Once the station locations have been finalized, the water and sewer connections can be identified, applied for through the utility agency, and designed.

23.6.3 Telecommunications and Surveillance Infrastructure

Draw chambers linked by multiple ducts should be designed into the corridor to ensure that the existing and future requirements for telecommunication and surveillance cables do not require sidewalk excavations along the BRT corridor. Each station should be linked into the telecommunication and surveillance cable network, as well as any mast-mounted surveillance cameras placed along the corridor.

23.6.4 Other Utilities

Often other utilities are encountered in the road reserve. These may be gas lines, oil pipelines, oil effluent lines, etc., and all pose a challenge to the design engineer.

23.7 Pedestrian Sidewalks and Bike Lane Design

> *"The way I see it, I can either cross the street, or I can keep waiting for another few years of green lights to go by."*
>
> — Camryn Menheim, actress, 1961–

23.7.1 Integration at Intersections

Whether shared or segregated facilities are provided for cyclists and pedestrians, both modes need to interact safely to cross at intersections. This can be achieved by providing signage and markings on the bike lane to indicate the end of an exclusive zone and the start of a mixed/intersection zone.

Curb lines should be dropped over appropriate lengths to allow bicycles, wheelchairs, and strollers to access the pedestrian crossings from the sidewalk zone (Figure 23.29).

Figure 23.29. Dropped curb line at BRT station access and refuge islands in Guangzhou, China. *ITDP*

23.7.2 Bicycle and Pedestrian Grade Separation

There are two conditions under which to consider grade separation: (1) To facilitate closed transfers between two station platforms that are physically separated; (2) To cross multilane arterials, for safety. However, these facilities are expensive, and hence should be used only where necessary. At-grade crossings are preferred because they help integrate the BRT system with the urban environment and make the system easily accessible to special needs customers. The width of the over/underpass and ramps must be determined by peak customer flows. To ensure universal accessibility, ramps are preferable to serve these over/underpasses, but gradients should not exceed 1:15, and landings should be provided every 1.5 meters to allow wheelchair customers opportunities to rest (Figure 23.30). In some locations where personal safety is an issue, some extra width to include commercial activities is recommended for underpasses. However, this may be costly.

Figure 23.30. Pedestrian ramp along the Bangkok, Thailand, BRT. *Karl Fjellstrom, Far East BRT*

23.8 Urban Design and Landscaping

> *"The smallest patch of green to arrest the monotony of asphalt and concrete is as important to the value of real estate as streets, sewers, and convenient shopping."*
>
> — James Felt, NYC Planning Commission, 1903–1971

23.8.1 Urban Design

BRT is focused on moving passengers through a series of public spaces that are safe and accessible to all. The introduction of landscaping and urban design features can greatly enhance the experience (Figure 23.31).

BRT terminals and station environments benefit from urban design and hard landscaping by creating vehicle-free pedestrian zones that offer safe, separated transfer between modes of transport or access to further non-motorized routes. Separation occurs with the use of bollards, low-level fences, benches or other street furniture, or by uniquely textured or colored surface treatments such as pigmented pavers or enhanced paving patterns (Figure 23.31).

The transition between various public areas is delineated by changes in texture or color, even transition strips in areas where bicycles and other faster modes of non-motorized transport are brought into a pedestrianized area. Appropriate signage and information displays complement the urban design and add in the ordered use of such plazas or public places.

Figure 23.31. Textured and colored surface treatments help delineate pedestrian zones from roadways in Bogotá's BRT corridor. *Karl Fjellstrom, Far East BRT*

23.8.2 Landscaping

BRT systems should add to the aesthetic quality of a city's public space. Only the station footprint may require landscape alterations. The other areas can be enhanced with additional plantings (Figure 23.32). Greenery may also be an option as a divider between the BRT system and other traffic lanes.

The linear dimensions of bus routes can be softened and separated from private-vehicle lanes and other land uses with strips of low-level planting. Planting serves to alleviate the visual impact of hard road surfaces in generally densely populated and built urban surroundings.

Trees and plants can also provide climatic protection to pedestrian and bicycle corridors linking with the BRT system. In tropical climates, trees and vegetation can even help partially cover the station structure itself in order to reduce inside temperatures. Likewise, the retention of greenery along a BRT corridor will offset the overall urban heat-island effect, which causes urban areas to exhibit heightened temperatures (Figure 23.33). Additionally, if curb cuts and graded connections are made between impervious surfaces and adjacent vegetation, the greenery can serve to collect stormwater runoff, allow for infiltration into the water table, and mitigate flooding (as discussed earlier in Section 23.3.3 Stormwater and Drainage).

Figure 23.32. In most cases, the median area along a BRT corridor can remain as green space. *Karl Fjellstrom, Far East BRT*

The development of the BRT system may actually provide an opportunity to create new green spaces in the city. A median can be converted from a dull concrete separator to something dominated by greenery at the same time that the busway is being constructed. In the case of BRT tunnels, there can be the opportunity to create new public spaces. In some instances, the covering of the underpass presents the opportunity for plantings and green space (Figure 23.34).

Figure 23.33. Busway greenery, as shown in this example from Nagoya, Japan, can help mitigate the urban heat island effect. *Lloyd Wright*

There is a science to choosing the right plants and trees within the landscape plan. The height of the tree and its eventual branches will have to clear the height of the BRT vehicles. Also, the tree's root structure should grow vertically rather than horizontally. Root structures that grow horizontally beneath the surface will likely cause busway materials to crack and buckle. Each type of tree has inherent growth characteristics, and thus some research is needed (or experts must be hired) to determine which is most appropriate for the busway environment. The expected life of the tree is also a key factor, since it can be quite disruptive to the system to require a new set of trees after only a few decades.

Local weather conditions will also determine the desirability of whether deciduous trees or coniferous trees are appropriate. A deciduous tree will shed its leaves during the colder seasons, and thus more heat and sunlight will penetrate to the ground during this period. A deciduous tree is thus part of an effective passive solar strategy for cities that experience both warm and cold seasons. However, one disadvantage of deciduous trees is the possible need to clean fallen leaves from the BRT infrastructure. By contrast, cities without cold seasons may prefer trees that do not shed leaves. These types of trees will provide shade year-round in consistently tropical or warm climates.

Figure 23.34. The covering of a new BRT underpass creates green space along the Central Norte corridor in Quito. *Lloyd Wright*

Landscaping should take note of existing underground services by limiting the use of species with intrusive root systems. Planting should also be designed being mindful of road infrastructure requirements, such as sight lines and maintenance requirements. Landscaping must be robust and not susceptible to the harsh micro-climatic environment experienced in close proximity to roadway infrastructure. Indigenous species are, as so often proven, the only sustainable option when designing landscaping associated with public transport, as irrigation is not always an option along lengthy public transport corridors. Indigenous species create fewer problems regarding invasive species and are also typically more suited to local soil and water conditions. Priority should be given to selecting indigenous trees rather than species that are not common to the area.

24. Intersections and Signal Control

> *"A bland smile is like a green light at an intersection, it feels good when you get one, but you forget it the moment you're past it."*
>
> — Douglas Coupland, novelist, 1961–

The objective of this chapter is to equip the reader with tested practical knowledge to design and evaluate the layout and operation of intersections along BRT corridors. Intersections can cause significant delays in BRT operations, particularly by hindering station access, and they are the points where the BRT project has the largest perceived impact on mixed traffic and walking.

An important strategy to improve the performance of intersections to better accommodate public transport, pedestrians, and other vehicles is to restrict general-traffic turning movements at intersections. *The BRT Standard* awards up to 7 points for good handling of BRT movements through intersections, with the most points given to systems that prohibit all turns across the busway.

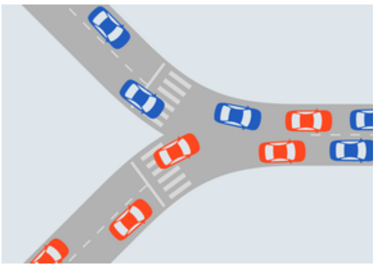

Figure 24.1. The conflict between vehicles in a Y junction indicates that this is an intersection. *Elebeta.*

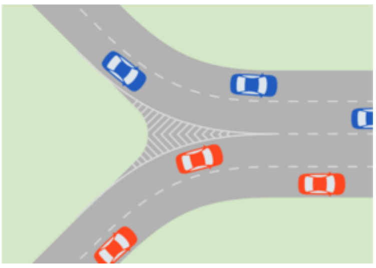

Figure 24.2. A channeled Y junction without conflicts does not have the basic element that defines an intersection. *Elebeta.*

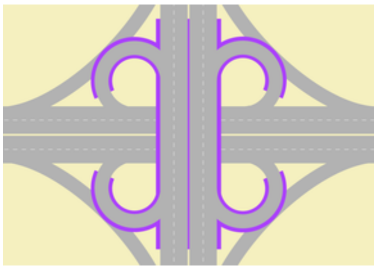

Figure 24.3. Separated-grade solutions can eliminate intersections. *Elebeta.*

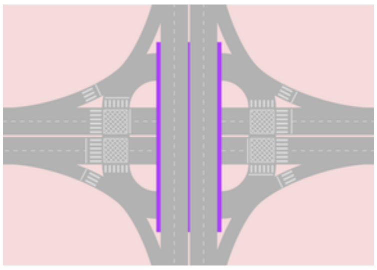

Figure 24.4. Depending on space restrictions, separated-grade solutions may not eliminate intersections. *Elebeta.*

Table 24.1. BRT Standard: Intersection Treatments

Treatment	POINTS
Turns prohibited across the busway	7
Signal priority at intersections	2
No intersection treatments	0

This chapter also discusses the placement of stations relative to intersections along the corridor and the treatment of public transport vehicle turning movements, which are desirable to have but can also harm an intersection's performance. Other elements of intersection treatments that are discussed include: signal prioritization technology for public transport vehicles, priority in roundabouts, narrow sections with mixed traffic, and techniques for keeping pedestrians and cyclists safe.

Definitions that pervade the whole chapter are laid out in the first section; the second section covers the general approach to intersection problem solving; and the subsequent sections discuss different tools to improve intersection efficiency, particularly when grade separation is available.

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24.1 Basic Concepts

> *"Change means movement. Movement means friction. Only in the frictionless vacuum of a non-existent abstract world can movement or change occur without that abrasive friction of conflict."*
>
> — Saul Alinsky, political activist, 1909–1972

24.1.1 About Intersections

The intersection is the area where two or more roads meet each other. The use of the word in Traffic Engineering technical language implies “roads for vehicles” and “at the same level,” but very often the expressions “at-grade intersections” or “single-grade intersections” are used to demonstrate the same concept. For flyovers and underpasses the term used is “interchange” or “separated-grade interchange.” When more than one mode is involved, the common traffic engineers’ wording is “crossing” as in “pedestrian crossing” (one of the roads is assumed to be a roadway); recently the term *multimodal intersection* has also been applied.

By this definition, an intersection implies conflicts of vehicles attempting to use the same space and can refer to a unidirectional T-shaped or Y-shaped confluence area. The conflict in this area becomes clear as there is not enough space to accommodate the two incoming flows as they move into the exiting stream in a congested situation (Figure 24.1). Conversely, a channeled Y-shaped junction may not be an intersection (Figure 24.2).

Because the majority of cases where two or more roads meet include many possible turning movements (not all conflicting), intersections can be seen as linking several other adjacent intersections as well—that is, an intersection is a larger conflict area that is composed of smaller conflict areas (or smaller intersections).

Footpaths (or “roads for people”) are more important to accessibility in populated areas, therefore roadways are usually constructed between footpaths. When two roadways meet, several walkway crossings are needed. So a multimodal intersection encompasses a larger area than just the roadways where people conflict in trying to use the same space. (To keep things in perspective, let us remember that drivers and passengers are people.)

The more conflicts there are in an intersection or in a crossing, the greater amount of time people will need to cross it safely. If there is a low frequency of vehicles arriving at the intersection where pedestrians, cyclists, or other vehicles want to cross, then those wanting to cross can do so safely without compromising travel time by what is known as “passage negotiation,” or waiting until the way is clear to cross. If over the years the vehicle frequencies throughout the day rise to the point where queues occur frequently or with enough intensity that the time required for pedestrians to cross safely becomes too long, then this is the moment to intervene.

An intervention is justified by comparing the present value for the cost of its implementation, maintenance, and operation against the present value of its benefits. Time savings is the easiest to assess of these benefits, assuming a safe operation and that costs are directly related to benefits, such as fuel consumption and pollution.

Interventions start with zebra crossings and yield signs. Larger interventions involve channeling the vehicles and creating refuge islands. These are methods to clearly divide an intersection into several smaller components, improving traffic safety and reducing the overall delay; roundabouts or mini-roundabouts are ways to channel vehicles as well. Above a certain threshold for throughput, traffic lights are required, and their integration into intersections may grow in really complex ways to accommodate all conflicts. To accommodate still more throughput, methods to divert traffic and restrict direct movements come into play, until finally grade separation of the conflicting flows becomes necessary.

In theory, a separated-grade traffic solution eliminates intersections (Figure 24.3), but in practice, due to space restrictions, intersections can also remain (Figure 24.4).

24.1.2 General Concepts

The concepts we present here are mostly about understanding the equations related to delay and queue sizes in signalized intersections, but note that these sections are not meant to be a comprehensive reference for these issues. The reader may want to further investigate the concepts of traffic density and traffic headway and how they relate to average traffic speed and flow. We provide further references for traffic signals in the bibliography.

We emphasize that when applying formulas attention should be given to units and unit conversions. The appropriate unit of time to observe phase times in traffic lights is the second, which can be used to observe the time to walk or ride a few blocks; meanwhile, we better perceive speeds in kilometers per hour (kph) or alternatively in miles per hour (mph). It is useful to remember that 1 hour is the same as 3,600 seconds and 1 mile is approximately 1.6 kilometers and 1 kilometer is approximately 0.6 miles.

24.1.2.1 Cross-Traffic Turn and Curbside Turn

For this chapter we have excluded the expressions “right turn” and “left turn” because they have different meanings in differently oriented systems. We have chosen to adopt “cross-traffic turn” and “curbside turn” instead.

Cross-Traffic Turn: a vehicle movement to exit the current traffic stream direction that requires crossing the opposite-direction traffic flow. If a busway or a bike lane is present near the median, there is also conflict with BRT vehicles or bicycles going straight in the same way and in the opposite way.

Curbside Turn: a vehicle movement to exit the current traffic stream direction that normally does not cross any vehicle flow. This movement conflicts with people on the sidewalk in both ways and, if the road is parallel to a curbside busway or a curbside bike lane, there is a conflict with that traffic as well.

U-Turn: a vehicle movement to join the traffic stream travelling in the opposite direction of the vehicle’s current flow. Depending on the width of the median this movement can be less conflicting than the cross-traffic turn or more conflicting, since the speed has to be lower to make a U-turn. For this reason, U-turns are sometimes prohibited at existing intersections and promoted away from the intersection by creating another intersection exclusively for the U-turn. Due to road geometry restrictions or other considerations, this movement may eventually be channeled to start from a waiting area from the curb side of the road as shown by the pink car in Figure 24.5, in which case it will conflict with both flows in the same way that a cross-traffic turn from a perpendicular street would.

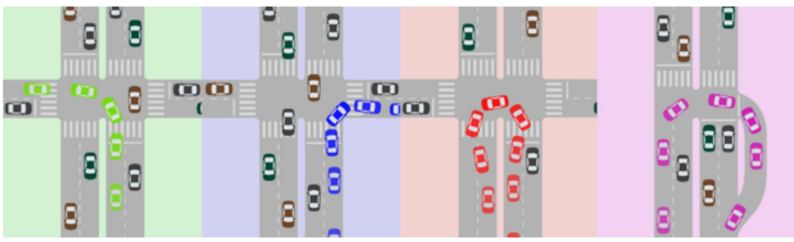

Figure 24.5. Example of a cross-traffic turn (green car), a curbside turn (blue car), a U-turn without space (red car), and a U-turn with space (pink car) for right-hand-oriented driving in China, the United States, Brazil, and most of Europe. *Elebeta.*

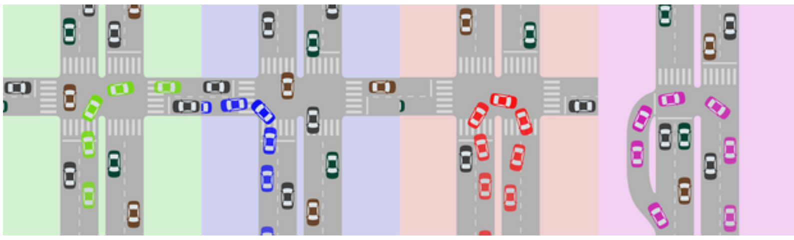

Figure 24.6. Example of a cross-traffic turn (green car), a curbside turn (blue car), a U-turn without space (red car), and a U-turn with space (pink car) for left-hand-oriented driving in India, Indonesia, South Africa, Tanzania, Australia, and the United Kingdom. *Elebeta.*

24.1.2.2 Speed

For the application of the concepts outlined in this chapter, speed is defined as the average traffic speed of all vehicles in a segment, for which we use the letter V that is derived from the word velocity. Speed is measured by the mean time of all vehicles crossing the segment divided by the segment extension. Under our modeling intents (or capacity evaluation) it can be imagined that all vehicles are moving at that speed.

Still, when looking at the broader concept of speed—the ratio of motion expressed in distance per unit of time—it is useful to remember that for a given segment distance (Dsegment), knowing the speed (Vsegment) is equivalent to knowing the travel time it takes to make it through the segment (Timesegment) and vice versa, as the equivalent equations show:

Eq. 24.1

$$V_{\text{segment}} = \frac{D_{\text{segment}}}{\text{Time}_{\text{segment}}} \leftrightarrow \text{Time}_{\text{segment}} = \frac{D_{\text{segment}}}{V_{\text{segment}}}$$

Where:

- V_{segment}: Velocity of the segment;
- D_{segment}: Segment distance;
- $\text{Time}_{\text{segment}}$: Travel time it takes to make it through the segment.

24.1.2.3 Delay

Delay is the additional travel time, if not explicit, that is added onto the base reference of travel time, which is an ideal situation without any conflicts where the passenger, pedestrian, or driver is the only user of the road (no other drivers, pedestrians, users, or traffic lights).

24.1.2.4 Passenger Car Unit (pcu)

A passenger car unit, or pcu, is a reference used to standardize different vehicle types by a common denominator. The conversion factor from a certain type of vehicle to a passenger car unit depends on the application intended after the conversion, when it is eventually calibrated for a specific use in a given situation. For example, this could be when consideration is given to the stress placed on the pavement or the potential of added congestion. Other considerations include whether the setting is an urban environment or along a highway, on a ramp, or in plain terrain.

In general, a motorcycle, for instance, tends to have an equivalent of less than one vehicle, and a mini-bus is equivalent to more than one vehicle; the larger and heavier the vehicle, the higher the number of vehicles to which it is equivalent.

24.1.2.5 Flow

Traffic engineering borrows concepts from fluid mechanics and uses "flow rate" as a measure of traffic intensity. From that definition, the word *rate* is commonly dropped and "flow" alone is treated as the physical quantity expressed by the number of vehicles crossing a transversal section (or cross section, like a stop line) during a certain time interval. Flow is usually represented by the letter q in equations, but we will avoid that here and use the full word instead.

It should be noted that the use of the word *volume* to express the same idea is accepted, despite being far from the original definition conceptually (in fluid mechanics the original comparative terms are *volume flow rate* and *mass flow rate*; the latter is more an appropriated reference as the vehicles can be somewhat compressed). Volume should refer to the total number of vehicles in the same way a liter refers to volume and liters per second refers to flow in hydraulics. The term is especially common in the expression "volume/capacity ratio."

Eq. 24.2

$$\mathrm{Flow}_{\mathrm{vehicles}} = \frac{Number_{\mathrm{vehicles}}}{\mathrm{Time}}$$

Where:

- $\mathrm{Flow}_{\mathrm{vehicles}}$: Number of vehicles crossing a transversal section (or cross section, like a stop line) per a given time;
- $\mathrm{Number}_{\mathrm{vehicles}}$:Number of vehicles;Time = Length of time the flow of vehicles is measured.

Flow can also be expressed for pedestrians, bicycles, or even passengers (per hour).

24.1.2.6 Capacity and Saturation

The capacity (flow rate) of a segment is given by the lower capacity of a section within it, and the term *bottleneck* for the lower-capacity section expresses this concept quite well.

The capacity of a section is defined as the maximum flow a section can handle under prevailing use. It is subject to the number of lanes, width of lanes, ramp inclination, cultural driving behaviors, and the use of surrounding areas, such as parking and stopping regulations, the presence of an intersection or traffic light ahead, and the existence and frequencies of bus stops.

Capacity can easily and objectively be measured, but some of the influential factors listed above cannot. Many models have been developed to improve the forecast of road capacity based on the knowledge of design and use of surroundings, but even the more detailed simulators need careful calibration to correctly represent driver behavior differences that tend to be unique to each place.

The simpler models do not commonly fit exactly to theories, either, and they are usually adjusted by experimental evidence. These models resort to the concept of **basic saturation flow**.

Basic saturation (flow rate) is the capacity for a section of a given standard ideal roadway, divided by the number of lanes of that given standard roadway. It is commonly expressed by "s0."

Capacity and speed are interdependent and the maximum flow does not happen when speeds are at their highest. This is because the distance a driver maintains from another vehicle in front of him or her increases more proportionally than the speed increases. In a section of unconstrained road, the maximum speed capacity occurs between 60 and 80 kilometers per hour.

Based on extensive observations, capacity models then define a way to forecast a **saturation flow** by multiplying the basic saturation flow by adjustment factors to account for various nonideal geometric, traffic, and environmental conditions of a given section, such as the number of lanes, lane width, presence of heavy vehicles, grade, parking facilities, bus blockage, area type, turning traffic along the segment, radius of turnings, pedestrian crossing traffic, but not considering traffic lights.

Saturation is commonly written as "S" in equations, but here we use "SaturationFlow" to avoid confusion with demand saturation level, usually "X," which represents the relationship between demand and capacity for a given infrastructure element such as an intersection or a station.

Eq. 24.3

$$\text{Saturation}_{\text{Flow}} = \text{basicsaturationflowperlane} * NLanes * (f_{\text{geometry}} * f_{\text{traffic}} * f_{\text{parking}} * f \ldots)$$

Where:

- SaturationFlow:Maximum flow a section can handle under prevailing use;
- basicsaturationflowperlane: Capacity of a given standard ideal roadway section;
- NLanes: Number of lanes;
- f_{geometry}: Adjustment factor to account for nonideal geometric conditions;
- f_{traffic}: Adjustment factor accounting for nonideal traffic conditions;
- f_{parking}: Adjustment factors to account for nonideal parking conditions;
- $f \ldots$: Other adjustment factors to account for various nonideal conditions.

Saturation (flow rate), therefore, is the capacity of a section that is **not** under the influence of a traffic light. For a section that approaches a traffic light, saturation is the capacity assuming a constant green, which would equal the flow observed during the queueing discharge (after allowing a few seconds for the flow to become regular again). For this reason saturation may be called discharge (flow rate). When working in a specific location, the saturation of sections can be measured, so the resulting product of all these factors is known.

As a practical rule, even slightly distorting the concept of ideal conditions for urban environments will yield an observed saturation of 1,800 pcu/hour for a lane. For the purpose of capacity, measuring an 18-meter articulated bus is equivalent to 2.5 pcu. So in a busway the saturation per lane is 720 articulated buses per hour.

Eq. 24.4

$$\text{SaturationFlow} = \text{CapFlow}_{\text{away-from-intersectioni}} = \text{saturationflowperlane} * \text{NLanes}$$

Where:

- SaturationFlow: Maximum flow a section can handle under prevailing use;
- $\text{CapFlow}_{\text{away-from-intersection}}$: Maximum flow of a section away from an intersection;
- saturationflowperlane: Maximum flow a given lane can handle;
- NLanes: Number of lanes.

24.1.2.7 Continuity

Although no direct formula application about continuity is used in this chapter, one basic property of an intersection is that all the flow into the intersection has to exit the intersection.

24.1.3 Traffic Signal Concepts

Traffic lights are a very common intersection management tool in business districts where the BRT corridor design is likely to face more challenges. Traffic light controllers can be coordinated and actuated (use detection) by utilizing more or less complex technology and algorithms. A lot of research and progress has been made in the past thirty years, but the practical use of the research is still relatively limited. The concepts presented in this chapter are helpful in understanding BRT design requirements to program traffic lights, be it on simple controllers or as policy delimiters to more complex systems.

Traffic lights eliminate some of the negotiations between vehicles on arrival by determining which movements may proceed at a given moment. Traffic lights may allow conflicting movements, usually not all of them are intense; pedestrians crossing the transversal street are a common one. By reducing negotiations, traffic lights prevent vehicles approaching the intersection from reducing their speeds, raising the time each vehicle spends in the intersection itself (which, by definition, is an area). Traffic signals increase the throughput while keeping intersections safe.

24.1.3.1 Phase

One set of movements that is allowed to occur at the same time is called a signal phase. It should be noted that some movements are allowed during several phases; in many countries, allowing curbside turns at all times is the standard. Some may use expressions like “allowing a particular turn in the beginning of phase two” when technically it should be “adding a short phase before phase two where a particular turn will be allowed.”

24.1.3.2 Effective Green Time (T_{green})

The phase duration (or length) refers to its “effective green time,” which is the time vehicles are considered effectively moving, which may start a little after the green light is given and end in the middle of yellow lights (where such are used), or in the first moments of red (clearance interval). For this chapter, where queueing and intersection capacity are evaluated, green time means “effective green time.”

24.1.3.3 Cycle Time (T_{cycle})

Excluding situations where special phases are activated by detectors, the traffic signals in an intersection repeat the order of the phases successively in cycles. The cycle time can be measured as the time between when the green light is given until the next time it is given again (after it has changed to red once). In this chapter, “cycle time” alone refers to a traffic light cycle time (route cycle times are not discussed).

24.1.3.4 Red Time (T_{red})

For the interest of intersection capacity and queueing evaluation, red time means cycle time minus (effective) green time.

24.1.3.5 Lost Time

Lost time is the period between the end of the effective green of a phase and the start of the next. Lost time depends on the signal programming for yellow times and overlapping red (clearance red). It also depends on the enforcement policy and driver behavior (longer lost times are associated with safer intersections), but for the given conditions, there are fixed values.

We refer to lost time as the total lost time per cycle, but lost time can be further split into the start-up and clearance for each phase, each of them being nearly two seconds. One can generally consider that a four-phase signalized intersection has lost a time of sixteen seconds, meaning that the total lost time *each cycle* is sixteen seconds.

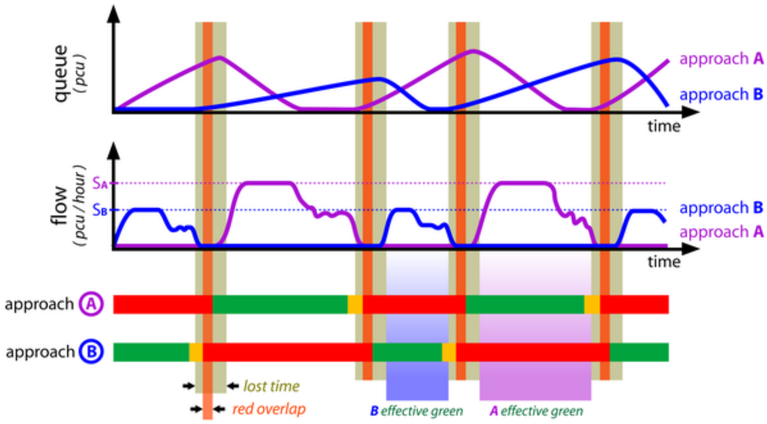

Figure 24.7. For each approach during effective green time, flow starts at saturation until the queue dissolves or the effective green time turns off. And for each approach during red time, there is queue formation, and lost time happens when neither approach has flow. *Elebeta.*

24.1.3.6 Traffic Light Plans

In the same way for intersections in general, the higher the number of turning movements there are in an intersection with traffic lights, the more difficult it is to serve them all. Some movements can happen simultaneously, while some cannot. Reducing the number of phases implies that the number of lanes allowing movements on any phase will be higher, and it also implies that the intersection will have a higher overall throughput (see Section 24.5: Restricting General Traffic Movements).

The optimal phase times in a signalized intersection are such that the cycle time is as brief as possible without growing queues. Having the minimum cycle is optimal because it implies the shortest possible red times, which is similar to the shortest possible waiting times. In order to not have queues, if demand and saturation flow is known for each approach, the minimal number of effective green seconds per hour required can be calculated for an approach that does not form queues. If this is calculated for all approaches, the minimum effective green time for that intersection as a whole is known, and the total number of effective green seconds in an hour shall be way below 3,600, leaving the difference to be designated as lost time.

Contradictory as it seems at first, the best signal programming is such that it has the maximum lost time per hour, because that implies the highest number of cycles per hour. For example, if required green time for vehicles in the intersection is 3,200 seconds, the intersection is close to collapsing. This is because there are only 400 seconds per hour to allow pedestrian crossings and lost time still needs to be added. Assuming there are two vehicle phases plus a minimal pedestrian phase of 6 seconds, and an extra 4 seconds for each phase change, each cycle will need an additional 18 seconds (= 6 + 4 * 3) beyond vehicle green time. This extra time for all cycles during one hour is defined as 400 seconds, so the intersection can have a maximum of 22 complete cycles (= 400 / 18) or 162 seconds (almost 3 minutes) of cycle time.

Time of day should be taken into consideration because infrastructure that is sized based on the peak use may eventually become underused at other times of the day. Traffic signal timing plans for peak moments could lead to unnecessary delays at other points during the day. Traffic light plans should change throughout the day as demand changes; one extreme example of this is shutting down a signal during late night and early morning hours (or switching to a yellow blinking signal).

Traffic signal programming shall change throughout the day, so that green and red cycle times must change based on different programming for the time of the day (as well as week and season) and, where available, change based on traffic detection applied to parameters in the programming for that moment. When we discuss these features as fixed, we must understand them as the limiting parameters for the traffic controller that allow adaptive changes based on detection.

We look at infrastructure layouts associated with the traffic-signal plan for the peak hours of the day for each flow, and if there is enough capacity during this time frame, then there certainly will be in others, although traffic signal programs need to be different to minimize travel times. To represent the peak, we use and measure the busiest hour of the day for the given flow (as a reminder: we survey data with smaller intervals than one hour, so a given measure of the busiest hour might have happened from 7:15 a.m. to 8:15 a.m., for example).

24.1.3.7 Traffic Signal Coordination

Coordination is the synchronization of several traffic lights along a path to produce a "green wave" for that route, eliminating waiting while still keeping the required/projected capacity for all flows. With proper planning, it is possible to coordinate several routes (including pedestrians and to some extent, public transport) in the same area by establishing priorities among them. Eventually, routes with lower priority end up having more breaks in their green waves and some intersections will need to have irregular green times for the transversal flows (still fixed in a larger cycle measure: one long, one short, one long, one short, and so on).

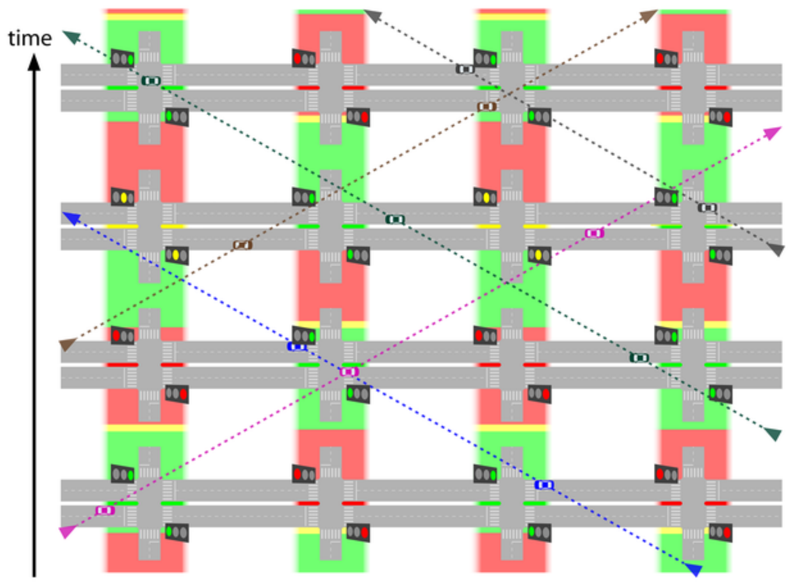

Figure 24.8. Traffic light coordination can provide green waves to several routes by synchronizing the opening of green phases with the flow speed. Image *Elebeta*.

24.1.3.8 Detection or Actuation

Actuation is the form in which the user informs his or her presence to a traffic signal controller, for example:

- A pedestrian pressing a button to request a crossing (Figure 24.9);
- A vehicle passing over a magnetic induction loop buried in the traffic lane (Figure 24.10).

Actuation can be used in many ways, isolated or in conjunction with traffic control signs:

- Add a required phase for pedestrians or cross-traffic turns (semi-actuated control);
- Determine the length of every phase (full-actuated control);
- Activate a preestablished plan that will eventually be coordinated (actuated pre-time control);
- Establish public transport priority (see Section 24.3.2: Active Signal Priority);
- Input data about movement requests to a central traffic control that computes several inputs at once to select a plan of operation;
- Input data about movement requests to central controllers that adjust traffic signal parameters by evaluating alternative strategies for the requirements in real time (adaptive control, among which "Split Cycle Offset Optimization Technique" or "SCOOT model" is a common reference for this type of adaptive central controller).

Figure 24.9. As an example of actuation, pedestrians may "call the controller for a service" by pressing a button, as in this crossing in São Paulo. *Jonas Malaco.*

Figure 24.10. To feed São Paulo's central traffic control, vehicles' metallic surfaces are detected when approaching an intersection. *Arthur Szász.*

24.1.3.9 Intersection Capacity

Considering the definition of an intersection as the area where vehicles come into conflict, the capacity of the intersection should be measured as the total number of (equivalent) vehicles that cross it, tallying the total of all the movement.

But for the purposes of this chapter, intersection capacity refers to the entrance section (the approach or stop line) of only the road segment being analyzed. Furthermore, we are particularly interested in signalized intersections, assuming that the corridor where the BRT is placed has preference at smaller non-signalized intersections that do not cause other meaningful interference to mixed traffic or to BRT, which is not included in the basic saturation flow measures.

24.1.3.10 Relative Green (K_{green})

The proportion of time allowed by a green light for a flow to cross an intersection *(Kgreen)* is given by the equation below.

Eq. 24.5

$$K_{\text{green}} = \frac{T_{\text{green}}}{T_{cycle}}$$

Where:

- K_{green}: Relative green, or the proportion of time given by a green light for a flow to cross an intersection;
- T_{green}: Time given by a green light for a flow to cross an intersection;
- T_{cycle}: Time given by the signal cycle.

The previous and following equations apply to fixed cycles, but to measure the relative green of a coordinated traffic light with irregular times, one should consider the total green time along a repetition cycle (short, long).

24.1.3.11 Relative Red (K_{red})

The proportion of time that traffic is held by a red light in a given approach *(Kred)* is given by the equation below.

Eq. 24.6

$$K_{\text{red}} = \frac{T_{\text{red}}}{T_{cycle}}$$

Where:

- K_{red}: Relative red, or the proportion of time that traffic is held by a red light in a given approach;
- T_{red}: Time given by a red light holding traffic from crossing an intersection;
- T_{cycle}: Time given by the signal cycle.

By the relation of this definition and that of red time, $T_{\text{red}} = T_{\text{cycle}} - T_{\text{green}}$, we can conclude that $T_{\text{red}} + T_{\text{green}} = T_{\text{cycle}} \leftrightarrow \frac{T_{\text{red}}}{T_{cycle}} + \frac{T_{\text{green}}}{T_{cycle}} = \frac{T_{\text{cycle}}}{T_{cycle}} \leftrightarrow K_{\text{red}} + K_{\text{green}} = 1$ and therefore:

Eq. 24.7

$$K_{\text{red}} = 1 - K_{\text{green}}$$

Where:

- K_{red}: Relative red, or the proportion of time that traffic is held by a red light in a given approach;
- K_{green}: Relative green, or the proportion of time given by a green light for a flow to cross an intersection.

Eq. 24.8

$$K_{\text{green}} = 1 - K_{\text{red}}$$

Where:

- K_{red}: Relative red, or the proportion of time that traffic is held by a red light in a given approach;
- K_{green}: Relative green, or the proportion of time given by a green light for a flow to cross an intersection.

24.1.3.12 Capacity at a Signalized Intersection Approach

The capacity at a signalized intersection approach is simply the saturation flow of the approach multiplied by the proportion of time it is in operation. Unless stated otherwise, intersection capacity refers to this.

Eq. 24.9

$$\text{CapFlow}_{\text{intersection}} = \text{saturationflowperlane} * \text{NLanes} * K_{\text{green}}$$

Where:

- $\text{CapFlow}_{\text{intersection}}$: Capacity at a signalized intersection approach;
- saturationflowperlane: Maximum flow a given lane can handle;
- NLanes: Number of lanes;
- K_{green}: Relative green, or the proportion of time given by a green light for a flow to cross an intersection;

The capacity away from the intersection can be considered by this definition, if one assumes that K_{green} is equal to one—that is, an uninterrupted flow.

Eq. 24.10

$$\text{CapFlow}_{\text{intersection}} = \text{saturationflowperlane} * NLanes$$

Where:

- $\text{CapFlow}_{\text{intersection}}$:Capacity at a signalized intersection approach;
- saturationflowperlane: Maximum flow a given lane can handle;
- NLanes: Number of lanes.

24.1.3.13 Demand Saturation Level (X)

Demand saturation level is a dimensionless form of expressing demand by comparing it to the maximum that the infrastructure under analysis can serve. Applied to a road section, it is given by demand flow (how many vehicles want to cross the section for the duration of time interval) over the saturation flow. This means that if the section is the entrance to an intersection, the reference is the discharge flow rate (how many vehicles can cross the section if the traffic light is green during the whole interval).

Eq. 24.11

$$X = \frac{\text{DemandFlow}}{\text{SaturationFlow}}$$

Where:

- X: Demand saturation level;
- DemandFlow: Number of vehicles that want to use the section for the time interval;
- SaturationFlow: Maximum flow the section can handle under prevailing use;

Demand saturation level is sometimes referred to as "saturation level" or just "saturation," which can create confusion with "saturation flow." Also, we use "demand level" and "X" in this chapter.

24.1.3.14 Demand to Signal Capacity Level (XSignal)

This is a variant form of expressing demand saturation level at the traffic light, and instead of comparing it to the maximum possible throughput, this compares it with the possible throughput under current programming. It is given by demand flow over capacity flow. The reference is the traffic sign effective capacity (how many vehicles can cross the section during the interval that the traffic light is green).

Eq. 24.12

$$\text{XSignal} = \frac{\text{DemandFlow}}{\text{CapacityFlow}}$$

Where:

- XSignal: Demand to signal capacity level;
- DemandFlow: Number of vehicles that want to use the section for the time interval;
- CapacityFlow: Maximum flow that can cross the section during the interval that the traffic light is green.

Eq. 24.13

$$\text{XSignal} = \frac{\text{DemandFlow}}{\text{SaturationFlow} * K_{\text{green}}}$$

Where:

- XSignal: Demand to signal capacity level;
- DemandFlow: Number of vehicles that want to use the section for the time interval;
- SaturationFlow: Maximum flow a section can handle under prevailing use;
- K_{green}: Relative green, or the proportion of time given by a green light for a flow to cross an intersection.

Demand to signal capacity level is particularly relevant for the calculation of traffic sign delay below in the particular formulation we use. Sometimes it is called "signal saturation level" as the following definition is also possible.

Eq. 24.14

$$\text{XSignal} = \frac{X}{K_{\text{green}}}$$

Where:

- XSignal: Demand to signal capacity level;
- X: Demand saturation level;
- K_{green}: Relative green, or the proportion of time given by a green light for a flow to cross an intersection.

Signal Delay (T_{signal})

The calculation assumes that arrivals are random and departure headways are uniform, which is applicable only for undersaturated conditions and predicts infinite delay when arrival flows approach capacity. This is realistic for design purposes, as we intend to promote undersaturated conditions.

Signal delay is composed of two terms:

- The first term (T_{queue}) is the delay due to a uniform rate of vehicle arrivals and departures at the signal;
- The second term (T_{random}) is the random delay term, which accounts for the effect of random arrivals. But if demand of signal capacity level is below 50 percent, then it should be ignored.

Eq. 24.15

$$T_{\text{signal}} = T_{\text{queue}} + T_{\text{random}}$$

Where:

- T_{signal}: Signal delay;
- T_{queue}: Delay due to a uniform rate of vehicle arrivals and departures at the signal;
- T_{random}: Random delay term, which accounts for the effect of random arrivals.

The first term is deductible as the area below the queueing in Figure 24.7 over the number of vehicles during a cycle (DemandFlow $* T_{\text{cycle}}$).

Eq. 24.16

$$T_{\text{queue}} = \frac{T_{\text{red}}^2}{2 * T_{\text{cycle}} * (1 - X)}$$

Where:

- T_{queue}: Delay due to a uniform rate of vehicle arrivals and departures at the signal;
- T_{red}: Time given by a red light holding traffic from crossing an intersection;
- T_{cycle}: Time given by the signal cycle.

The extra delay in queuing, caused by the non-regularity of arrivals in the traffic light (T_{random}) is a function of the demand-to-signal capacity level (XSignal) and a regularity of vehicles (buses in our case) arrival coefficient (K_{reg}).

If the signal saturation (XSignal) is low, the randomness of arrivals will not generate extra time in queueing formation. As the signal saturation increases, the impact on extra time due to the expected randomness of arrivals becomes bigger than the increments. If the signal saturation is bigger than one (there are more vehicles willing to use the lane than what the traffic light can handle), there will be severe busway congestion (congestion would happen even if there were no random arrivals at all). So, the extra queueing delay due to randomness is calculated by:

Eq. 24.17

If Xsignal $< K_{\text{reg}}$, then $T_{\text{random}} = 0$

If $K_{\text{reg}} \leq$ Xsignal < 1, then: $T_{\text{random}} = \frac{\frac{\text{XSignal} - K_{\text{reg}}}{1 - \text{XSignal}} * 1}{\text{SaturationFlow}}$;

If Xsignal ≥ 1, then there would be severe congestion ($T_{\text{random}} \rightarrow \infty$).

Where:

- XSignal: Demand to signal capacity level;
- Trandom: Random delay term, which accounts for the effect of random arrivals.
- SaturationFlow: Maximum flow a section can handle under prevailing use;
- K_{reg}: Regularity factor; it is a number related to the chance a bus has to arrive within the signal cycle as detailed below:
  - It would equal one if there were total regularity in vehicle arrivals;
  - It would be 0.5 if half of the vehicles arrive more than one signal cycle later than when they are expected;
  - The value used to represent uncertain arrivals is 0.5.

This formula is a variation of the model proposed by Webster in 1958, slightly simpler than originally proposed but with a smoother transition when the random delay becomes more relevant than the practical modification most commonly applied.

24.2 Approach to Intersection Design

"Idiopathic, from the Latin meaning we're idiots cause we can't figure out what's causing it."

— Gregory House, MD (as played by actor Hugh Laurie), "Role Model," House, 2005

Figure 24.11. The introduction of BRT and better design changes poorly controlled and congested intersections, often leading to efficiency improvements for both public transport vehicles and mixed traffic. *Lloyd Wright.*

BRT systems are generally built on corridors where mixed-traffic congestion is already a problem, or where congestion is likely to occur in the near future; otherwise there would be no benefit in building a segregated busway. The worse the congestion appears, the greater the benefit of the exclusive busway (Figure 24.11). If a BRT system makes public transport services better but mixed traffic worse, it will be less politically successful than if it makes public transport better and also improves mixed-traffic flow. BRT system planners therefore generally try to minimize adverse impacts on mixed traffic.

Figure 24.12. Intersection design affects the BRT system's efficiency, pedestrian safety, and the access and flows of mixed-traffic vehicles. *Lloyd Wright.*

Intersections are critical to stations, as they represent an important point along any BRT corridor. A poorly designed intersection or a poorly timed signal phase can substantially reduce system capacity and speed, especially by hindering access to stations. Finding solutions to optimize intersection performance can do much to improve system efficiency. Generally, the three main objectives of intersection design along a BRT corridor are:

1. To provide safe and convenient crossings for pedestrians;
2. To minimize delay for BRT vehicles;
3. To minimize delay for mixed traffic.

Travel times for walking trips are improved by following these objectives, but it should be noted that pedestrians' safety and accessibility have the highest priority. Some methods take into account pedestrian times in order to analyze alternatives, and the approach discussed here does not equalize pedestrians by inputting delays into the process. Current procedures mostly try to fit demand needs into the available space so that pedestrians can make all crossings safely; bus lane queues are not so long that they block stations; and desired car movements are still possible, all without worsening congestion. Keep in mind that if public and private transport users' times were equalized, every street with one vehicle carrying fifty passengers every two minutes would have an exclusive bus lane.

It is generally not advisable to use a standard intersection configuration throughout a BRT corridor. Rather, it is best to design the intersection for the specific conditions at the given location. The impact of a planned BRT system on overall intersection performance is often a significant consideration when deciding on a service plan for the BRT system, the location of the stations, and the design of the stations.

BRT system planners have used the following tools to rationalize intersections:

- Simplify the BRT system's routing structure to optimize turning movements into the corridor;
- Optimize the number of intersections along the corridor;
- Restrict as many mixed-traffic turning movements on the BRT corridors as possible;
- Optimize the location of the station relative to adjacent intersections;
- Optimize the signal phasing and consider signal priority for public transport vehicles.

Figure 24.13. A typical major intersection on a BRT corridor in Guangzhou, China. Note that the station of the BRT corridor is located away from the intersection with Chibei Avenue, and in order to turn across traffic, the two-phase intersection requires a U-turn in the perpendicular road. Before the BRT, this four-phase intersection was a major traffic-congestion point. Image *Karl Fjellstrom, ITDP.*

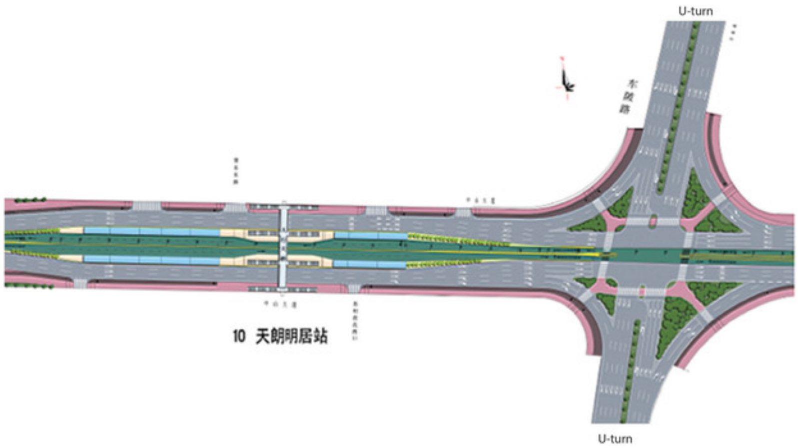

Figure 24.14. The same intersection as depicted in Figure 24.13 on a BRT corridor in Guangzhou, China. The station is located away from the intersection of the BRT corridor and Chibei Avenue. In order to turn across traffic, the two-phase intersection requires a U-turn in the perpendicular road. Before the BRT, this four-phase intersection was a major traffic-congestion point. *ITDP and GMEDRI.*

Every decision and solution proposed during the intersection design process should be technically supported by the elaboration of a comprehensive traffic study, where directional flow counts for cars and pedestrians are categorized and carried out at every active intersection (signalized or not) along the corridor being designed. This is necessary to diagnose the current performance of each intersection and forecast a future scenario incorporating the operational changes a BRT corridor might bring.

24.2.1 Corridor Audits

As a first step to intersection design, BRT system planners should carefully review the existing mixed-traffic bottlenecks in the corridor. A small number of bottlenecks are often responsible for the vast majority of mixed-traffic delay. These bottlenecks are usually due to one or more of the following conditions:

- Narrow bridges and tunnels;
- Traffic convergence points;
- Poorly regulated/enforced parking;
- Suboptimal timing at traffic signals;
- Improperly designed and channeled intersections;
- Badly placed bus stops or unregulated stopping of public transport vehicles.

Quite often a new BRT system can lead to a reduction of the number of lanes available to mixed traffic. While ideally the removal of a large number of buses from the mixed-traffic lanes will avoid worsening congestion in the mixed-traffic lanes, this is not always possible, and the mixed-traffic saturation level may increase.

Figure 24.15 illustrates the vehicular demand saturation level along a planned BRT corridor and what could be expected if one lane is removed.

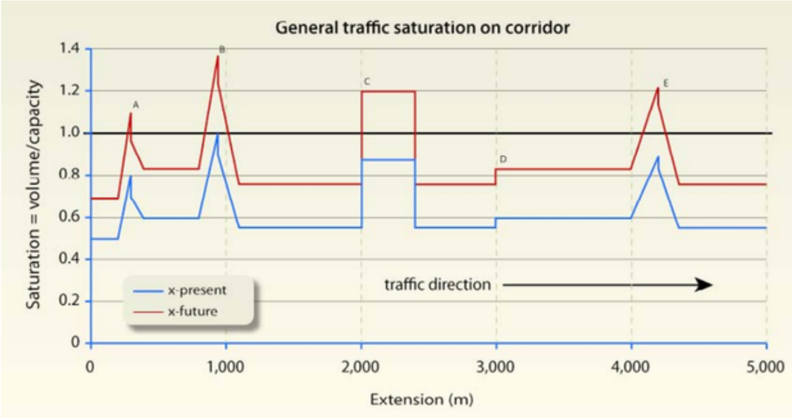

Figure 24.15. Current demand saturation level for mixed traffic can be expected to off-set the transference of one lane to the planned BRT system. *ITDP.*

The most serious bottlenecks—points A, B, and E—are signalized intersections. Point C might be a bridge or tunnel where, for example, lanes are reduced from three to two, increasing saturation by 50 percent. Point D might be a popular destination such as a shopping mall where an extra volume of vehicles enters the road, increasing saturation. It might also be a popular bus interchange, a street market, or an area with regulated on-street parking.

If no measures are taken to mitigate the lane removal due to the BRT implementation, then congestion restricted to point B will occur at A, B, C, and E. These points now require more careful attention.

24.2.2 Solution Approach

Once the basic routing structure of the new BRT system has been determined, system designers should have a reasonable idea about likely vehicle frequencies within the system.

Considering the placement of the BRT corridor and its requirements, the non-intersection bottlenecks should be addressed first. These problem points can generally be resolved through a combination of tightening parking regulation and enforcement, strengthening vendor regulation and enforcement, narrowing medians, improving parallel roads, or widening roads if all else fails.

The second analysis should determine if the busway will congest given the current intersection signal phasing and lane allocation along the BRT corridor. Each intersection in the corridor should be analyzed. An example of the intersection delay impacts calculation is given in the next section. Intersections that do not match the BRT requirements should be redesigned.

Once the implementation of the new BRT system requires changing the intersection design anyway, the opportunity should be taken to improve the overall efficiency of the intersection. Packaging these intersection improvements with the introduction of the new BRT system will help improve public acceptance of the new BRT system. The less efficient the intersection was before the BRT system, the greater the potential there will be to design the new system in a way that improves conditions for both public transport passengers and mixed traffic.

24.2.3 Signal Delay on BRT

Table 24.2 shows an example of the variation in the average traffic signal delay for each BRT vehicle crossing an intersection as a function of the red and green signal duration within a defined cycle time.

Signal delay is given by Equation 24.15 and fixed parameters for the example are:

- Cycle time: Tcycle = 80 seconds;
- BRT vehicle frequency across the intersection: DemandFlow = 200 articulated-bus/hour;
- BRT lanes: NLanes = 1 lane;
- Discharge flow rate: saturationflowperlane = 720 articulated-bus/hour/lane.

Table 24.2. - Signal delay as function of red light

Red light time (seconds)	Green light time (seconds)	Average signal delay (TR) (seconds)	Random queuing delay (TQs) (seconds)	Total signal delay (TS) (seconds)	Demand to signal capacity level (XSignal)
0	80	0.00	0.00	0.00	0.28
10	70	0.87	0.00	0.87	0.32
20	60	3.46	0.00	3.46	0.37
30	50	7.79	0.00	7.79	0.44
36	54	11.22	0.18	11.40	0.51
40	40	13.85	2.25	16.10	0.56
42	38	15.27	3.68	18.94	0.58
43	37	16.00	4.53	20.53	0.60
44	36	16.75	5.52	22.27	0.62
45	35	17.52	6.65	24.18	0.63
46	34	18.31	7.98	26.29	0.65
47	33	19.12	9.56	28.67	0.67
48	32	19.94	11.45	31.39	0.69
49	31	20.78	13.78	34.56	0.72
50	30	21.63	16.71	38.35	0.74
51	29	22.51	20.51	43.02	0.77
52	28	23.40	25.62	49.02	0.79
53	27	24.31	32.86	57.17	0.82
54	26	25.23	43.94	69.18	0.85
55	25	26.18	63.00	89.18	0.89
56	24	27.14	103.50	130.64	0.93
57	23	28.12	248.14	276.26	0.97

Thus, if there are 200 articulated buses per hour in a single lane, and there is an 80-second traffic signal cycle with a red phase of 35 seconds, then there is no difference between total signal delay and average signal delay. In this case there is no additional delay resulting from the randomness of vehicle queues at the stoplight. However, if there is more than 35 seconds of red time, the random queuing of buses at the traffic light begins to add additional delay.

In summary, intersection delay is largely a function of red time as a share of total signal time. If demand-to-signal capacity level is greater than 0.65, random delay becomes significant, and the project design should be changed to give a higher proportion of green time, and/or a second BRT lane on the approach to the intersection should be considered (Figure 24.16).

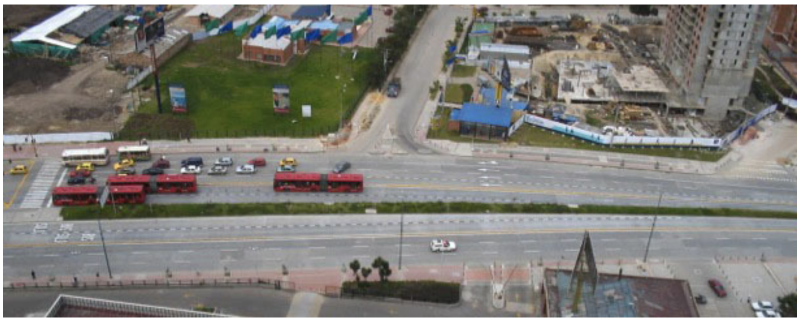

Figure 24.16. Single to double lanes just before the intersection in Bogotá to ensure proper capacity. *Oscar Edmundo Diaz, GSD+.*

24.3 Traffic Signal Priority

> *"On a traffic light green means go and yellow means yield, but on a banana it's just the opposite. Green means hold on, yellow means go ahead, and red means where the hell did you get that banana."*
>
> — Mitch Hedberg, comedian, 1968–2005

Signal priority for BRT vehicles is the adjustment of traffic signals to give priority to a corridor with a BRT system over a corridor without one, and to give priority to the BRT system over mixed traffic within the same corridor. Once equipment and techniques were developed to do this in a responsive way after the detection of BRT vehicles approaching an intersection, the expression "active signal priority" became the way to indicate this advance. Since then "passive signal priority" is used to indicate that such detection technology is not being applied.

Figure 24.17. Active signal priority for BRT and restricted turning movements for vehicles in mixed traffic can do much to improve public transport travel times. *Lloyd Wright.*

24.3.1 Passive Signal Priority

Together with signal phase simplification, passive signal priority is crucial to proper BRT intersection design. The two techniques are complementary and must be considered jointly for implementation.

Prioritization is primarily achieved by extending the relative green time for the BRT corridor over the crossing streets that do not have public transport. This action reduces the travel time of the entire traffic stream (both BRT and mixed-traffic) on the corridor at the expense of the travel time of the crossing traffic stream.

Without special consideration for BRT, the optimal phase time in a signalized intersection is such that the cycle time is as brief as possible without growing queues. At the highest extreme, this guideline would change to give as much green time as possible to the BRT corridor without resulting queues. The longest green signal phase would depend on the flow of mixed traffic on the crossing street. The ideal way to balance the traffic light, however, is to consider the average wait time by each flow, including pedestrians multiplied by the number of people in each flow.

In applying traffic signal priority to a BRT corridor, it is typical that cycle time becomes as low as 60 seconds and does not rise above 120 seconds except at major intersections or during peak hours in order to allow larger relative green time for the BRT corridor. The relative green time faced by the BRT system should be extended above 50 percent, if possible. It is typical for the BRT green time to be 30 seconds in a 60-second cycle or 40 to 60 seconds in a 120-second cycle.

Synchronization of green signal phases between intersections (or "green wave," see coordination as discussed in Section 24.1.3: Traffic Signal Concepts) is not common with BRT systems because BRT travel times are not regularly subject to variable dwell time at stations (especially when multiple route services use the same corridor or frequencies are high). If BRT vehicle speeds are reasonably predictable or controlled, then it is possible to coordinate traffic lights in a BRT corridor. This practice is used in Ottawa, Ontario, Canada (Levinson et al., 2003b). If boarding and alighting times are somewhat regular and of the same magnitude of the green time of the green wave planned for mixed traffic, coordination will lead to the opposite effect, as every time the BRT vehicles dwell in a station they are likely to reach the next traffic light at the beginning of the red light.

24.3.2 Active Signal Priority

Active, or real-time priority techniques, change the actual traffic signal phasing when a BRT vehicle is observed to be approaching the intersection.

The normal vehicle identification mechanism is to have a transponder detect the BRT vehicle prior to its arrival at the stop line. If the BRT vehicle is detected during the green phase, and the green phase is nearing the yellow phase, then the green phase is extended. If the detection occurs during the red or the yellow interval, the green time is recalled more quickly than normal. Some general guidelines for applying phase extension or phase shortening include:

- The minimum side street green time is set based on the amount of time pedestrians need to cross the road;
- The amount of green signal extension or advance should be up to a specific, set maximum;
- The BRT corridor green is not generally both advanced and extended in the same cycle.

The green times are likely to be most easily extended at intersections with light cross traffic.

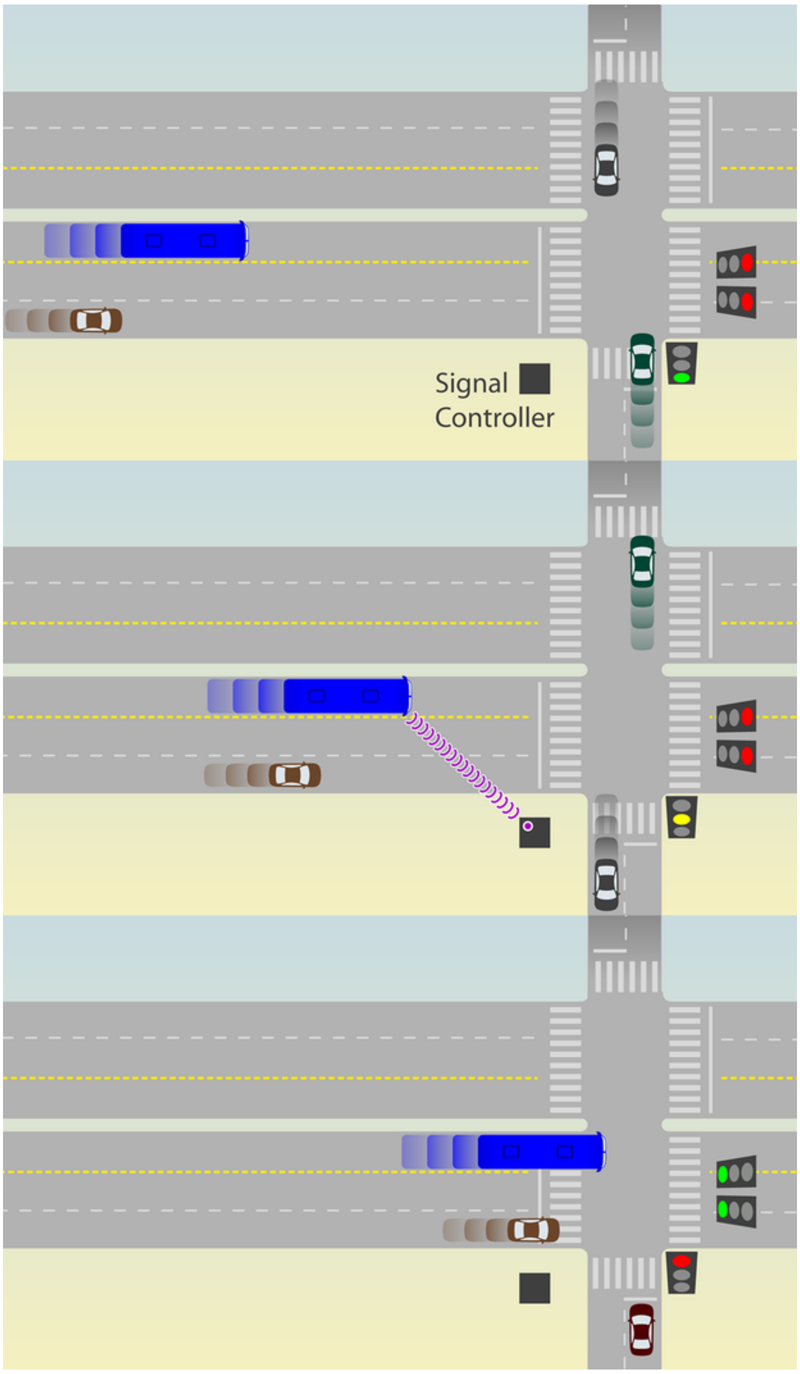

Figure 24.18. Active priority can reduce red time for the BRT corridor when the BRT vehicle is detected approaching the intersection. *ITDP*

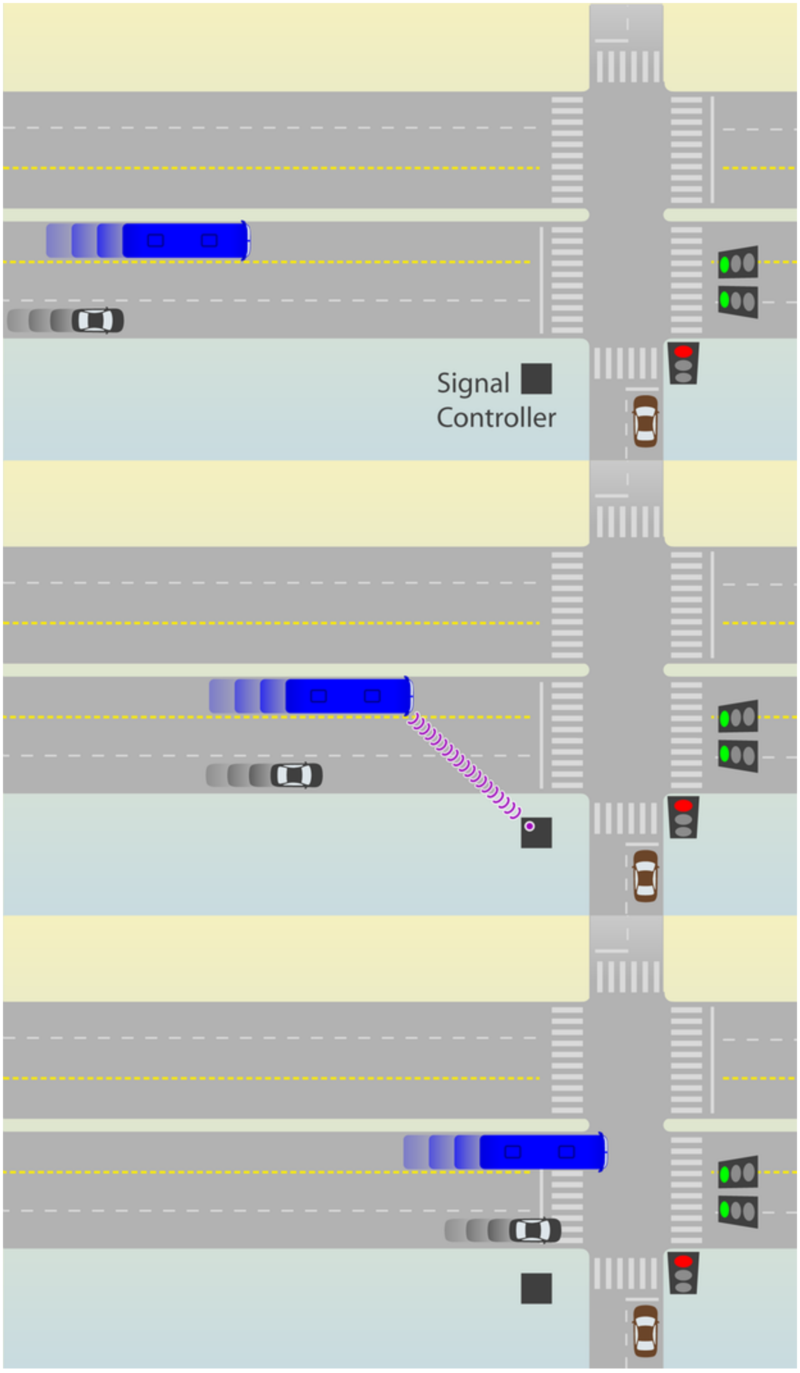

Figure 24.19. Using active priority, the green time for the BRT corridor is extended when a BRT vehicle is detected approaching the intersection. *ITDP*

The importance of active traffic signal priority on BRT vehicle speeds tends to be greatest in systems with fairly low bus volumes, particularly with bus headways longer than five minutes where intersections are frequent and might be a relevant measure for increasing system speeds. In such instances, signal priority may reduce signal delay by between 10 and 20 percent. In this context, it is often easier to give buses signal priority at intersections without major disruption to mixed-traffic flows.

When BRT vehicle headways are less than 2.5 minutes, it is generally difficult to implement active signal priority at all: the non-BRT traffic direction would essentially be in a state of a permanent red phase. However, even with BRT vehicles at high frequencies, giving active priority to the BRT running on less important cross streets can yield benefits of between 4 to 10 percent of the delay in traffic signals. While this savings is not as significant as some other priority measures such as restricting mixed-traffic turns, it can be a justifiable expenditure contributing to efficiency gains as vehicle detection, signaling equipment, and priority software become more common, and their costs increasingly affordable.

At an even higher level of sophistication, the priority phasing can be based on observed traffic levels for both the BRT vehicles and the general traffic. A special weighting can be given to BRT vehicles or to the BRT corridor. In traffic systems where flows are quite irregular, real-time control that adjusts signal times to observed traffic levels can yield benefits. In such real-time systems, phase changing is usually based on a trade-off between the benefits and costs faced by the green and red approaches and for the general principle of shortening red times; a fully actuated system based on total vehicle movements, which also includes BRT vehicles, is probably more important than BRT-specific detection. The application of signal priority, both passive and active, is looked at further in Section 24.7: Merging with Mixed Traffic in Narrow Sections and Section 24.8: BRT Lanes at Roundabouts.

24.4 Station Location Relative to the Intersection

> *"The engineer's first problem in any design situation is to discover what the problem really is."*
>
> — Anonymous

Intersection and station design should minimize the added travel time of all customers. The station location in relation to the intersection will affect the BRT system's flow, speed, and required right-of-way. Pedestrian travel times, which seem to be the more obvious reason for determining a station's location, are far less relevant than they first appear.

Because conditions vary from intersection to intersection, it is generally advisable to find an optimal solution for each intersection rather than to presume that a single solution will always be optimal. The greater the amount of information the planning team has available regarding demand, the easier it will be to evaluate alternatives and find an optimal solution under the existing restrictions.

24.4.1 Station Location Possibilities

The following station locations are possible:

- At the intersection:
  - For side-aligned stations, the station can be either nearside or far side—that is, before or after the intersection in each direction;
  - For median stations, if not split, the station will be nearside in one direction and far side in the other;
- Away from the intersection;
  - Near the intersection;
  - Far from the intersection (or mid-block);
- Under or over the intersection.

24.4.1.1 At Intersections

The normal justification for putting the bus stop at the intersection is that it reduces walking times for customers with destinations or transferring on the crossing street. Unless the red time is really short (fewer than twenty seconds) and station saturation (discussed in Chapter 7: Capacity and Speed) is really low, the resulting saturation of the combination of the intersection plus station (i.e., the proportion of time a BRT vehicle will occupy the area with two functions: queue-box waiting for green light and boarding area) is likely to be greater than one, and this will lead to congestion that will end only after the peak (Figure 24.20). Such a situation clearly will not be compensated for by reducing customer walking times. It also will not be of help to customers that are alighting at that station or must only cross that intersection.

Additionally, such justification is often based on presumptions and rarely on data; only micro-level destination maps based on surveys can effectively quantify walking time benefits of station location relative to the intersection. Furthermore, the large number of transferring customers should be prevented when route service planning is designed.

In the rare case that the station must be located at the intersection, there is an emerging consensus that locating the station before the intersection is preferable, particularly in split platform configurations if the BRT lane is near the median.

Figure 24.20. Buses waiting for a traffic light after boarding and alighting is completed in São Paulo; today this station is moved back. *Arthur Szász.*

24.4.1.2 Away from the Intersection

Stations should in general be around a hundred meters from intersections. As highlighted above and as discussed in the remainder of this section, there should be some space between the intersection and the station since it:

- Provides the possibility of taking away mixed-traffic space without changing road capacity for the section;
- Prevents bus queues at the intersection from hindering the station;
- Leaves width at the intersection for increasing mixed-traffic capacity and turns (Figure 24.21).

Figure 24.21. Double to single BRT lane transition before intersection in Guangzhou, China. *Karl Fjellstrom, ITDP.*

We further divide the description of the station's location into "near it" or "far from it" (or "mid-block") with regard to the intersection. The aspect to be taken into consideration here is customer access to the station.

Mid-block stations will require access infrastructure not shared nor closely related to the intersection's pedestrian crossings. In the typical environment discussed here, that is, a station located between mixed-traffic signalized intersections, signalized at-grade options are the likely ideal solutions. But such a solution introduces a new intersection (considering the multimodal definition of it) that needs to be taken into account when evaluating capacity of both the station and mixed-traffic.

We should remember that a crossing for access will be required for curbside mid-block stations as well. Mid-block stations are arguably safer to access than near-intersection stations and cycle times can be shorter. Saturation correction must be applied (see Section 24.4.6: Correction Factor for Station Saturation at Traffic Light).

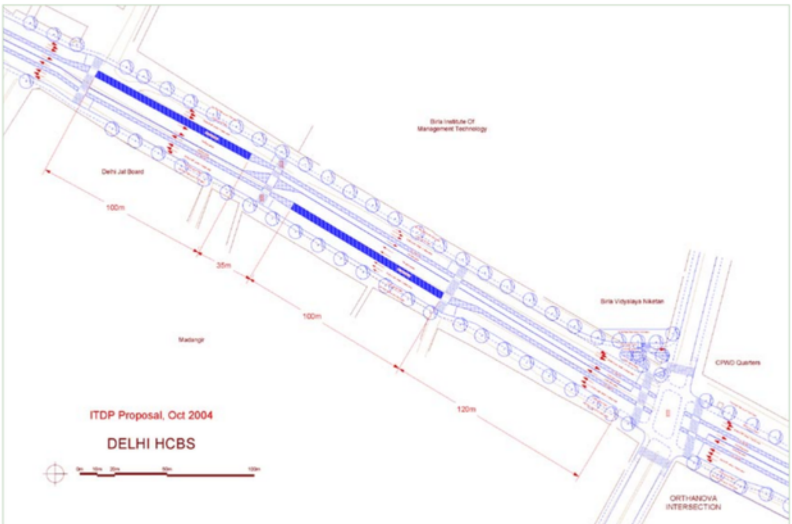

Figure 24.22. In this proposed road layout for Delhi, the mid-block BRT stations are given additional right-of-way and several access points. At the intersections, right-of-way for vehicles in mixed traffic is maximized. *ITDP.*

24.4.1.3 Above or Below the Intersection

This alternative is discussed in Section 24.10: Grade Separation, where other aspects of grade-separated solutions are presented.

24.4.2 Minimizing the Number of Mixed-Traffic Lanes Away from the Intersection

Usually the mixed-traffic bottleneck is the intersection, where capacity is 50 to 30 percent (proportional to the green fraction of each approach) of mid-block capacity. So if BRT stations are far from intersections, the general-traffic road capacity can be reduced in its surroundings without any significant impact on the capacity and performance on the segment as a whole. This means that mixed-traffic lanes can be removed, and the space given to the BRT station, thus enabling the widening required for BRT at stations to accommodate passing lanes, and hence provide high capacity at stations without impacting mixed-traffic capacity at all (Figure 24.23).

Figure 24.23. A mid-block station location in Seoul allows greater right-of-way width for the station area. *City of Seoul.*

For example, at the bus stop, if bus frequencies are high and an overtaking lane is needed at each station, the extra width required will be around 12 meters. If the station is located at the intersection, these 12 meters will be difficult to supply while also providing 6-meter turn lanes for mixed traffic. Separating these functions will allow the same right-of-way to be used for the bus station at mid-block, and for left and right turn signals at the intersection. Figure 24.22 shows an application of this concept within a proposal for the Delhi BRT system.

Capacity in a given control section (CapFlow) is expressed in the equation below. Eq. 24.18

$$\text{CapFlow}_{\text{intersection}} = \text{saturationflowperlane} * \text{Nlanes} * K_{\text{green}}$$

Where:

- $\text{CapFlow}_{\text{intersection}}$: Capacity of the evaluated section of control, usually in pcu/hour;
- saturationflowperlane: Saturation flow of one lane (in "ideal conditions," around 1,800 in urban areas pcu/hour);
- N_{lanes}: Total number of available lanes;
- K_{green}: Relative (effective) green time, which is given by Equation 24.5:

$$K_{\text{green}} = \frac{T_{\text{green}}}{\text{Tcycle}}$$

Where:

- K_{green}: Relative green, or the proportion of time given by a green light for a flow to cross an intersection;
- T_{green}: Time given by a green light for a flow to cross an intersection;
- T_{cycle}: Time given by the signal cycle.

One can evaluate the possibility of narrowing the mixed-traffic road away from the intersection without affecting the capacity of the segment by assuring that capacity away from the intersection (where relative green time can be considered 1 or 100 percent) is greater than capacity in the intersection.

$$\text{FlowCap}_{\text{away}} \geq \text{FlowCap}_{\text{intersection}}$$

$$\text{saturationflowperlane}*\text{NLanes}_{\text{away}}*K_{\text{green away}} \geq \text{saturationflowperlane}*\text{NLanes}_{\text{intersection}}*K_{\text{green intersection}}$$

$$\text{NLanes}_{\text{away}} * K_{\text{green away}} \geq \text{NLanes}_{\text{intersection}} * K_{\text{green intersection}}$$

$$\text{NLanesaway} \geq \text{NLanes}_{\text{intersection}} * \frac{K_{\text{green intersection}}}{K_{\text{green away}}}$$

Examples:

- If near-intersection mixed traffic has 3 lanes ($\text{NLanes}_{\text{away}} = 3$), and relative green time is 60 percent ($\frac{T_{\text{green}}}{T_{\text{cycle}}=0.6}$), then far from intersection ($\text{Nlanes}_{\text{away}}$) can be 2 lanes without affecting the segment performance:$\text{NLanes}_{\text{away}} \geq$ $3 * 0.6 = 1.8$;

- If near-intersection mixed traffic has 2 lanes ($\text{NLanes}_{\text{away}} = 2$), and relative green time is 50 percent ($\frac{T_{\text{green}}}{T_{\text{cycle}}=0.5}$), then far from intersection ($\text{Nlanes}_{\text{away}}$) can be only one lane without affecting the segment performance: $\text{NLanes}_{\text{away}} \geq 2 * 0.5 = 1.0$;
- If we are planning a mid-block station with signalized pedestrian crossing for the first example, we would have to keep relative green for traffic mid-block above 90 percent.

24.4.3 Minimizing the Recommended Distance between the BRT Station and the Intersection from a Mixed Traffic Perspective

NOTE: THIS DISTANCE IS FOR STATIONS THAT TAKE AWAY MIXED-TRAFFIC LANES, NARROWING THE AVAILABLE SPACE FOR CARS AWAY FROM THE INTERSECTION AND ENSURING THAT MIXED-TRAFFIC CAPACITY IS NOT AFFECTED!

Away from the signalized intersection means far enough to guarantee that the capacity flow in the intersection can last the entire green phase. This is equivalent to ensuring that the queueing space with the same number of lanes of the intersection approach has enough capacity to hold all vehicles that can cross the intersection in the duration of the green phase.

This means the distance from the intersection (Diststation-intersection) has to be greater than the space for queueing vehicles times the number of vehicles that will cross the retention line in one lane.

Considering a saturation flow per lane (saturationflowperlane) of 1,800 pcu/hour is equivalent to one vehicle every two seconds (passing across the intersection in one lane) and the distance between (the front of) two vehicles (lengthpcu) is 5 meters, this implies that for each second of the green phase the queue will be 2.5 meters short.

$$\text{Queue discharge rate} = \frac{\text{flow}_{\text{saturation}}}{\text{length}_{\text{pcu}}}$$

Another way to think about this is that the "speed of the shock wave" starting at the retention line after the traffic signal opens is 2.5 meters per second. That is, the second car behind (5 meters behind) will start to move 2 seconds after the first, the third car behind (10 meters from the retention line) will move after 4 seconds and so on.

$$\text{Velocity}_{\text{discharge shockwave}} = \frac{\text{flow}_{\text{saturation}}}{\text{length}_{\text{pcu}}}$$

Therefore the distance between station and intersection (Diststation-intersection) has to be equal to or greater than the distance that the shock wave can move during the duration of the green phase (Tgreen). Representing the speed of shock wave by Velshock-wave, this can be expressed as:

$$\text{Dist}_{\text{station intersection}} \geq V_{\text{shock wave}} * T_{\text{green}}$$

Using meters and seconds for the measures we have:

Eq. 24.19

$$\text{Dist}_{\text{station intersection}}[\text{in meters}] \geq 2.5 * T_{\text{green}}[\text{in seconds}]$$

Where:

- $\text{Dist}_{\text{station-intersection}}$:Distance between station and intersection;
- T_{green}: Time given by a green light for a flow to cross an intersection.

  Examples:
- If green time is 40 seconds, the station must be at least 100 meters from the intersection, equal the length of queue discharged during the green time:

$$\text{Dist}_{\text{station-intersection}}[\text{in meters}] \geq 2.5 * 40 = 100$$

- If green time is 90 seconds, the station must be at least 225 meters from the intersection, equal the length of queue discharged during the green time:

$$\text{Dist}_{\text{station-intersection}}[\text{in meters}] \geq 2.5 * 90 = 225$$

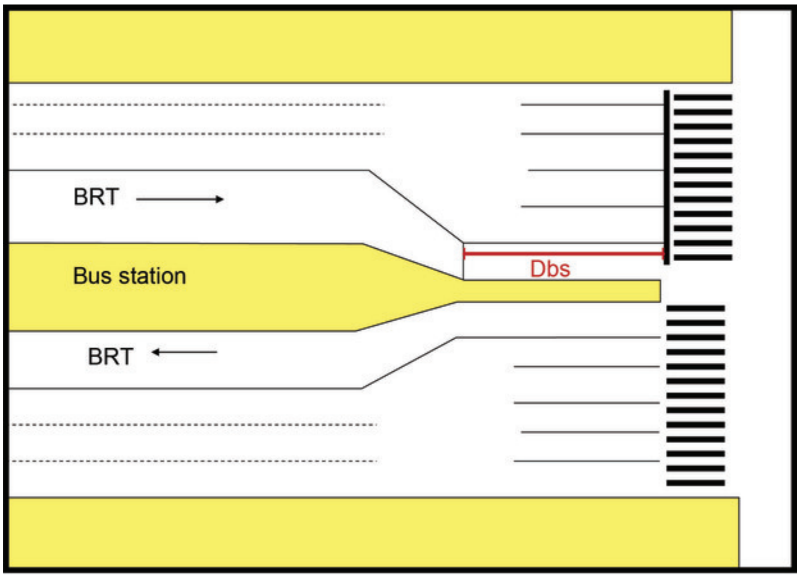

Figure 24.24. Diagram of the distance between the station and the signalized intersection (Diststation-intersection shown as Dbs). *ITDP.*

24.4.4 Minimizing the Recommended Distance between the BRT Station and the Intersection from a BRT Perspective

Another compelling reason for separating the station and the intersection is that it minimizes the risk that BRT vehicles will be backed up at the station, which will inhibit the functioning of the intersection and the functioning of the station. If these two potential bottlenecks are co-located, the risk of mutual interference between the station and the intersection increases. Consequently, it is advised to include a safety buffer in the station design for those stations to be located near a signalized intersection. This additional length will temporarily hold buses that: (1) in case of a blockage have cleared the station but are forced to queue up at the intersection until the conflict is resolved, or (2) have cleared the station during the red phase and have to wait for the green phase (Figure 24.25 and Figure 24.26). This buffer should also be around a hundred meters, as the following equations show.

This problem is still serious in “open” BRT systems without clearly designated stopping bays, as bus queueing can be longer than the platform. Besides that, such systems can cause a chaotic boarding process that not only creates stress for the customer but also increases boarding times (Figure 24.27).

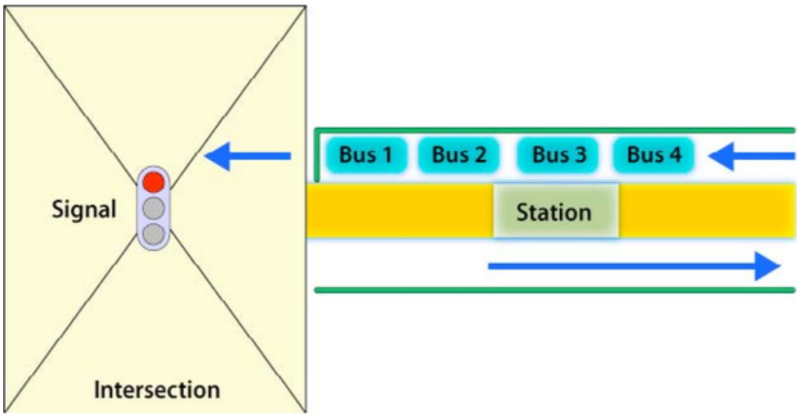

Figure 24.25. For the direction of the BRT system that stops at the station before the intersection, there is a risk that vehicles will be delayed due to the signal phase. *ITDP.*

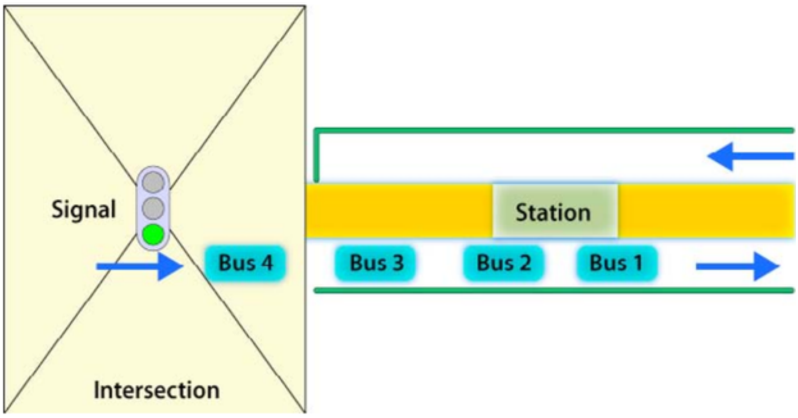

Figure 24.26. For the direction of the BRT system that stops after the intersection, there is a risk that vehicles create a backup into the intersection and block traffic. *ITDP.*

Figure 24.27. For the direction of the BRT system that stops after the intersection, there is a risk that vehicles create a backup into the intersection and block traffic. *ITDP*

The buffer size ($\text{Dist}_{\text{station-intersection}}$) should be the space required by queuing BRT vehicles.

$$\text{Dist}_{\text{station intersection}} \geq N_{\text{vehicle}} * \text{Length}_{\text{vehicle}}$$

Where:

- $\text{Length}_{\text{vehicle}}$: Average length of lane space consumed by the queuing BRT vehicles; adding two values:

  - Length of the BRT vehicle;
  - Length of space between BRT vehicles when stopped (usually assumed to be 1 meter).
- N_{vehicle}: Likely number of vehicles to queue during the red phase (T_{red}) of traffic signal, discussed below.

Assuming BRT vehicle frequencies (Freq_{bus}) are 50 percent below the BRT lane saturation flow ($\text{SaturationFlow}_{\text{bus}}$) – that happens practically always, as this represents 360 articulated buses per hour that would carry more than 40,000 customers per hour per direction – N_{bus}, which is equivalent to the height of the upper graphic in Figure 24.7, can be determined by:

Eq. 24.20

$$N_{\text{vehicle}} = \frac{T_{\text{red}} * \text{Freq}_{\text{vehicle}}}{\left(\frac{1-\text{Freq}_{\text{vehicle}}}{\text{SaturationFlow}_{\text{vehicle}}}\right)}$$

Where:

- N_{vehicle}: Number of vehicles;
- T_{red}: Time given by a red light holding traffic from crossing an intersection;
- $\text{Freq}_{\text{vehicle}}$: BRT vehicle frequency;
- $\text{SaturationFlow}_{\text{vehicle}}$: Maximum flow BRT lane can handle;

Example utilizing typical data of an average city in India:

- T_{red} = 50 seconds (or 50/3,600 hours to use consistent units = 1/72 hour);
- $\text{Freq}_{\text{vehicle}}$ = 200 articulated-buses / hour (equivalent to 1 vehicle each 18 seconds);
- $\text{SaturationFlow}_{\text{vehicle}}$ = 720 articulated buses / hour (one lane, equivalent to 1 vehicle each 5 seconds);
- $\text{Length}_{\text{vehicle}}$ = 19.5 meters (18.5 meters + 1 meter).

$$N_{\text{vehicle}} = \frac{\frac{50}{3600} * 200}{1-(200/720)} = 3.8\text{vehicles}$$

Because one cannot actually have 3.8 buses queueing, N_{vehicle} must be rounded to the nearest integer, so it is equal to 4.

$$\text{Dist}_{\text{station-intersection}} \geq N_{\text{vehicle}} * \text{Length}_{\text{vehicle}}$$

$$\text{Dist}_{\text{station-intersection}} \geq 4 * 19.5$$

$$\text{Dist}_{\text{station-intersection}} \geq 78$$

Thus, the minimum recommended distance between the BRT station and the intersection would be 78 meters.

BRT systems currently in operation prove that mixed traffic misbehavior is a relevant source of operation disruptions throughout the public transport system. Traffic spillbacks are commonly seen in heavily congested intersections blocking perpendicular movements along the BRT corridor, so it may be proper to analyze the tolerance; space needed is proportional to red time.

24.4.5 Optimizing Walking Distances

As mentioned in the introduction to this section, the willingness to place a station close to the intersection under the excuse of reducing walking times is rarely based on data. In the rare case of low-density areas with few clear origin-destinations where demand is known, the optimal spot can be easily determined. Such locations are not likely to be near busy intersections, and in the event that they are and the intersection is clearly the best location from the perspective of reducing walking time, it is more likely that it is better to move the station back at the length of a few buses than risk hindering the station. That can be perceived considering only the customer that intends to alight in that location: he or she may need an extra minute to walk to the intersection and would need an extra minute inside the vehicle stuck in the station because the vehicle in front is waiting for the green signal. If we consider that all the other customers not alighting there will increase their travel time by one minute and that the queue is likely to get longer (and everyone will wait more than one minute), then it is clear that the station should be moved away from the intersection.

The previous paragraph makes clear that, in high-density areas, to optimize station location with high precision requires labor-intensive, site-specific surveys, and analysis of the origins and destinations must be performed taking into consideration a pedestrian path network encompassing an area within a radius of one thousand meters or more from the possible extremes where the station can be placed. Additionally, several different street crossings should be looked at as well as the placement of other stations. That is, make the simulation model detailed to the level that every block face is a centroid, if not every address.

Our limited experience with such endeavors on central areas has shown that moving a station within a range of two hundred meters has no noticeable effect. But It should be remembered that *changing the number of stations within a given corridor extension has a significant impact on overall travel time*; that impact is determined by the average distance between the stations as discussed in Chapter 7: Capacity and Speed and requires a much less detailed survey and analysis.

Correction Factor for Station Saturation at Traffic Light

Chapter 7: Capacity and Speed discusses at length the *level of saturation of the station, or the proportion of time that BRT vehicles are blocking the station*. In particular, mid-block stations are likely to be accessible by at-grade crossings right in front of them. It is generally advisable to investigate the degree to which this intersection increases the saturation of the station.

Roughly, the combination of the station's normal saturation (which we will call Xstation) and the additional saturation caused by traffic signal interference will reveal the degree of busway saturation. As a general rule, it is best to design the station with a saturation level of under 0.4 at the station, meaning that the station is occupied only 40 percent of the time.

A correction factor that estimates what would be the new level of saturation of the station if the traffic light is positioned right in front of it (X_{is0}) can be expressed in function of:

- Signal cycle time (T_{cycle});
- Signal red time for the BRT approach (T_{red});
- Average stop time per bus in the station composed by dwell, boarding, and alighting times (T_{station}).

Correction for a Long Red Phase ($T_{station} < T_{red}$)

The relation between Tred and Tstation is the most important; the concern about interference is most acute when the bus stopping time (TB) is short and the red phase (TR) is longer, or of a similar magnitude. Interference is only of limited concern if the red phase is very short.

In this case, to calculate the saturation of the station when faced with interference from the traffic signal, the following formula can be used:

Eq. 24.21

$$X_{is0} = \frac{X_{\text{station}} * T_{\text{cycle}}}{T_{\text{cycle}} - T_{\text{red}} + 0.5 * TB}$$

Where:

- X_{is0}:Correction factor that estimates what would be the new level of saturation of the station if the traffic light is positioned right in front of it;
- X_{station}: Station's normal saturation level;
- T_{cycle}: Time given by the signal cycle;Tred = Time given by a red light holding traffic from crossing an intersection;
- TB: Bus stopping time.

Correction with a Short Red Phase ($T_{station}$ ⩾ T_{red})

If the red signal phase is very short relative to the boarding and alighting time, then even if the signal changes to red just as boarding and alighting has been completed, it will be a short time before the light is green again. Thus, there is less concern about interference between the station and the intersection.

Eq. 24.22

$$X_{is0} = \frac{X_{\text{station}} * T_{\text{cycle}}}{T_{\text{cycle}} - \frac{T_{\text{red}}^2}{2 * T_{\text{station}}}}$$

Where:

- X_{is0}: Correction factor that estimates what would be the new level of saturation of the station if the traffic light is positioned right in front of it;
- X_{station}: Station's normal saturation level;
- T_{cycle}: Signal cycle time;
- T_{red}: Signal red time for the BRT approach;
- T_{station}: Average stop time per bus in the station composed by dwell, boarding, and alighting times.

Examples

1. Calculating station to intersection interference with a long red phase

$X_{is0} = \frac{X_{\text{station}} * T_{\text{cycle}}}{T_{\text{cycle}} - T_{\text{red}} + 0.5 * TB}$

- $X_{station}$ = 0.35;
- T_{cycle} = 700 seconds;
- T_{red} = 500 seconds;
- $T_{station}$ = 10 seconds.

$$X_{is0} = \frac{0.35 * 700}{700\text{seconds} - 500\text{seconds} + 0.5 * 10\text{seconds}} = 1.195$$

In this hypothetical example the station would operate on just the 200 seconds of green, but not on the 500 seconds of red, because just some seconds after the red phase begins the bus will finish boarding, but it will obstruct access to the bus stop during the entire 500 seconds of red. Thus, at a value of 1.195 the high saturation leads to considerable congestion of the busway.

2. Calculating station to intersection interference with a short red phase

$X_{is0} = \frac{X_{\text{station}} * T_{\text{cycle}}}{T_{\text{cycle}} - \frac{T_{\text{red}}^2}{2 * T_{\text{station}}}}$

- $X_{\text{station}} = 0.35$;
- $T_{\text{cycle}} = 30$seconds full signal phase;
- $_{\text{Tred}} = 15$seconds of red phase;
- $_{\text{Tstation}} = 40$seconds of vehicle stopping time.

$$X_{is0} = \frac{0.35 * 30}{30 - \frac{15^2}{2*40}} = 0.386$$

In this case, because the red phase is quite short, there is fairly minimal risk that the traffic signal will disrupt the functioning of the bus stop, so saturation increases only marginally, from 0.35 to 0.386.

24.5 Restricting General Traffic Turning Movements

> *"No matter how many times you save the world, it always manages to get back in jeopardy again. Sometimes I just want it to stay saved! You know, for a little bit? I feel like the maid; I just cleaned up this mess! Can we keep it clean for . . . for ten minutes!"*
>
> — Mr. Incredible (Craig T. Nelson), The Incredibles, 2004

The overall capacity of the intersection is given by the sum of the capacity of each approaching lane. By its turn, the capacity of each approaching lane is given by the sum of saturation flow of the lane multiplied by the sum of the relative green times of the phases for when the lane is active.

No matter how many phases there are on the traffic light, the sum of relative green for all vehicular phases with relative lost time is constant (if there were no pedestrian phases, it would be equal to one). The initial step to programming traffic lights is to divide this fixed amount among the phases with the general assumptions that (1) a movement not allowed during a given phase will block a lane and (2) that the saturation flow per lane is the same (for turning it can be lower): *for any given signalized intersection, if a phase is removed (therefore the movements of that phase are removed) and the green time including the approaches for the movements of the removed phase are included into another phase (both in the same phase), then the overall capacity of the intersection will necessarily increase.*

This is empirically clear for a user arriving in a balanced intersection, since a larger number of phases in a traffic light means waiting longer and having a lower share of green time.

Of course it is not interesting to create capacity for movements without demand. The following subsections will discuss alternatives to divert traffic in order to increase capacity by eliminating phases. We will see that in some cases, intersection capacity is still increased even if the demand for some eliminated movements, namely cross-traffic turns, are forced to pass over the intersection twice.

Widening the intersection can be of great assistance, but doing it alone rarely can achieve the same benefits of reducing phases from four to two. In a relatively normal situation where turning volumes are large enough to the point that after the intersection the straight flow can fit in one less lane than before the intersection (as discussed in Section 24.4.2: Minimizing the Number of Mixed-Traffic Lanes Away from the Intersection), it is possible to narrow the exiting section, allowing the entrance section of the opposite way to be broader (Figures 24.28 and 24.29); the extra width can be useful for mixed traffic, enhancing mixed-traffic capacity, or to allow BRT turning movements where required (see Section 24.6: Allowing BRT Turns).

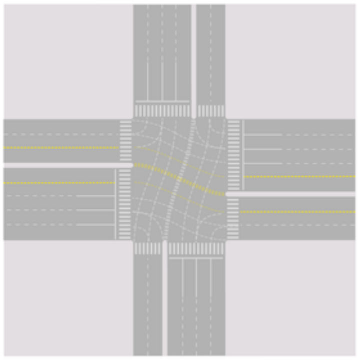

Figure 24.28. Exchanging width between entrance and exit sections where turning volumes are high enough to allow the change to improve capacity meaningfully. *Elebeta.*

Figure 24.29. Cape Town, South Africa's standard four-phase intersection with a cross-traffic-turn waiting area using the narrowed width of the opposite way. *Bruce Sutherland.*

Box 24.1. Narrowing lanes

Narrowing lanes is a recognized traffic calming measure and a possible way to increase the intersection approach capacity. Even though the saturation flow will be reduced in each lane, if one more lane can be squeezed into the stop line, capacity may increase and a better use of space for queueing may be provided.

Places where congestion is a serious issue may already have addressed regulation that allows using narrow measures, and, if not, public works guidelines have to be changed.

The United States Federal Highway Administration suggests that, despite the desired lane width of 3.6 meters to maximize flow, right-of-way or pedestrian needs may dictate use of a narrower lane width; lane widths below 2.7 meters are not recommended for new design, but in some very constrained retrofit situations on low-speed roadways, lane widths as low as 2.4 meters should be considered where appropriate (Figure 24.30).

Figure 24.30. Lanes as narrow as 2.4 meters are an effective way to improve intersection capacity, as in this intersection in Montgomery County, Maryland, USA. *Google Earth.*

24.5.1 Eliminating Intersections

The extreme case of reducing phases would only allow for one phase, which would be equivalent to eliminating the intersection itself, clearly increasing capacity.

Thus eliminating intersections along the busway seems at first a good idea. For median-side busways this can be done by simply forbidding cross traffic, while still allowing flow from the transversal street to join the mixed traffic in the corridor at the curbside as in Figure 24.31, providing access to the corridor.

Figure 24.31. Prior to Quito's Ecovía line, mixed-traffic vehicles were allowed to cross through this intersection as well as negotiate cross-traffic and curbside turns. To give priority to public transport, crossing straight and cross-traffic turn movements have been blocked. *Lloyd Wright.*

The flaw in adopting such an extreme solution is that eliminating phases is based on diverting traffic demand in favor of the exclusive movements, so its movement can be done with other flows. Eliminating the movement (in this case, crossing the corridor) does not eliminate the demand for it; the movement has to happen somewhere else.

This measure will reduce accessibility when applied without discretion and will concentrate crossing demand in a few locations (Figure 24.32). Before eliminating an intersection, it is necessary to understand which alternative paths the demand will use to cross the corridor and compare the impacts of both situations: if the volumes are low or if the alternatives will not generate more delay to the BRT, then it really is a good idea to eliminate the intersection. Eventually, it will become necessary to create new intersections to split conflicting volume of one intersection into several to increase green times for the BRT.

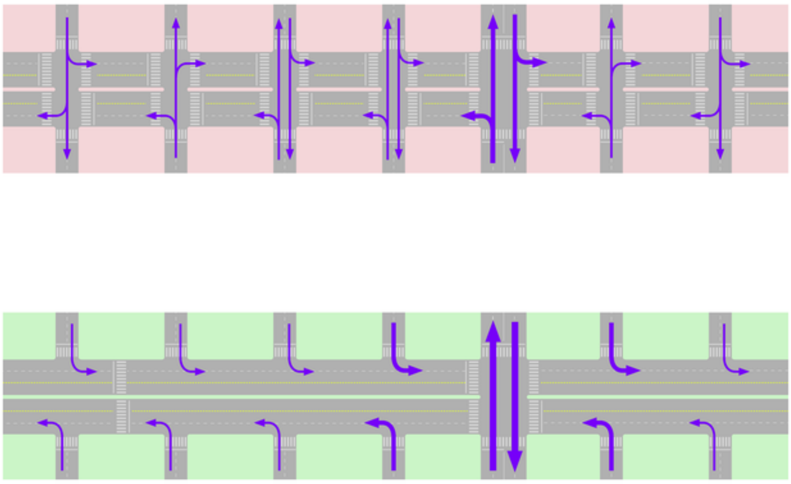

Figure 24.32. Closing intersections reduces accessibility, and may lead to harder to handle intersections. With no stations, BRT vehicles can benefit from signal coordination. *Elebeta.*

If there are no stations in the surrounding area, then BRT vehicles can pass through several intersections at once if a synchronized signal system is used (see Section 24.1.3: Traffic Signal Concepts and Section 24.3.1 Passive Signal Priority). However, when there are stations between intersections, the BRT vehicle will pass through the green phase at the first intersection and then stop at the station for customer boarding and alighting. By the time the vehicle resumes movement toward the second intersection, the signal phase may have changed to red (Figure 24.33).

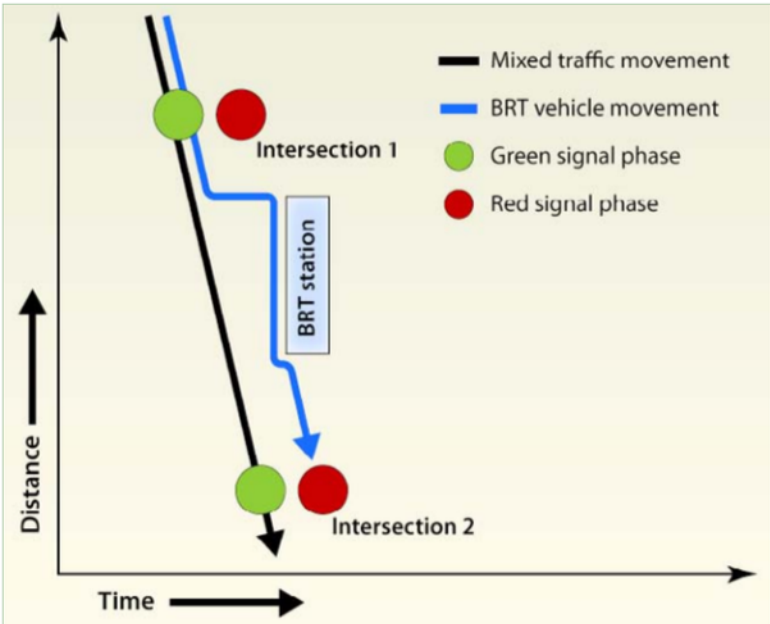

Figure 24.33. Coordination for mixed traffic does not help the BRT corridor when there is a station between intersections. If the green time of the green wave has the same length of total dwell time at stations, the effect can be particularly harmful, as it increases the chances that the BRT vehicle's arrival at an intersection after a station will be during the red time. *ITDP.*

But when intersections are too close together in order to optimize the station location relative to them, an assessment has to be made regarding how important the station location is for boarding and alighting customers, the detour forced on mixed traffic close to the station, and to what extent it hinders the whole BRT system due to interference between the station and the intersection. There are three options:

1. Close one of the intersections: this generates mixed-traffic detour time and higher cross volumes at other points that may impact the BRT corridor as well;
2. Transfer or remove the station: this increases walking time for BRT users of that station;
3. Keep station and intersections: this generates delay for all customers in the BRT that pass through the intersection.

Even for normal mixed traffic, having two intersections too close together will sometimes lead to problems of the same nature as discussed in Section 24.4.2: Minimizing the Number of Mixed-Traffic Lanes Away from the Intersection and Section 24.4.3: Minimizing the Recommended Distance between the BRT Station and the Intersection from a Mixed-Traffic Perspective vehicles queued at one intersection will back up to the point where vehicles are unable to clear the previous intersection during a green phase. Equation 24.22 below defines the calculation for the distance above which this type of conflict shall not occur.

Eq. 24.23

$$D_{i1-i2} \geq 3 * Max(T_{\text{green-i1}}, T_{\text{green-i2}})$$

Where:

- $D_{\text{i1-i2}}$: Distance in meters between intersection 1 and intersection 2;
- $T_{\text{green-i1}}$: Green signal time in seconds at intersection 1;
- $T_{\text{green-i2}}$: Green signal time in seconds at intersection 2.

A mixed-traffic lane can generally handle 1,800 vehicles per hour. This quantity translates to two vehicles per second (3,600 seconds in an hour). When vehicles are stopped at a stoplight, the average amount of space they take up is 6 meters; this space includes the vehicle and some space between vehicles. This average vehicle distance means that for each second of time, 3 meters of vehicle-equivalents can be moved through the intersection.

This distance between the intersections guarantees that there is enough space for queueing vehicles, so that it does not happen that the green light is open and there are vehicles stuck in the upstream traffic light. Proper synchronization can reduce this distance to practically zero.

Example

The following scenario is outlined in order to determine whether two intersections 100 meters apart will result in free-flow operation or in congestion:

- $D_{\text{i1-i2}}$ = 100 meters;
- $T_{\text{green-i1}}$ = 50 seconds;
- $T_{\text{green-i2}}$ = 30 seconds.

To determine if the distance between these intersections is sufficient, Equation 24.19 can be applied:

$$100 \geq 2.5 * Max(50, 30)$$

$$100 \geq 150 \leftarrow \text{FALSE}$$

Since 100 meters is less than the required 150 meters, there is not enough space between the intersections.

In the direction from 1 to 2 it is possible (if 2 is red while 1 is green) that vehicles queuing at 2 will back up onto the first intersection and the last 50 meters of queue will be trapped before intersection 1.

In the direction from 2 to 1 it is possible (if 1 green starts the same time the first vehicle from 2 arrives at the intersection), then the last 20 seconds of green in 1 will be useless, since vehicles stop flowing after 30 seconds in intersection 2.

24.5.2 Shortening and Eliminating Phases

In this subsection we name traffic diversion models and traffic sign phase schemes as we describe them in order to refer to them in the following text and in the next subsection.

24.5.2.1 Typical 4-Phase-Intersection

In a typical intersection that allows all movements (Figure 24.34), four phases are required; usually each origin has its phase ("standard-four-phase") but an alternative scheme with one phase for each direction (two ways) in straight movement and curb-side turns, and one phase for each direction (two ways), cross-traffic turn may be used as well, which we will refer to as the "symmetrical phase."

The standard configuration has the advantage of not requiring dedicated queue space (queue box) for cross-traffic turns and also allow sharing one lane for cross-turn and straight movements (it can be the most median-side or the second closest to it) and let the intensity of the flow variations along the day balance the use of this lane. The symmetrical phases are interesting when cross-traffic-turn flows are relatively low and straight movements are intense in both ways (cross-traffic-turn phase will be short and straight will be long). Our practical experience suggests that symmetrical tends to be better if a clear bidirectional flow exists, but it ultimately requires an assessment of the flows intensity to each application.

A combination of the two is also possible, using cross-traffic-turn phase for one direction, and one phase per origin in the other direction ("mixed-four-phase").

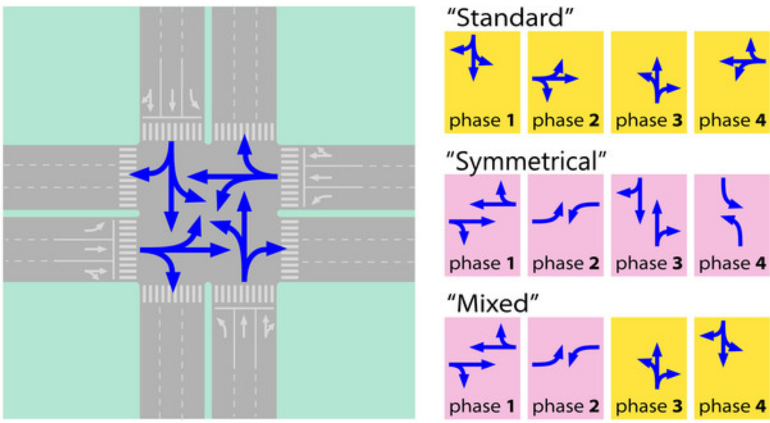

Figure 24.34. Possible movements and signal phases at a typical four-leg intersection. *ITDP.*

24.5.2.2 Movements Conflicting with BRT

Figure 24.35. Along Quito's Central Norte corridor, vehicles in mixed traffic are given a phase to perform left turns. Image *Lloyd Wright.*

When the BRT has to cross a typical four-stage intersection, the main concern is to increase the green time for the corridor direction. Eliminating phases are likely to be very effective in doing so, but it is important to keep in mind that it is not the primary goal. Eliminating phases in a way that green time is not increased for the BRT approaches will improve only mixed-traffic performance.

To eliminate the phases we must focus on the *movements that conflict with the BRT* (Figure 24.36) and try to reroute them in such a way that they can cross the corridor in one phase and briefly—that is, providing width to the crossing movement approaches. Providing width to parallel movements is important to improving general traffic, which is also desirable, but not paramount.

For the remainder of the section we will assume that the busway is median-side aligned and that the busway crosses the intersection straight; if the busway is curbside and/or it is turning between perpendicular roads, the same reasoning applies and the same alternatives for detour mixed-traffic movements will be considered, but in a different and appropriated way.

With a median-side BRT, standard-four-phase sign can no longer be applied, as it will conflict with the cross-traffic turn (Figure 24.35), so the symmetrical or the mixed-four-phase has to be used.

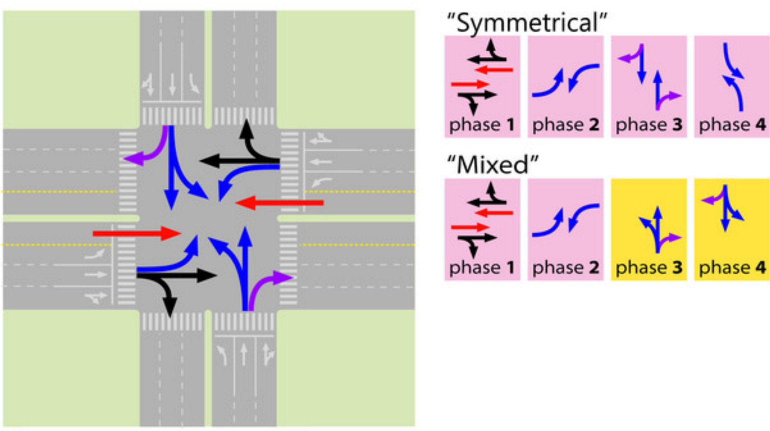

Figure 24.36. With the insertion of BRT (red) in a four-stage signal, the cross-traffic turn from the same direction needs to have its own phase. *Elebeta.*

24.5.2.3 Diverting Curbside Turns

Diverting curbside turns does not remove a phase, but it can free space for queueing and increase capacity for the remaining movements.

Moving curbside turns away from the intersection is usually simple if parallel streets are available (Figure 24.37). It will require a cross-traffic turn in the parallel street corner, which may start to spread the main corridor intersection problems to a broader area. Detouring the curbside flow from the crossing street is particularly interesting because it can leave the width of the whole approach available to conflict movements, reducing the crossing time (red for the corridor) in the same proportion this curbside-turn flow is to the total flow, even if four phases are in use. From a BRT point of view, there is no interest in diverting the parallel curbside flow at the intersection, as it is not a conflicting movement.

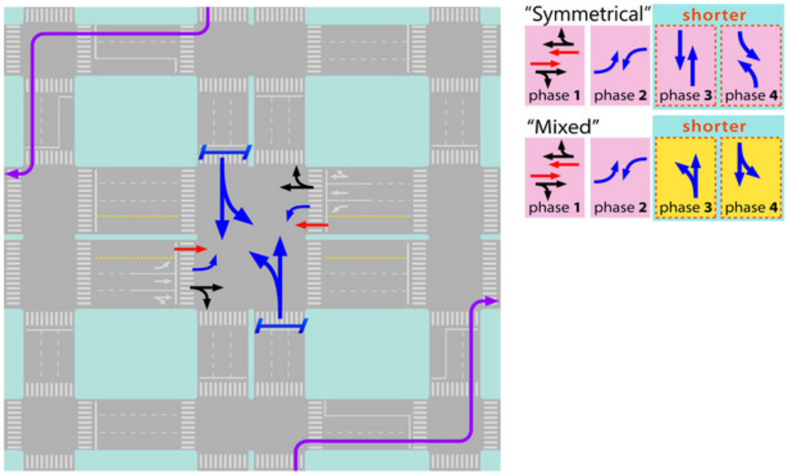

Figure 24.37. Curbside-turn detour can leave width in the main intersection available to crossing flows. *Elebeta.*

24.5.2.4 Diverting Cross-Traffic Turns

There are several ways of eliminating cross-traffic turns in the main intersection by detouring the flow. These can be applied both to the flows parallel to the corridor and to the flows crossing the corridor (and turning parallel to it). Without cross-traffic turns, the intersection can have only two phases, but applying a detour to only one direction (both ways) means eliminating one phase already.

24.5.2.5 Curbside-Turn, Cross-Traffic Turn, and Cross-Traffic Turn ("curb-first")

This detour follows a curbside detour proposed through auxiliary streets, with a curbside turn at the parallel street before the intersection, followed by two successive cross-traffic-side turns (Figure 24.38). This variation is more effective to apply to the corridor perpendicular to the BRT, as it frees width in its main approach to straight flow only. When compared with other alternatives (discussed below) this detour might be more beneficial to mixed traffic as opposed to the BRT, since it may justify reduction of proportional green time in BRT's direction.

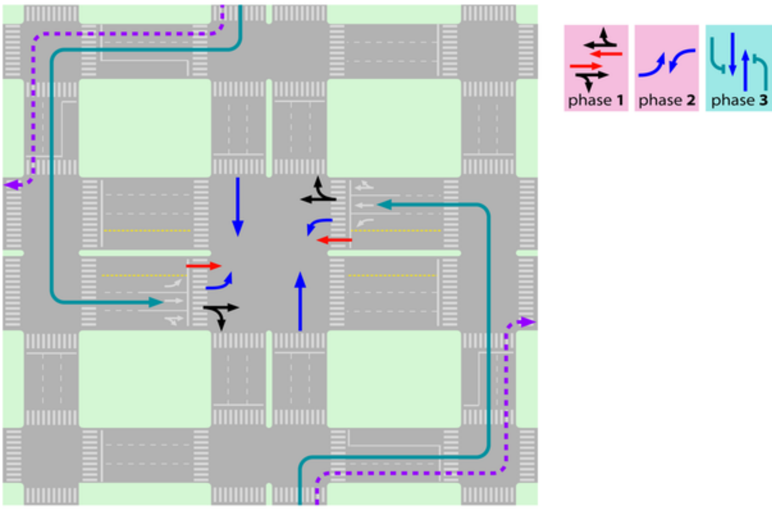

Figure 24.38. By detouring a cross-traffic turn to a curbside parallel street before reaching the intersection, a phase is eliminated in the main intersection. *Elebeta.*

24.5.2.6 Loop

For the loop, the flow looking to perform a cross-traffic turn has to instead cross straight through the intersection and perform three curbside turns and then cross straight through the intersection again (Figure 24.39 shows an application of this flow that is initially parallel to the BRT), even though this has the clear disadvantage of using the intersection twice. Although the other way can be better, this alternative is always interesting for the BRT crossing flow, because it necessarily reduces red times. For the parallel flow it is interesting while flows are low enough not to take one lane width on the crossing-BRT phase.

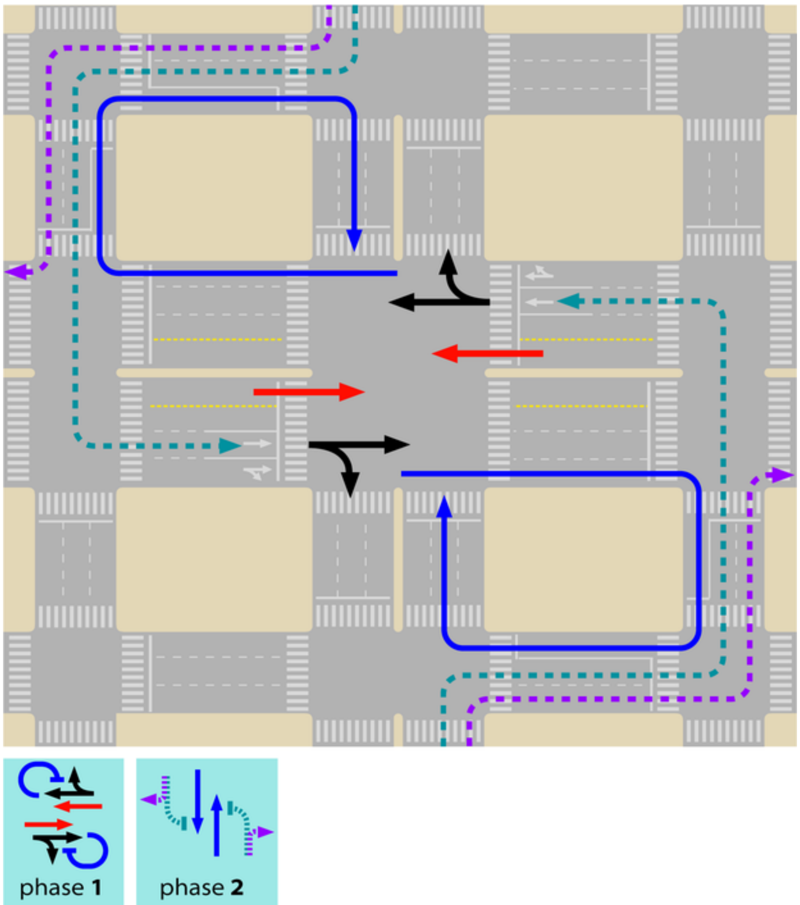

Figure 24.39. Three curbside turns after crossing the intersection is a simple alternative to eliminating cross-traffic turns; despite crossing the intersection twice, it does not create much conflict with existing flows. *Elebeta.*

24.5.2.7 Previous Cross Turn ("previous cross")

Before reaching the main intersection, the diverted flow is allowed to cross-traffic turn in a location where there is no perpendicular crossing traffic (i.e., where previously no crossing intersection existed), the opposite straight flow has to be detained to allow this move, but it can be stopped synchronously to the main intersection. After the cross, the diverted flow follows perpendicular to the main corridor until a suitable location for a curbside turn is reached; from there it will run parallel to the original flow in the direction of another intersection in the crossing road, downstream the main intersection, where it will join the flow by means of another cross-traffic flow in a two-stage traffic light (where previously no crossing existed or now has to be forbidden) also synchronized with the main intersection (Figure 24.40).

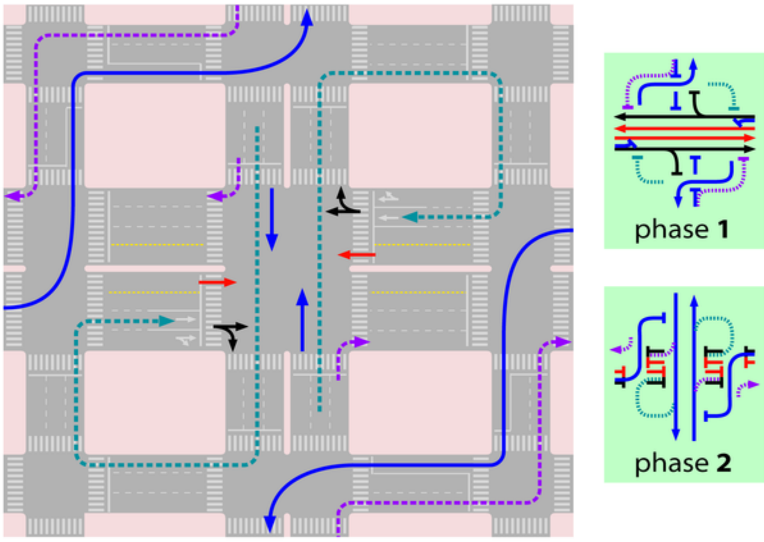

Figure 24.40. It is possible to provide a two-phase coordination for detouring cross-side turns to leave the road upstream and return downstream of the main intersection; additional synchronized traffic lights are required. *Elebeta.*

The "previous cross" detour is the best alternative for the parallel flow to the BRT corridor that wants to turn across traffic on the main intersection because it definitely moves the conflict away from the most crowded intersection. But it cannot be applied in both directions (parallel and perpendicular) as it would require a three-phase intersection for exiting/returning to the main avenues. It also may create capacity conflict if, in the perpendicular direction of approach, the curbside-turn is being diverted, so consideration should be taken to redirect it back to regular curbside turning at the intersection. If cross-traffic turn, also in the perpendicular direction, is diverted by means of the "curbside first," then serious conflict would rise, so the perpendicular flow shall be redirected to a "loop."

The previous cross alternative is similar in concept to the "displaced left-turn" intersection in the United States (Figure 24.41), which can be applied where width is available.

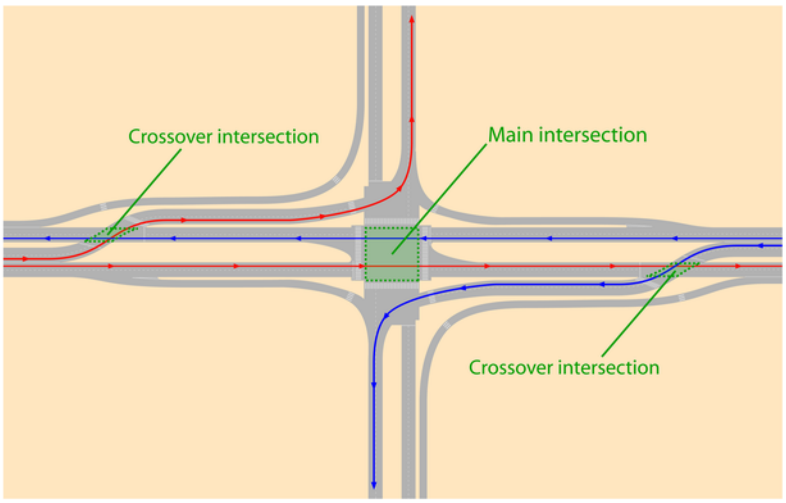

Figure 24.41. In the United States, the concept of previous turn is applied in a less dense urban context by the name of "displaced left turn" intersection. *Elebeta.*

24.5.2.8 Curbside Turn and U-Turn ("curb-u")

A cross-traffic-flow detour is made by first making a curbside turn at the crossing road, followed by a U-turn in the crossing road at a suitable location approximately one hundred meters from the major route, and then driving straight through the intersection. From the main intersection capacity point of view, this alternative has no advantage over the loop as it takes away the same width as the loop in both approaches. It is suitable when the loop is not an option, because the alternative is already congested or too long, which would create political problems with car drivers; besides, there would have to be sufficient width to accommodate the U-turn as well as length for a waiting area. To be applied to the traffic coming from the perpendicular direction to the BRT, as this movement crosses the bus lanes it creates undesirable conflicts for the BRT system. The U-turn traffic light should be two-phase only, synchronized with the main intersection.

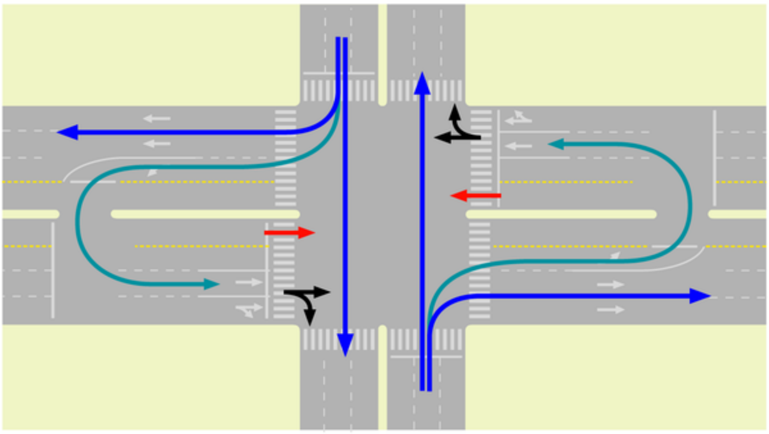

Figure 24.42. Making a U-turn after entering, by means of a curbside turn, the opposite way of the desired direction is another way to perform a cross-traffic turn without need of an exclusive phase. This alternative requires a queueing area and uses two approaches to the intersection as well. *Elebeta.*

24.5.2.9 U-Turn and Curbside Turn ("U-curb")

Another alternative is possible by means of making a U-turn at a median break downstream of the crossing road, followed by a right turn at the crossing road (Figure 24.43).

The U-turn and queue area may be accommodated at the curbside instead of in the median side, as shown in Figures 24.44, 24.45, and 24.46, where it accommodates cross-side-turn detoured flows from both the parallel and perpendicular streets: parallel doing U-turn then curbside, the perpendicular doing curbside then U-turn.

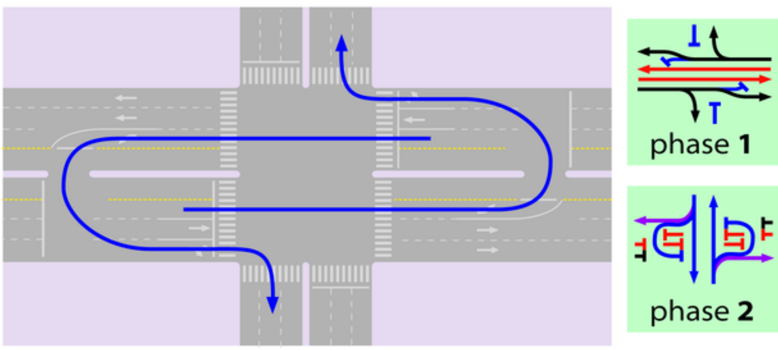

Figure 24.43. U-turns after crossing the intersection are an alternative to eliminate a cross-traffic-turn phase, but they require the flow to cross the intersection twice and require width for queueing downstream. *Elebeta.*

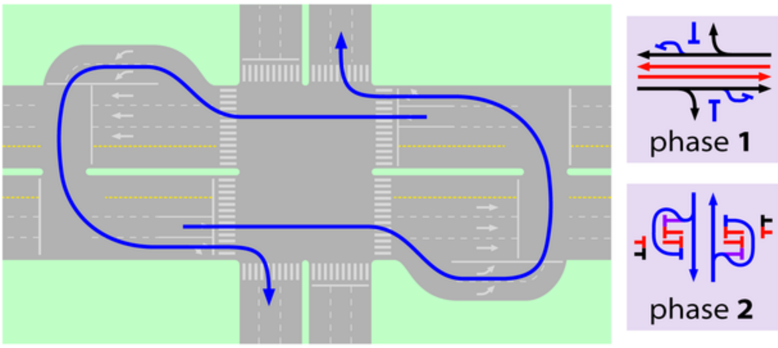

Figure 24.44. Waiting area for a U-turn can be placed closer to the curb, instead of close to the median. *Elebeta.*

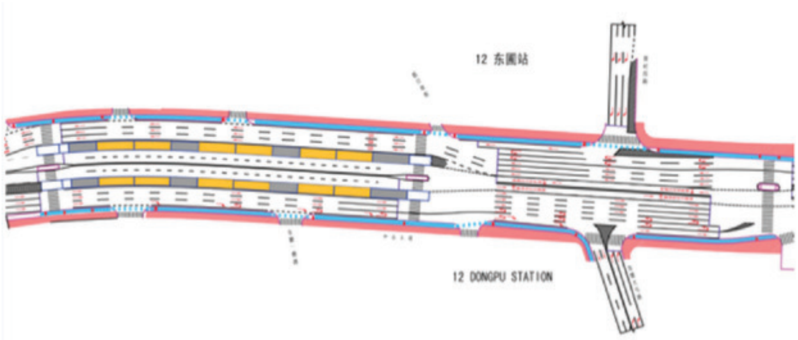

Figure 24.45. Dongpu BRT station in Guangzhou, provides at-grade station access at both ends, combined with U-turns. *ITDP with GMEDRI.*

Figure 24.46. This intersection near Dongpu BRT Station in Guangzhou was previously a major traffic black spot—a location where traffic accidents often occurred—but now it works very smoothly for all modes, with a two-phase signal combined with U-turns and pedestrian crossings. *Karl Fjellstrom, ITDP.*

24.5.2.10 Diverting Straight Flow: Parallel Street

The use of the immediate parallel street in one way as an auxiliary street is an effective alternative for mixed traffic. Even a narrow two-way street transformed into a one-way street with parking prohibition can be a meaningful alternative for straight traffic and avoid the need for widening and expropriation. If applied both to BRT corridor and the corridor crossing, it can alleviate intersections. In São Paulo it is common that the "auxiliary" streets end up having higher throughput than the main corridors (Figure 24.47).

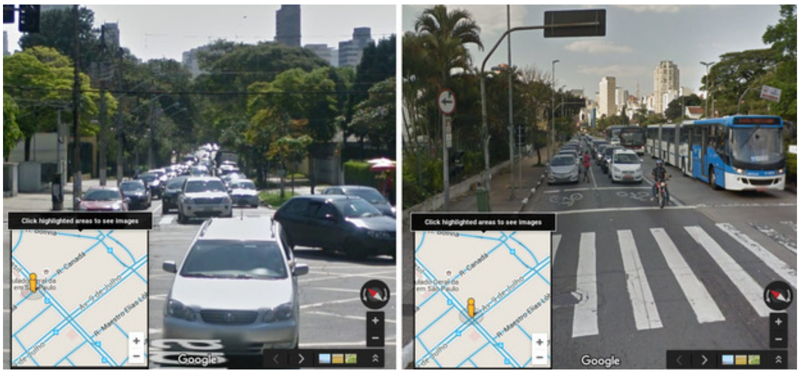

Figure 24.47. Auxiliary street (left) has higher mixed-traffic capacity than the main corridor (right) in São Paulo. *Google Maps.*

24.5.2.11 Moving Across or Making a U-turn Away from the Intersection

If the station location is seen as imperative, the intersection could be closed in order to avoid problems with the BRT system operation. Mixed traffic can be detoured around it. The examples for curbside and U-turn (Figures 24.48, 24.49, and 24.46) applied this detour to straight movements, too, even if the movements do not always surround the station.

24.5.3 Creating Two-Phase Intersections

Many of the detour options assume that an adjacent secondary-street system exists and has the capacity to absorb additional traffic caused by the proposed diversions. When they do not exist, widening one of the roads to accommodate U-turns and/or previous cross-traffic turns is usually a more feasible alternative. Deciding which detour alternatives apply to each flow requires a careful evaluation of both the demand intensity and fluctuations throughout the day in the intersection and surrounding streets, as well as the possibility of widening the approaches.

An infinite number of designs exist, including roundabouts and hamburger-shaped intersections and others that have yet to be created. *The goal is to increase the proportion of green time given for the corridor direction*, which will result in a natural increase of capacity for traffic.

Alternatives that invert the way—that is, making a right-handed system in a location where a left-hand system is used or vice versa—should not be proposed (in our experience, even if the flow is completely channeled and pedestrians and bicycle crossings are grade-separated, there should be safer alternatives). The common situation of a flowing busway amid congested mixed traffic is enough potential danger to deal with at the intersection. The importance of an enforcement policy to slow down BRT drivers in this situation cannot be stressed enough.

For mixed traffic in particular, measuring travel time alone is not the right metric to evaluate and monitor the quality of a solution. It is very likely (and frustrating) that one will see congestion returning after implementation on a major intersection. When that happens, one must remember that, besides accommodating rapid public

Figure 24.48. Traffic is diverted past this TransOeste station in Rio de Janeiro before it is allowed to perform U-turns away from the station. *Google Earth.*

Figure 24.49. Dongpu BRT station in Guangzhou (see layout at Figure 24.45) provides at-grade station access at both ends, combined with mixed-traffic U-turns. *Karl Fjellstrom.*

transport, there are capacity gains for mixed traffic. Congestion seems to be the only general traffic deterrent, so if a good design will enable more people to cross the intersection by car, then that might mean that either travel times or congestion were eliminated somewhere else or that more people are willing to come to that area and benefit from the activities that part of the city has to offer.

When the adjacent land use is primarily residential, there is likely to be considerable resistance to the above proposals. One should keep in mind that this is a normal pressure of city growth (historically, cities grew out of road intersections), and a broader perspective to regulate the use of land may need to be brought into the project.

24.5.4 Comparison Examples

For an initial general analysis of the possible configuration, we graphically present the cycle time as a function of required relative green times for vehicular phases (Figure 24.50). We consider both the situation where a pedestrian phase is required and not. When required, we assume the pedestrian phase will need 10 seconds plus 4 seconds of clearance, which is the time needed for crossing three lanes. The clearance (or lost time) for each phase is 4 seconds as well.

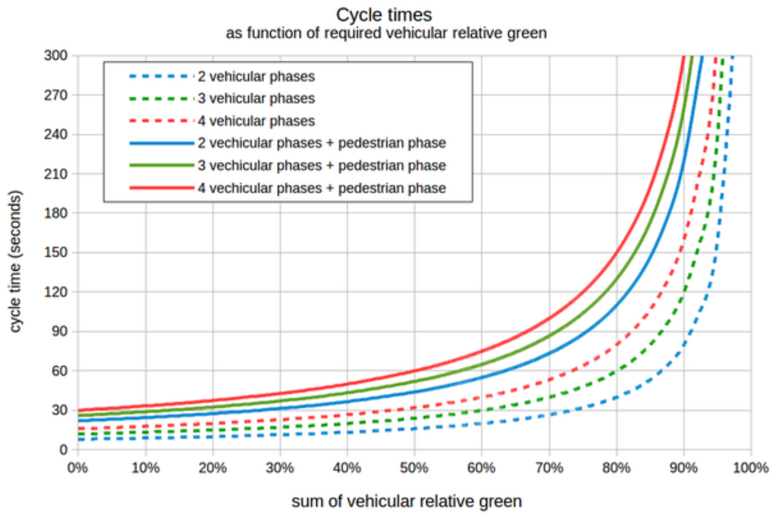

Figure 24.50. When demand requirements get too close to traffic signal capacity (overall intersection capacity) required cycles get too long very quickly. *Elebeta.*

By observing the chart, it is clear that when the pedestrian crossing phase is present, at the moment green times are required to be 75 percent, the intersection is near to collapse. This threshold is between 80 and 85 percent if no pedestrian phase is required.

The chart also shows that increasing cycles beyond 120 seconds is not efficient in any situation. In the best case (4 vehicular phases plus pedestrian phase), increasing it to 150 seconds (+25 percent) results in a 5 percent increase in capacity, and raising it to 300 seconds will add 10 percent more capacity. Such a desperate measure will of course prevent queueing formation during the peak hour and that certainly reduces travel times, but other measures can be much more efficient.

If the BRT users are not to be stuck in traffic, and delay is computed equally to the car users, then it is very likely that raising cycle times above 120 seconds will result in overall time losses. Furthermore, if curbside turns are detoured or refuge islands are used as discussed in Section 24.9, then a proper set of two-phase signals will not require a pedestrian-only phase. In such a situation cycle times above 60 seconds are likely to be useless, and cycle times above 90 seconds are certainly not justifiable.

As seen in Section 24.3, short cycles greatly reduce the chances of spillbacks on the busway, hindering stations.

For a comparison of different configuration impacts, we will assume a very symmetrical four-leg intersection, where the flow from each origin is equal and the left and right turns each represent 25 percent of traffic movements, straight represents 50 percent, and there is no U-turn demand. We will also assume a three-lane approach for mixed traffic in each leg as previous figures in this section show, with saturation capacity flow rate of 1,800 pcu/hour. When required, only one lane is used for cross-traffic turns per approach. We maintain the same assumptions to draw the chart regarding clearance times (4 seconds per phase change) and pedestrian phases (14 seconds per phase when phase required, and we assume it is not required in two-phase intersections).

24.5.4.1 Typical Four-Phase Intersection

For comparing the four-phase intersection, we will fix cycle times at 120 seconds (2 minutes) and evaluate the effect of green time for the straight flow in one of the directions considering detouring curbside turns for each direction (two ways), and we will divide the overall capacity of the intersection by the number of lanes approaching it (NLanes in our example is 12 and results are in table 24.3).

Table 24.3. Four-Phase Capacity Examples

Cycle Time (seconds)	Phases	Direction 1 Curb-Side-Turn	Direction 2 Curb-Side-Turn	Direction 1 Straight Movement Green Time (seconds)	Average Lane Capacity (pcu/hour)
120	standard	-		23	338
120	symmetrical	-	-	31	416
120	standard	detour	-	19	338
120	symmetrical	detour	-	23	404
120	standard	-	detour	26	338
120	symmetrical	-	detour	35	404
120	standard	detour	detour	23	338
120	symmetrical	detour	detour	26	390

Under the proposed scenario, a "standard-four-phase" signal has 90 seconds to distribute among the phases (30 out of 120 seconds are for pedestrian plus clearance times of phases changes), so this means 22.5 seconds per phase (rounded to 23 in the table) in the symmetrical situations. By detouring curbside turns to one side only (letting only 75 percent of demand be served), 3 seconds can be removed from the lesser demanded phases and passed to the other two (19 and 26 seconds); the capacity of each lane of each approach is always equal, meaning that 4,050 vehicles overall could pass through the intersection in one hour in the 12 lanes (= 338 x 12).

In comparison, the "symmetrical phases," which do not require a pedestrian phase, can distribute 104 seconds among the phases, and it ends up being 31 seconds for the straight traffic and 21 seconds for the cross-traffic turn (this last information is not on the table but is deductible). If lanes could be used in fractions, then allocating three-quarters of a lane to cross-traffic turns would lead to a balanced situation of 26 seconds of green time for each phase, which is the case when both curbside turns are removed from the intersection.

On the balanced situation, when the symmetrical phases have the lowest capacity, they still have the same capacity as the standard phases, the higher throughput being a consequence only of the absence of the pedestrian-only phase. As a general rule, symmetrical phases are more efficient than standard phases. Mixed-phase results are not shown, but they are in between, closer to standard phases as they require pedestrian phases, too.

24.5.4.2 Reducing Number of Phases Effects

The previous discussion about four-phase intersections lay the groundwork for not considering the “mixed-four-phase” alternative in the following examples. This is also a reason why there is no need to present a previous cross-traffic turn, interlacing the BRT lane and mixed traffic (Figure 24.82), which shifts mixed traffic to the median side into a position that allows a standard four-phase intersection to work where no other alternative is possible; *the symmetrical-phases signal works better*.

To compare the effects of alternative schemes for phase reduction, we will consider a 90-second cycle time without a pedestrian-only phase but with an additional BRT lane in one direction on the median side (also as shown on most figures in this section). The resulting green time for the BRT for each alternative is presented beside the intersection capacity of mixed traffic in Table 24.4, where:

- **Average lane capacity:** the average of the mixed-traffic lanes capacity that would be measured at the stop lines approaching the main intersection;
- **Overall intersection capacity per lane:** in certain configurations, some vehicles pass through two stop lines in order to execute their turning movements, and this measure would be similar to average lane capacity above, except that it does not count the second passage of the same vehicle.
- **Total throughput with auxiliary intersections per lane at intersection:** this adds the flows that were completely diverted away from the main intersection (curbside-turn detour and previous cross-traffic-turn detour) as if they were effectively passing through the intersection. By bringing the value to the number of lanes of the intersection, this presents a practical estimate of how much the capacity of the main intersection can be pushed to benefit from using the auxiliary ones.

Table 24.4. Increasing Capacity Examples

Option	Cycle Time (seconds)	Phases	BRT Direction Curb-Side-Turn Detour	BRT Direction Cross-Traffic-Turn Detour	Perpendicular Direction Curb-Side-Turn Detour	Perpendicular Direction Cross-Traffic-Turn Detour	Figure	BRT Green Time (seconds)	Average Lane Capacity (pcu/hour)	Overall Intersection Capacity per Lane (pcu/lane)	Total Throughput with Auxiliary Intersections per Lane at Intersection
A	90	symmetrical	-	-	-	-	Fig. 24.35	22	395	395	395
B	90	symmetrical	detour	-	-	-		16	384	384	439
C	90	symmetrical	-	-	detour	-	Fig 24.37	25	384	384	439
D	90	symmetrical	detour	-	detour	-		19	370	370	493
E	90	3	-	-	detour	curb-first	Fig 24.38	43	496	496	567
F	90	2	-	loop	detour	curb-first	Fig. 24.39	51	819	716	819
G	90	2	-	Previous-turn	detour	loop	Fig. 24.40	47	819	702	936
H	90	2	-	Previous-turn		loop		41	819	716	819
I	90	2	detour	curb-first	detour	curb-first		41	819	819	1092
J	90	2	-	loop	-	loop		41	819	655	655
K	90	2	detour	loop	detour	loop	“clove like”	41	819	614	819
L	90	2	-	u-curb	-	curb-u	Figs. 24.43 and 24.44	49	819	655	655

M	90	2	-	curb-u	-	u-curb	33	819	655	655

In our scenario, detouring all curbside turns away implies that 25 percent of cars are not using the approaching lanes to the intersection, and 75 percent of them are. So for each vehicle at the intersection, there is an additional third outside, which means a 33 percent increase in "intersection capacity."

In comparison with the four-phase (symmetrical) signal, even the three-phase signal implies a considerable increase of green time for the BRT. Reducing 4 phases to 3 leads to a 25 percent increase for the capacity at the intersection (and 50 percent considering auxiliary intersections) with satisfactory relative green time near 50 percent. Meanwhile, from the point of view of mixed traffic throughput, the reduction from 4 to 2 phases in the worst cases (U-turn alternatives and only loops: J, L, and M), an 80 percent increase for the throughput occurs at the intersection, and in the best alternative (option I), there is a 107 percent increase at the intersection while green times are in the same range (except for alternative M, which uses U-turns at the perpendicular street). Implementing a two-phase signal is clearly the best thing to do.

When traffic signals are balanced to serve the demand with a two-phase traffic signal, it will result in the capacity of about 820 pcu/hour. For this situation a cycle of 90 seconds with 4 seconds of clearance is typically used. Additionally, if the flow looking to turn is placed on the (curbside) parallel streets in both directions (option I), then one can reach an equivalent of 1,092 pcu/hour. This results in 60 percent of uninterrupted lane capacity as an average for two directions, which is likely to represent 75 percent of the average of the best grade-separated solution and be better than many graded-separated solutions (see Section: 24.10.3 Restricting Turning Movements Together with Grade Separation). Plus, this is 320 percent of the average capacity of a standard four-phase intersection. Clearly, the consideration of the detour alternatives to reduce signal phases can do a lot to increase green time for the corridor as well as capacity for mixed traffic.

Figure 24.51. A tunnel is used to connect two intersecting corridors in Bogotá. Even if the connection is good, walking times could be reduced if routes shifted from one corridor to another. *Lloyd Wright.*

Figure 24.52. Separated-grade walking connections provide safety but also are limited in convenience. Walking transfers can cause physical hardship. *Lloyd Wright.*

24.6 Allowing BRT Turns

"An Englishman, even if he is alone, forms an orderly queue of one."

— George Mikes, writer, 1912-1987

While service plan simplification and organization may, to an extent, minimize turning movements for BRT vehicles in the busway, by concentrating service access to the corridor in a few intersections, turning is necessary and desired where it best serves the demand (in opposition to allowing it where it is convenient by geometry). By planning BRT routes that change between corridors (i.e., with turns), easy platform transfers for the customers are made possible, better, or not even necessary for most users. Thus, turning movements by BRT vehicles should be an integral part of designing an effective overall route structure. As the BRT system expands and provides an increasingly dense network of lines, the connections between these lines become more complex. While a BRT system expands, a growing number of trunk corridors crossing each other is expected.

The costs of not allowing turning movements by BRT vehicles are quite evident, especially in terms of customer convenience. Quito's three BRT corridors (Trolé, Ecovía, and Metrobus-Q) all operate as independent corridors, despite each intersecting one another at several points in the city. At one of the critical intersections between two intersecting BRT corridors in Bogotá (Caracas and Jimenez), customers must transfer by negotiating passages along stairs and an underground tunnel (Figures 24.51 and 24.52). In both these examples, allowing turning movements by the BRT vehicles could have permitted simpler and more convenient platform transfers for the customer. Furthermore, constructing connecting pedestrian tunnels can add much to the overall infrastructure costs of the system. This is copying the bad parts of rail systems. In the Bogotá situation, customer convenience has been significantly increased by allowing turn movements and direct transfers between the Caracas and Jimenez corridors.

There are several solutions to allow BRT vehicle turning that avoid consuming much of an intersection's capacity—mostly needed for cars in the intersection—and the appropriate solutions will depend on the available budget and right-of-way, the number of vehicles in the BRT system and their turning volumes, and the level of mixed traffic and its turning volumes. The optimal solution will be location-specific and each intersection must be evaluated and optimized separately. Here are common options for busway turning movements:

1. Dedicated turning lanes and additional signal phases for BRT vehicles;
2. BRT vehicles operating in mixed-traffic turning lanes;
3. BRT turning movements prior to the intersection;
4. Transform the crossing into a roundabout;
5. Grade separation (discussed in Section 24.10).

24.6.1 Dedicated Turning Lanes and Additional Signal Phases for BRT Vehicles

A dedicated turning lane for BRT vehicles has the advantage of keeping the BRT vehicles in a controlled space at all times (see Figure 24.53). This arrangement may require an additional signal phase if there was no previous cross-traffic-turn phase. Otherwise, the dedicated turn would take place at the same time that the mixed traffic is allowed to turn left.

Figure 24.53. The green phase for a BRT vehicle entering the Val de Marne busway in Paris. *National Bus Rapid Transit Institute (NBRTI).*

Possibly the greatest challenge to this configuration is finding the physical space to place the additional turning lane. The roadway would likely have to accommodate at least five lanes (Figure 24.54). If two lanes of mixed traffic in each direction are to be maintained for straight-car movements, then seven lanes of road space would be required.

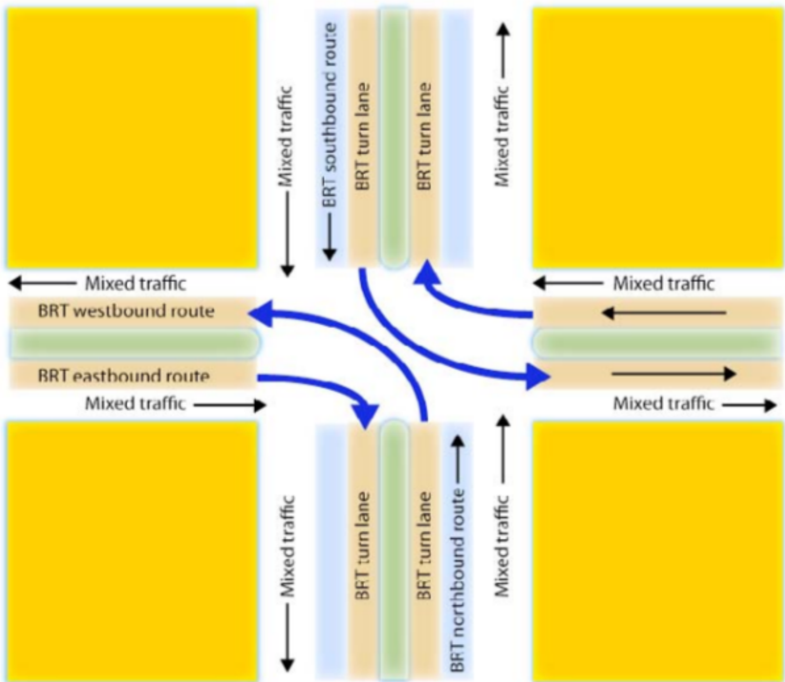

Figure 24.54. Configuration for a system with a fully dedicated BRT turning lane. *ITDP.*

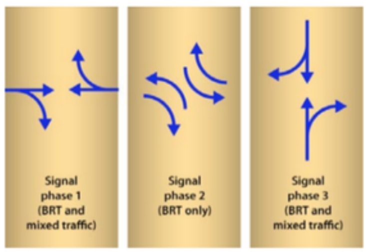

Figure 24.55. In order to permit the BRT turning movements suggested in Figure 24.54, a three-phase traffic signal would be required. *ITDP.*

The configuration suggested in Figure 24.54 would require a three-phase traffic signal, as indicated in Figure 24.55, and in the case of a median-station configuration it can provide full access to all route permutations without walking: a southbound vehicle turning east will give customers access to westbound routes via the platform transfer at the first station. In designing this option, one would choose the highest demand routes to receive the transfer-free routing.

In this scenario, one could technically also allow cross-traffic-turn movements for mixed-traffic vehicles for traffic from north and south, but even more additional lanes would be required. Ideally though, mixed traffic should be diverted as proposed in the previous section (Section 24.5: Restricting General Traffic Turning Movements) as the BRT cross-traffic turn phase will usually be very short (like the queue-jumping phase proposed in 24.5.2.1).

If the turning BRT vehicle frequencies are low enough, the BRT-only short phase can accommodate both right and left turns from one direction as BRT vehicles' drivers can negotiate entrance to the other corridor. That would avoid the need for two waiting lanes for turns.

The complexity of dedicated turning lanes obviously increases as turning options for both BRT vehicles and mixed-traffic vehicles increase. In the extreme case of permitting all BRT turning options and all mixed-traffic turning options, then a total of six traffic-signal phases would be required (Figure 24.56). This number of phases clearly holds disadvantages in terms of waiting times for both BRT and mixed-traffic movements and reduces the capacity of the intersection so drastically—besides requiring four lanes, four BRT lanes, and likely six for mixed traffic—that is very likely to not be feasible in a location where two important corridors cross each other.

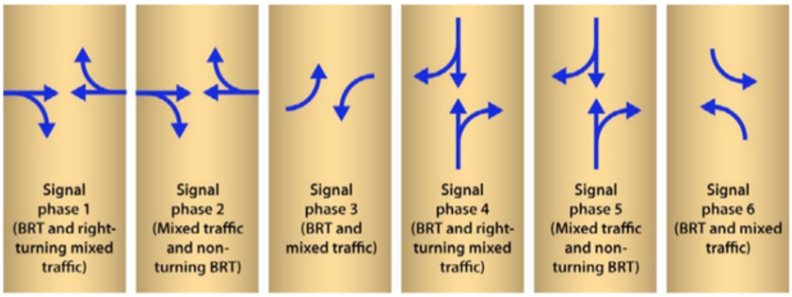

Figure 24.56. To permit a full range of both BRT and mixed-traffic turning movements, six signal phases would be required. *ITDP.*

24.6.2 BRT Vehicles Operating in Mixed-Traffic Turning Lanes

In this scenario, all turning BRT vehicles must leave the dedicated busway and enter mixed-traffic lanes. Thus, a cross-traffic-turning BRT vehicle will leave the busway and directly enter the cross-traffic-turn lane for cars. A curbside-turning BRT vehicle must leave the median-side busway and merge to the curbside of the street to reenter the median-side busway on the new corridor.

This technique is the most common solution that has been used in many of the "open" BRT systems, such as in Kunming, China, and is being planned on several "direct services" BRT systems (Figure 24.57). If there is no physical separation of the busway, the merge with the mixed traffic can happen anywhere in the proceeding block. If there is physical separation, it must occur at the previous intersection, or a slip lane must be provided.

Figure 24.57. In Kunming, turning BRT vehicles leave the busway and enter a mixed-traffic lane to finalize the turning movement. *ITDP.*

From a signal phase standpoint, this option is the easiest to implement, as it does not require changing the signal phase, and does not require any major new infrastructure. However, this option does present serious disadvantages in terms of congestion delay for the turning BRT vehicles, not to mention the assumed inefficiency of four stages to mixed traffic. Further, if the mixed-traffic congestion is heavy, the BRT vehicles attempting to turn may not be able to readily leave the busway, and thus can cause delays to all BRT vehicles, even those vehicles continuing in a straight routing. The BRT vehicle turning right has particular challenges since it must essentially cross all mixed-traffic lanes both before and after the intersection. Attempting these lane changes is particularly difficult if the system is using 18.5-meter articulated vehicles or 24-meter bi-articulated vehicles.

Any time BRT vehicles must leave an exclusive busway operation and enter mixed-traffic lanes the system loses a certain amount of psychological status with the customer. Mixed-traffic operation makes the system much more akin to a conventional bus system rather than a highly efficient public transport system.

24.6.2.1 Queue-Jump Signalization for BRT Vehicles (Pre-Signals)

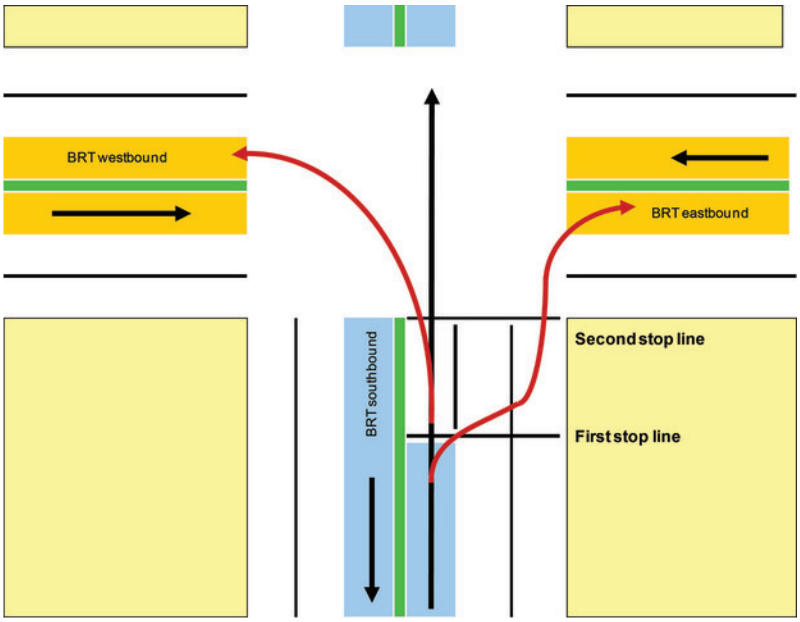

Figure 24.58. While mixed-traffic vehicles are held for an extra ten seconds at the first traffic-signal stop, BRT vehicles are given a queue-jumping head start. Technically this counts as eight phases. *TCRP*

A signal system can be utilized to give BRT vehicles a head start on turning movements prior to private-vehicle turning movements. In this case, a dual traffic signal is utilized for each direction of travel. One traffic signal is located at the intersection, and another traffic signal is located approximately 30 to 50 meters prior to the intersection. At the traffic signal prior to the intersection, the BRT vehicles on the busway would receive a green signal of approximately 10 seconds prior to the green signal for the mixed traffic (Figure 24.58). During this head start, the BRT vehicle would be able to exit the busway and cross to the other side of the street. This is the equivalent of having eight stages and, besides the same problems with congestion in mixed traffic, a BRT vehicle that arrives in the middle of the green phase will be blocked by cross-traffic-turning cars and block eventual vehicles behind it. Figure 24.59 shows an example of pre-signal without BRT turning; it is used as a way to allow mixed traffic turn cross-traffic when the roadway width is constrained.

Figure 24.59. Pre-signals for buses, holding normal vehicles in Cape Town, South Africa, work like a queue jump to a straight movement in a mixed-traffic section. *Bruce Sutherland.*

24.6.3 BRT Turning Movements Prior to the Intersection

To avoid having a special BRT turning phase in a main intersection, an alternative is to create a special bus-only turn (this is as good for left turns as for right) phase at an intersection before a major intersection where there is less crossing demand than in the main crossing corridor, or no demand at all (Figure 24.60). For a few blocks, the BRT vehicle will operate on secondary streets (in mixed traffic or in a dedicated lane) until it rejoins the busway. This option requires the availability of usable secondary streets and consideration regarding the placement and use of stations by turning routes (not to move it too far from the origin/destination of many trips on the other side of the main intersection).

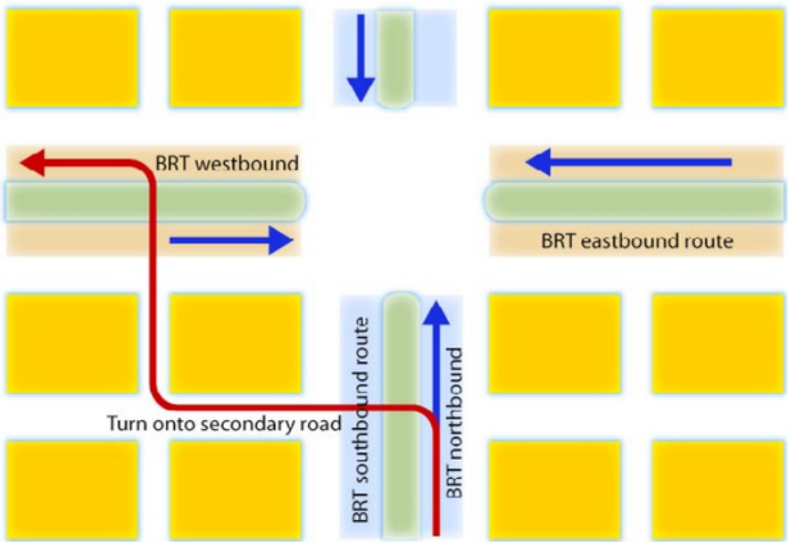

Figure 24.60. In this scenario, the BRT turning movement is made prior to the main intersection. The BRT vehicle temporarily operates on the secondary road network. *ITDP.*

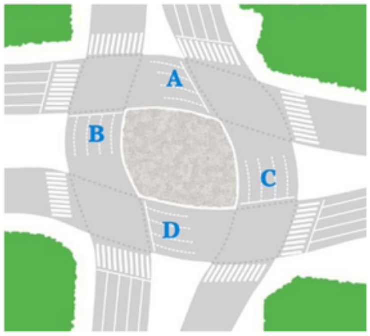

Figure 24.61. In this scenario, the intersection is converted to a roundabout with vehicle queuing areas at points "A," "B," "C," and "D." The BRT vehicles enter mixed traffic just before the intersection and move through the intersection with a two-phase signal. *ITDP*

24.6.4 Convert Cross into a Roundabout

If two crossing corridors happen to be two broad highways, enough right-of-way may be available to convert a standard four-phase intersection into a two-phase signalized roundabout. This is a clever alternative that should be remembered, as in many developing-nation cities, such right-of-way is available but underutilized.

The exclusive BRT busway terminates approximately 50 meters prior to the intersection with the BRT vehicles entering mixed traffic at that point. This approach essentially turns the junction into a grid of one-way streets. It requires a fairly large amount of right-of-way at the junction.

Figure 24.61 indicates how the junction between two major boulevards can be turned into a two-phase traffic circle by creating a kind of mini-grid of one-way streets. At low traffic volumes, the BRT buses enter mixed traffic prior to the intersection. A series of queuing areas (marked as "A," "B," "C," and "D" in the figure) help stage vehicle flows through the roundabout. These areas are referred to as "waiting boxes."

Figure 24.62 outlines the vehicle movements for the first signal phase for this roundabout conversion. This example is given from the perspective of a British-style road configuration. All eastbound BRT vehicles and mixed-traffic vehicles that are making right-hand turns would pass through the intersection and queue in area "C" at a traffic light. All east- and westbound traffic can proceed straight. All vehicles making left-hand turns can proceed. All westbound traffic would pass through the intersection and queue in area "B."

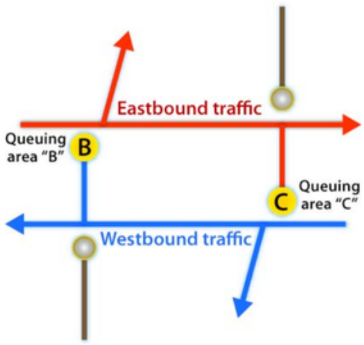

Figure 24.62. Vehicle movements for signal phase 1 in a cross converted into a roundabout. *ITDP.*

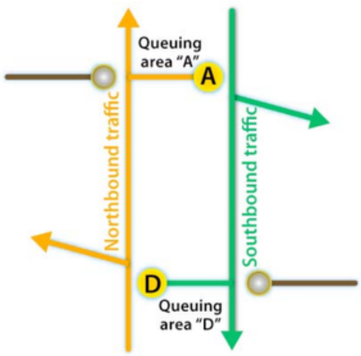

Figure 24.63. Vehicle movements for signal phase 2 in a cross converted into roundabout. *ITDP.*

In the second signal phase, all northbound and southbound traffic can proceed straight, all left-hand turns can proceed, and all right turning traffic would queue in areas “A” and “D” (Figure 24.63).

This solution will work up to the point where the amount of space in areas “A,” “B,” “C,” and “D” is sufficient to accommodate all the turning traffic. The required and available space are discussed in Box 24.2.

Opposite of the rule to increase capacity, the cycle on a signalized roundabout of this type should be short, so the queueing box can handle volumes (manual operators must be very careful when handling these intersections, keeping an eye on the queueing boxes to decide when to alternate to the next phase). Other alternatives of busways through roundabouts are discussed in the next section.

Box 24.2. Required and available space for queueing boxes:

For the purpose of evaluating queueing space, we consider that:

- The amount of road space that a passenger car practically uses is 15 square meters; this includes some distance kept between vehicles to separate them from each other when queueing at the traffic light ($\text{Area}_{\text{pcu}} = 15m^2$);
- The amount of road space needed for a 12 meter-bus to queue is 30 square meters, therefore its equivalence factor is 2.0, i.e., one 12 meter-bus uses twice the space a pcu;
- An articulated BRT vehicle has an equivalent factor of 3.5 pcu;

The available area capacity and the required area (or demanded area) to transform a cross into a roundabout are:

Eq. 24.24

$$\text{Available Capacity}_{\text{queue box}} = \frac{\text{Area}_{\text{wait-box}}}{\text{Area}_{\text{pcu}}}$$

Where:

- $\text{AvailableCapacity}_{\text{queue box}}$: Number of cars that fit in wait box (in pcu);
- $\text{Area}_{\text{wait box}}$: Amount of space in the wait box (either ”A”, ”B”, ”C” or ”D” in Figure 24.61);
- Area_{pcu}: Amount of road space a passenger-car uses 15 m^2 (it should be expressed in the same unit of $\text{Area}_{\text{wait box}}$).

Eq. 24.25

$$\text{RequiredCapacity}_{\text{wait box}} = \text{Flow}_{\text{left turn}} * \text{Time}_{\text{cycle}}$$

Where:

- $\text{RequiredCapacity}_{\text{wait-box}}$: Number of cars that need to fit in wait box (in the same unit the numerator of the measure described below, normally pcu);
- $\text{Flow}_{\text{left turn}}$: Number of vehicles that turn left during the peak (normally expressed in pcu/hour, see basic concepts of this chapter);
- $\text{Time}_{\text{cycle}}$: Time duration of a complete traffic light cycle during the peak (normally expressed in seconds, so here the same unit of the flow above needs to be converted, dividing the value by 3,600).

In order for the configuration to function, the available space capacity must be equal or greater than the required capacity.

Example

The following scenario provides an example of calculating the required and available capacity of the proposed roundabout queuing space:

- Turning movement = 540 pcu/hour = 0.15 pcu/sec;
- Cycle time = 90 sec.

Required capacity = 0.15 * 90 = 13.5 pcu

- Unitary pcu space = 3 m * 5 m = 15 m^2;

- Length = 30 m;
- Width = 12 m.

Available capacity = (30 m * 12 m) / (15 m^2/pcu) = 24 pcu

In this case, the available capacity is greater than the required capacity (24 pcu ⩾ 13.5 pcu), so the proposed roundabout conversion could function.

Considering the Figure 23.61, when the number of mixed traffic vehicles and BRT vehicles rises to the point that areas “A,” “B,” “C,” and “D” are too small to accommodate them all, turns should be restricted for mixed traffic but not for BRT vehicles. Effectively, the queuing areas “A,” “B,” “C,” and “D” would be reserved for BRT vehicles.

24.7 Merging with Mixed Traffic in Narrow Sections

“Well, you would have to say what is the criteria to determine the success of any merger? It would have to be that the companies are stronger financially, that they took market share, and they are on a very steady footing in terms of their performance.”

— Kevin Rollins, businessman and philanthropist, 1952-

Sometimes a BRT system must pass through a narrow stretch of road that is impossible to widen. Such areas may include bridges, tunnels, city gates, or flyovers. As shown below, having the BRT running with mixed traffic only in this narrow section may not be too harmful for the public transport system if appropriate measures are taken.

This situation can be seen as an intersection (a form of a bottleneck) as there is conflict for using the same space. Usually the heaviest congestion occurs not on the narrow link but just before it, forming a large queue just to enter onto the bottleneck point. When the facility itself is not congested, only the approach to the facility, a traffic signal is generally not needed, and it may be better to end the exclusive busway just a short distance before the bottleneck. The distance should be sufficient only to allow a convenient distance for merging (40 to 80 meters). This curtailment of the busway will allow BRT buses to pass through most of the congestion point without provoking any reduction of mixed traffic capacity at the critical section (Figure 24.64).

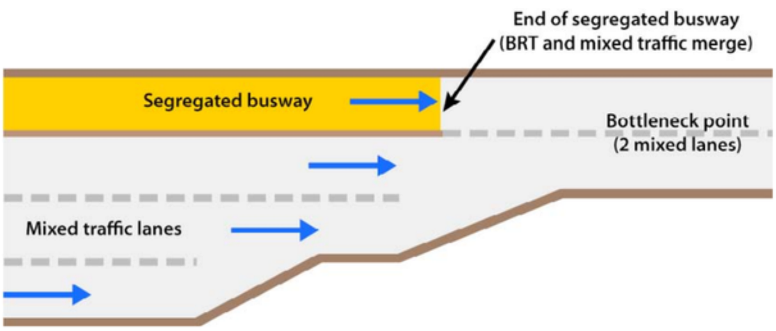

Figure 24.64. In the case of a severe bottleneck point, it may be best to terminate the exclusivity of the busway prior to reaching the bottleneck. *ITDP*

If the critical link is an approach to a signalized intersection (Figure 24.65), then BRT should be given signal priority (active priority if BRT has lower frequency, passive priority in all other cycles), and the head start in the green phase ($T_{\text{headstart}}$) should be given by:

Eq. 24.26

$$T_{\text{headstart}} = \frac{\text{Dist}_{\text{stop to narrow section}}}{\text{StartSpeed}_{\text{BRT}}}$$

Where:

- $T_{\text{headstart}}$: Time of head start in the green phase;
- $\text{Dist}_{\text{stop to narrow section}}$: Distance between the stop line of the signal preceding the narrow section;
- $\text{StartSpeed}_{\text{BRT}}$: An average head start speed that the BRT vehicle needs as an advantage over mixed traffic to reach the section first. We suggest 3 m/s (11 km/hour). Using meters and seconds the equation becomes:

$$T_{\text{headstart}}[seconds] = \frac{\text{Dist}_{\text{stop-to-narrow-section}}[meters]}{3}$$

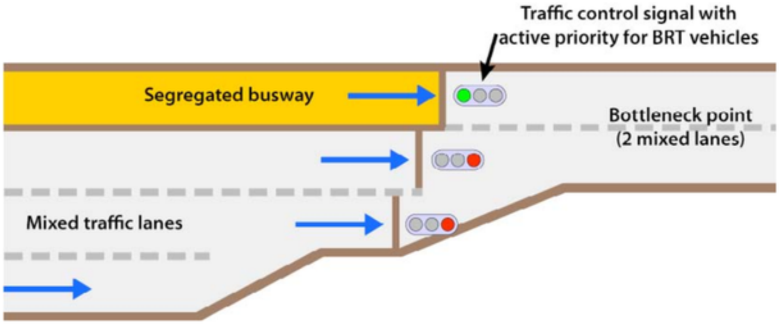

Figure 24.65. In the case of a severe bottleneck approach with traffic lights, signal priority is to be given to BRT (passive or active). *ITDP*

The example given in Figure 24.65 essentially acts as a queue-jumping mechanism in which the BRT vehicles are given an advantage through a bottleneck point.

The head start, however, is useless if the facility itself also becomes congested. If there is a risk that the bottleneck facility itself may become congested (due to mixed traffic spillback of conflicts ahead of the narrow section), active signal priority based on the detection of mixed traffic should be used.

The signal before the section would work normally (or if a signal did not exist one would be created and flash yellow) until traffic detectors note that the narrow link has become congested (at its most downstream portion). At that point, the signal would be activated, and a red light would be given to mixed traffic until the narrow section clears. The use of such a traffic signal will help to avoid congestion inside the busway. Instead the delay is transferred to the mixed traffic in the previous link, resulting in improved velocity for BRT vehicles at the narrow link. For tunnels, this approach has the extra advantage of avoiding idling vehicles within heavily polluted conditions.

24.8 BRT Lanes at Roundabouts

> *"So many roads. So many detours. So many choices. So many mistakes."*
>
> — Carrie Bradshaw (as played by Sarah Jessica Parker), "Coulda, Woulda, Shoulda," Sex and the City, 2001

Intersections with roundabouts can create considerable uncertainty for the busway system. If the BRT vehicle must cross several lanes of mixed traffic within a heavily congested roundabout, the BRT vehicle may be hindered from proceeding.

However, there are some solutions to the difficulties posed by roundabouts. There are at least five distinct possibilities for accommodating BRT systems through a roundabout:

1. Mixed traffic operation;
2. Mixed traffic operation with signalized waiting areas;
3. Exclusive lane along the inside of a roundabout;
4. Exclusive busway through the middle of the roundabout;
5. Grade separation.

24.8.1 Mixed-Traffic Operations:

If mixed traffic and BRT system volumes are not particularly heavy and/or if the roundabout has no traffic lights, then simply allowing the BRT vehicles to enter mixed traffic may be an effective and simple solution. In such cases, the BRT vehicle will leave the dedicated busway upon entering the roundabout, which may be either controlled through a traffic signal (eventually a new traffic signal and/or activated by the vehicle approach) or left to operate on a yield priority basis.

24.8.2 Mixed-Traffic Operation with Signalized Waiting Area:

In this situation, a standard intersection is converted to a roundabout with signalized control as described in the end of Section 24.6.4. When a standard intersection has reached its saturation point, then BRT-only waiting areas should be created and private vehicles must be accommodated in a variety of turning options already discussed.

24.8.3 Exclusive Lane along the Inside of a Roundabout:

In cases where BRT and mixed-traffic volumes dictate that some priority must be retained for the BRT vehicles, then making the inside lanes of the roundabout exclusive to BRT can be an effective option (Figure 24.66). In this case, the BRT vehicles can access the exclusive roundabout lanes either by crossing mixed-traffic lanes or by receiving priority signalization. Likewise, to exit the roundabout and re-enter the principal busway, the BRT vehicle must cross mixed-traffic lanes. As with the entry to the roundabout, the BRT vehicles can either maneuver across mixed traffic to exit the roundabout or another set of traffic signals can be used to facilitate the operation.

Figure 24.66. TransJakarta's first corridor passes along the inside of several roundabouts. *Google Earth.*

24.8.4 Exclusive Busway through the Middle of a Roundabout:

Depending on the physical contents of the roundabout, a dedicated lane could be constructed through the center of the roundabout. In this case, the busway is built straight through the roundabout, while mixed traffic continues to circulate around it. Quito's Ecovía line provides an example of this technique (Figure 24.67). Likewise, the Cali, Colombia, system also makes use of this approach (Figure 24.68). The ability to construct a dedicated lane through the center of the roundabout will only be feasible when the center area of the roundabout does not host a fountain, sculpture, or other permanent piece of urban infrastructure. The construction of the BRT system should not involve the loss of any items of cultural identity. In this design, a traffic signal controls movement through the roundabout.

Figure 24.67. Quito's Ecovía line cuts directly through a roundabout. *Lloyd Wright.*

Figure 24.68. In Cali, the busway also passes through the center of the roundabout area. *Metrocali.*

24.8.5 Grade separation

This alternative is discussed at the Section 24.10, after other aspects of grade-separated solutions are presented.

24.9 Integrating Pedestrian and Cyclist Movements

> *"The way I see it, I can either cross the street, or I can keep waiting for another few years of green lights to go by."*
>
> — Camryn Manheim, actress, 1961-

A highly efficient intersection for mixed traffic and BRT vehicles may not be user-friendly to other street users, especially vulnerable users such as pedestrians and cyclists. Further, the entire viability of the BRT system can be undermined if the surrounding pedestrian environment is not amenable to attracting customers to the BRT station. This section examines design options that not only are conducive to effective vehicle movements at intersections but also options that successfully accommodate pedestrian and cyclist movements.

A standard two-phase traffic signal configuration does not offer any exclusive movements for pedestrians (Figure 24.69). The pedestrian is blocked by crossing or turning traffic in either phase. In such circumstances, the pedestrian must seek a discernible break in the traffic and make a quick crossing. Such conditions may put pedestrians at considerable risk.

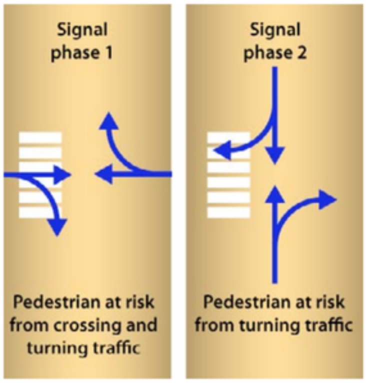

Figure 24.69. In a standard two-phase traffic signal, pedestrians are potentially at risk during both phases. *ITDP.*

The lack of safe pedestrian options can also be the case for three- and four-phase intersections, depending on the configuration. If intersections are designed to slow turning vehicles and if turning vehicle volumes are not that high, the problem may not be serious, and it is eventually better for pedestrians that do not have to wait a whole cycle to cross. However, if turning volumes are high or intersections allow high speed curbside turns, bicyclists and pedestrians going straight will have problems crossing the road.

The normal solution to this problem is the creation of a pedestrian refuge island between the curbside turn slip lane and the intersection while not allowing curbside turns during the red signal phase (Figure 24.70). Pedestrians can generally cross to this pedestrian refuge island during the red phase and then cross when the light turns green. Another possible solution for this is a short "leading pedestrian interval" that allows pedestrians to cross in front of the curbside turning vehicles prior to the change of the signal to green. This option still requires preventing curbside turns on the red signal but mitigates the need for the pedestrian refuge island. More discussion on safe pedestrian access is included in Chapter 29: Pedestrian Integration and Chapter 31: Bicycle and Pedicab Integration.

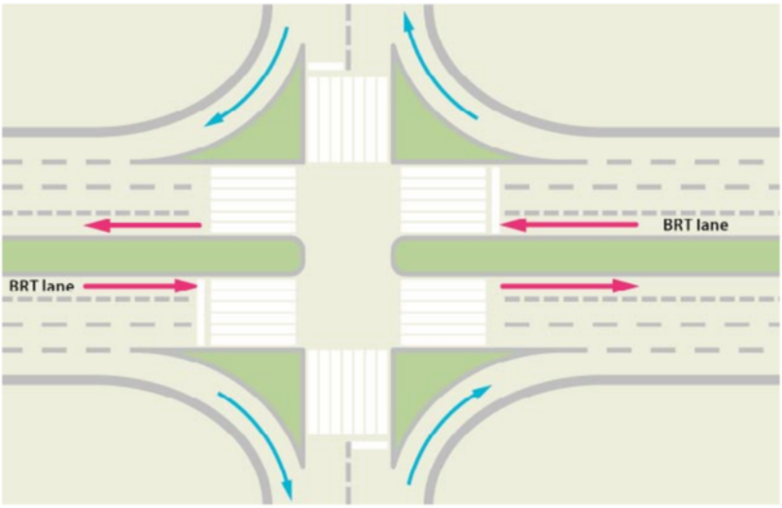

Figure 24.70. The introduction of a pedestrian island between the curbside-turn lane and the crossing can significantly help pedestrians safely cross within the standard two-phase traffic signal. *ITDP.*

For cyclists, intersection risks often emanate from turning vehicles that threaten straight movements by the cyclists. Since the motorized vehicles are often traveling much faster than the bicycles, there is a great potential for conflict and risk at turning locations. Cyclists may feel particularly vulnerable when wanting to turn across traffic.

There are at least two mechanisms for permitting cyclists to safely navigate intersections:

- Infrastructure giving physical priority to cyclists and allowing them to cross prior to private vehicles; and/or,
- Dedicated signalization for cyclists.

Figure 24.71. In Chinese cities such as Xi'an, cyclists are given designated waiting areas from which they have priority access to crossing the street. *Karl Fjellstrom.*

Figure 24.72. In the UK, a priority bicycle stopping area is placed ahead of the stopping line for motorized vehicles. *Lloyd Wright.*

In several countries, dedicated areas located in front of the stopping line for motorized vehicles have been an effective option (Figures 24.71 and 24.72). The idea is to give cyclists a head start over motorized vehicles in crossing the intersection. The cyclists are given a designated box to wait for the green signal phase. In some cases, this physical priority can be combined with an advanced green signal phase as well.

A schematic of the bicycle priority measures utilized in Xi'an is given in Figure 24.73 for each of the two signal phases.

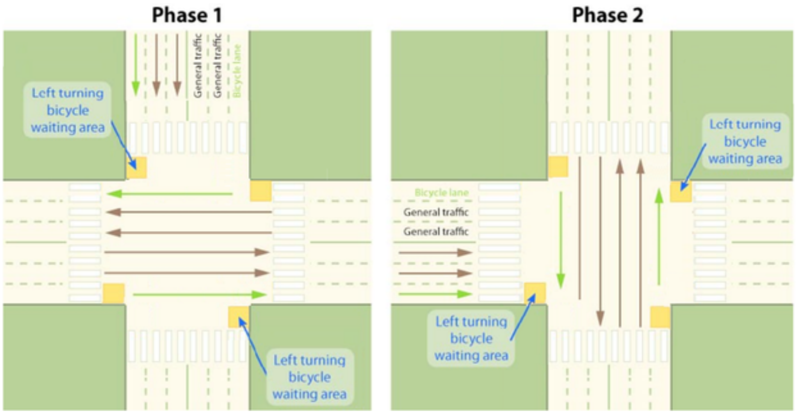

Figure 24.73. Schematic of the dedicated waiting area utilized for bicycles wishing to make cross-traffic turns in Xi'an. *ITDP*

24.10 Grade Separation

"Conflict can and should be handled constructively; when it is, relationships benefit. Conflict avoidance is not the hallmark of a good relationship. On the contrary, it is a symptom of serious problems and of poor communication."

— Harriet B. Braiker, psychologist, expert on stress management, 1948–

Grade separation brings many benefits from the perspective of travel time savings by raising intersection capacity for both BRT vehicles and mixed traffic vehicles. But the infrastructure can be costly, depending on local circumstances. In many instances, the time savings to BRT customers and to private vehicles will fully justify the added infrastructure costs, but limited capital resources will typically constrain infrastructure expenditures.

24.10.1 Criteria for Grade Separation

In all of our BRT studies to date we have never really had to resort to a single flyover, meaning that there were always solutions to guarantee BRT operations that would reduce overall current travel times with the available space. In other words: without resorting to grade separation, solutions are likely to be found where the advantages to public transport customers are greater than the hindrance to private vehicle users.

Nonetheless, when the capacity of a four-phase intersection is reaching saturation (more than 450 vehicles/lane/hour in 180-second cycle times), it is fairly typical for engineers to suggest the construction of a flyover or an underpass that allows straight movement for one main road (two of the twelve movements), while all other movements remain at the same level. Such general inclinations often lead toward a political understanding that flyover constructions along the BRT corridor are necessary. Besides that, a corridor project usually has to deal with existing flyovers.

The introduction or existence of flyovers or underpasses along the corridor requires special treatments for BRT systems, but they represent an opportunity to dramatically improve BRT vehicle operation. Exclusive busway use of a flyover is a successful technique used in several existing BRT systems despite its potential major adverse visual impacts, which are highly undesirable from an aesthetics standpoint in cities and urban areas.

An ideal separated-grade solution should only let low intensity intersections remain (low enough to not require traffic lights). If it removes mixed traffic and BRT intersections, then it is best to keep BRT at the grade where access is facilitated, likely to be street level with at-grade crossing.

If the grade-separation solution will not eliminate all conflicts, the first option is to use grade-separation infrastructure for BRT usage and exclusively for BRT if needed.

While the discussion in this section is concentrated on flyovers as a means of grade separation, underpasses are frequently the preferred option from an aesthetics standpoint. Generally, the cost of a busway on a flyover will be at least ten times the cost of a normal at-grade busway (per kilometer). The cost of a busway in an underpass will be similar to that of a flyover unless there are adverse subsurface conditions such as the presence of services (utilities), high water tables, or hard rock conditions that may result in underpasses not being technically or economically feasible.

24.10.2 Station Location with Grade-Separated Solutions

If the grade-separated solution design maintains BRT lanes through intersections, the same concerns discussed without grade separation about queue blocking the stations apply. When a BRT lane is grade separated, hindering the station is not a concern, but effective pedestrian access becomes a major issue.

In most instances (ramp of 3 percent and headroom of 4 to 5 meters), grade separation will require placing the stations more than three hundred meters away from the intersection. This siting restriction will add walking time for customers travelling between the station and the intersection and nearby destinations adjacent to the area. Quito's Central Norte line uses grade separation quite effectively with tunnels whisking BRT vehicles through congested intersections. However, the tunnels also imply that at important destinations, such as the Plaza de las Américas, the closest station is a considerable distance away (Figure 24.74). Thus, for the likely high number of customers using this busy area, the time savings from the grade separation can essentially be lost due to the longer walk.

Figure 24.74. In the case of Quito's Central Norte line, the presence of a BRT underpass has meant that the closest station to a key destination, the Plaza of Américas commercial center, is several hundred meters away. *Lloyd Wright.*

As an alternative to obtain intersection efficiency (with time savings that serve all customers through the section) at the cost of a convenient station location (that serves local-specific customers), it is possible to place the station beneath or above the intersection. The Metro Center station of the Washington Metro exits directly into the basement floors of commercial shops. In such cases, though, accessing ground-level shops and offices will require a grade transfer for customers, implying either stairs, escalators, and/or elevators.

Both the Brisbane and Ottawa BRT systems site stations at the tunnel level. In Brisbane, the station is just before the tunnel and thus provides good customer access to local destinations (Figure 24.75). In Ottawa, the station connects directly to a commercial shopping center (Figure 24.76). Further, in the case of Ottawa, the tunnel station nicely protects customers from the harsh winter weather. Quito also has achieved great success with its Villa Flora station, which goes beneath a heavily trafficked roundabout on Maldonado Avenue (Figure 24.77).

Figure 24.77. BRT Quito's Villa Flora roundabout traffic with underpasses. *Google Earth.*

Figure 24.75. Placing stations just before a BRT tunnel, as in Brisbane, helps customers comfortably access local destinations. Image *Queensland Transport.*

Figure 24.76. A station placed inside a tunnel in Ottawa provides easy access and weather protection. *Lloyd Wright.*

Effective pedestrian access as well as visually neutral solutions can be designed. For TransMilenio Phase II's "Avenida Boyacá" station along the Avenida Suba Corridor, the solution was to locate the station above Avenida Boyacá, level with the flyover. Pedestrians access the platform via an elevator from a small pedestrian plaza where fares are collected. This solution allowed for the strategic location of this station, which will make future transfer points on the projected Avenida Boyacá closer to each other. Ultimately, the implementation of solutions of this sort will depend on budgetary constraints.

Figure 24.78. TransMilenio's Boyacá Station is on the flyover on Suba Corridor, allowing access from Avenida Boyacá below. *Google Street View.*

Figure 24.79. TransMilenio's Boyacá Station entrance below flyover is through a small pedestrian plaza along Avenida Boyacá. *Google Street View.*

Figure 24.80. Seen from the flyover on Suba Corridor, TransMilenio's Boyacá Station seems a regular large station with underground access. *Google Street View.*

Figure 24.81. TransMilenio's Boyacá Station on the flyover is an example of adapting BRT to existing grade separation. *Google Street View.*

24.10.3 Restricting Turning Movements Together with Grade Separation

As said in the introduction to this section, unless all vehicle intersections are eliminated from the BRT lane by the separated-grade solution, the first option is to consider grade-separation infrastructure to be used by the BRT. In such cases, the concern is to determinate if cost of a separated-grade station can be afforded and is justified by the time saved by users of that station. This cost consists of the infrastructure and/or the time losses generated to private vehicle users that will lose a second or a third lane on the separated-grade infrastructure (and if it is politically affordable, too).

A second possibility is to direct BRT vehicles to the flyover in mixed traffic (see Section 24.7: Merging with Mixed Traffic in Narrow Sections), which will result in stations being far from the intersections. Additionally, this configuration can be particularly problematic if there is a connecting BRT corridor running on the perpendicular street below the flyover or above the underpass.

The third possibility is building the flyover on the road perpendicular to the BRT corridor. In this case, the flyover does not introduce any special difficulty in relation to the (same-level) intersection already discussed and if it cannot eliminate the intersection with mixed traffic, it can certainly alleviate the intensity and the number of conflicts, increasing the BRT green time (as this subsection will lead us to conclude by analyzing the following last possibility).

The last possibility is that the flyover is designated for mixed traffic alone and BRT remains on the street level. As the others do not create intersection with BRT, this fourth possibility is only of interest for the remainder of this subsection (though all four must be considered when evaluating benefits).

If a single flyover in the median is built, the BRT vehicles in the median will have to cross the mixed traffic going onto the flyover. This scenario creates either the need for a new signalized intersection prior to the flyover, or a merging lane where the BRT buses and mixed traffic can cross, introducing possible delay and confusion for both the BRT system and the mixed traffic. Figure 24.82 shows the conflict.

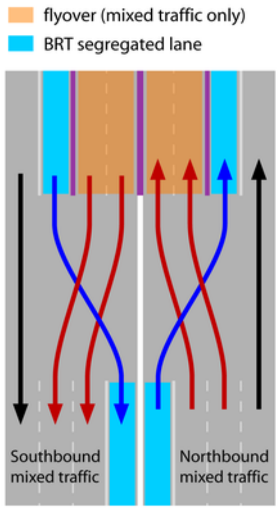

Figure 24.82. Schematic of Delhi roadway in which BRT vehicles must cross mixed traffic that is attempting to access a flyover. Image *Elebeta.*

Figure 24.83. In Senen Street, TransJakarta interlaces with mixed traffic to avoid the flyover and reach the station near the intersection. The restart of the bus lane is on the ground level, close to the flyover. The flyover has two lanes and only two more are available to reach the intersection below it. The covered pedestrian flyover seen at the left is a link between the inside area of stations in BRT Corridor 2 and Corridor 6 as the user cannot leave the system's "paid areas." *Google Maps.*

If two separate access lanes are constructed for the flyover, one for each traffic direction, it is possible to leave a space between them for the BRT system to continue along the surface as in Figure 24.84.

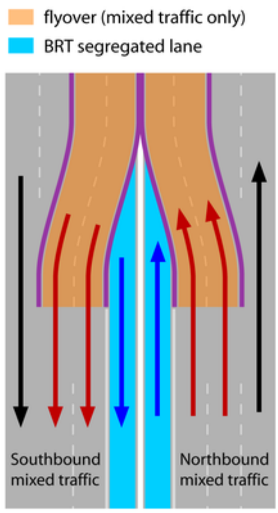

Figure 24.84. Alternative design for a flyover that allows BRT vehicles to proceed without conflicts to the area below the flyover. *Elebeta.*

In this configuration, the BRT will intersect the crossing street under the flyover, so we must consider the alternatives of Section 24.5 with the introduction of the flyover to reduce the number of phases. We present the results of a scenario in which BRT has a green signal with the insertion of a grade-separation infrastructure of two lanes per way (Figures 24.87 to 24.89), maintaining the assumptions in subsection 24.5.4: volumes are equal in all approaches, right and left turns each represent 25 percent of the demand and no U-turns are allowed (therefore 50 percent of traffic is straight), no pedestrian-only phases are required (it is possible to cross the intersection with the given phases), and 90 seconds is still the cycle time of reference.

Although the flyover can cause the impression that four new lanes are created, no mid-block extra width is created (Figures 24.82 and 24.84). Eventually the intersection under the flyover can have some extra width, but usually two lanes near the median are used to place the supporting structure of the flyover, so there is in fact only two extra lanes in the intersection as a whole. Below, we will evaluate the uninterrupted flow in these four lanes.

In our example, the first problem with the mixed traffic comes at the point of flyover access, as half of the traffic has turning intentions, and if permitted to do this, turns at the intersection (under the flyover or above the tunnel) are not enough. Or, if the detours start after the ramp begins, the single lane given for mixed traffic to stay on the flyover is not enough. Widening or sharing space with BRT is required. The solution presented in Section 24.7 does not apply here without further complications as there are two downstream sections (overpass and ground) to be managed. Designing with the assumption that the intersection will not congest because the design is good for the forecast demand is simply naive: when it comes to cars, all the designer can expect is to improve capacity, and sooner or later congestion will return. Given our goals, placing BRT in a shared space with cars in this potential bottleneck is a bad proposal.

So the maximum capacity we present for mixed traffic is still subject to the intersection below the flyover working well. If it gets congested, access to the flyover will also be congested. For proper comparison with the solutions without grade separation, and also because the effective access to the "intersection plus flyover" set has three lanes for mixed traffic, we present the results per lane, assuming each intersection approach has three lanes, as detailed below:

- *Average lane capacity:* the average of the mixed-traffic lanes' capacity that would be measured at the stop lines approaching the main intersection. On the presence of a flyover, mixed traffic parallel to the BRT's approach is considered three lanes, but only two of these were effectively used to balance the traffic sign);
- *Overall intersection capacity per lane:* in the loop configuration, vehicles pass twice through stop lines in order to execute a cross-traffic turn, and the second pass does not count toward this capacity, but rather it is the same result described in the "average lane capacity" above, except that it does not count the second passage of the same vehicle across the intersection.
- *Total throughput with flyover and auxiliary intersections per lane at intersection:* this adds in the flows that were completely diverted away from the main intersection (detours and flyover) as if they were effectively passing through the intersection. By bringing the value to the number of lanes of the intersection, this presents a practical estimate of how much the capacity of the main intersection can be pushed to benefit from using the auxiliary ones and flyover as a whole.

Options where the detours are below the flyover assume that the height clearance makes it possible, which is not always the case. Access ramps to and from perpendicular streets may also be taken into account in order to make turning detours on the flyover possible.

Table 24.5. Flyover Capacity Examples

Option	Cycle Time (seconds)	Phases	BRT Direction Straight Flow	BRT Direction Curb-Side-Turn Detour	BRT Direction Cross-Traffic-Turn Detour	Perpendicular Direction Curb-Side-Turn Detour	Perpendicular Direction Cross-Traffic-Turn Detour	Figure	BRT Green Time (seconds)	Average Lane Capacity (pcu/hour)	Overall Intersection Capacity per Lane (pcu/lane)	Total Throughput with Auxiliary Intersections per Lane at Intersection
A	90	symmetrical		-	-	-	-	Fig. 24.35	22	395	395	395
A1	90	symmetrical	on flyover	-	-	-	-		16	329	329	439
E	90	3		-	-	detour	curb-first	Fig. 24.38	43	496	496	567
E1	90	3	on flyover	-	-	detour	curb-first		43	355	355	567
I	90	2		detour	curb-first	detour	curb-first		41	819	819	1092
I1	90	2	on flyover	detour	curb-first	detour	curb-first	Fig. 24.87	27	729	729	1458
I2	90	2	on flyover	detour	loop onto flyover	detour	curb-first onto flyover	Fig. 24.88	49	547	547	875
J	90	2		-	loop	-	loop		41	819	655	655
J1	90	2	on flyover	-	loop	-	loop		39	691	518	691
K	90	2		detour	loop	detour	loop		41	819	614	819

K1	90	2	on flyover	detour	loop	detour	loop		35	703	469	937
K2	90	1	on flyover	detour	loop onto flyover	detour	loop onto flyover	Fig.24.89	10	1520	1216	1216
K3	60	1	on flyover	detour	loop onto flyover	detour	loop onto flyover	Fig.24.89	10	1380	1104	1104
K4	45	1	on flyover	detour	loop onto flyover	detour	loop onto flyover	Fig.24.89	10	1240	992	992

Option A1 is fairly common with conventional bus services (as in Bangkok, Figure 24.85) and BRT (as in Jakarta, Figure 24.86). Mixed-traffic vehicles have access to the flyover and thus are given a substantial priority at the intersection. By contrast, public transport vehicles servicing the intersection area are often mired in heavy congestion. There is limited benefit of using a flyover or underpass if a four-phase signal timing is maintained. In our established scenario, the overall increase in the whole intersection capacity is quite small, with the capacity only rising from 395 pcu/lane/hour to 439 pcu/lane/hour.

Figure 24.85. While vehicles in mixed traffic can bypass a congested intersection in Bangkok, public transport vehicles are often consigned to serving stations near the intersection. This can result in slow average speeds for public transport. *Lloyd Wright.*

Figure 24.86. This five-leg intersection under the Senen Street flyover in Jakarta has several forbidden turns; the intersection of two BRT corridors and a four phase-signal causes delays in both corridors and is even worse than mixed traffic. *Google Maps.*

Using three phases, moving from option E to option E1, curiously adds no benefit with the use of the flyover. Even with 50 percent of the traffic being diverted to the flyover and the reduction of the approach parallel to the BRT from three to two lanes (while one lane is used for cross-traffic turns), only one lane is able to process both curbside turns, and cross-traffic turns from the perpendicular direction all result in the same relative green distribution with or without the flyover. But mixed traffic using only one lane for such a long phase (the same as the BRT phase) reduces the intersection's overall capacity substantially (71.5 percent). Adding the flow on the flyover (60 percent) results in exactly what is coincidentally the same overall capacity as having an intersection plus flyover.

Without a flyover, the best observed configurations consist of the following options: (Option I from Table 4.5, Figure 24.87) doing all detours on the curbside parallel street to turn onto the desired direction once the other street is reached, letting only straight flows in the perpendicular street and in the flyover is the Option (I1) that results in larger capacity for mixed traffic and not coincidentally the shortest green time for the BRT (27 seconds), except for the four-stage alternative (A1). That happens because the only conflict left at the main intersection is perpendicular straight flow (in three lanes) against perpendicular cross-traffic turn (in two lanes). Having 63 seconds of red time may not be unbearable for a low frequency BRT, but it will almost certainly not allow a station to be positioned between the two intersections (the main and the auxiliary), since the resulting saturation for the conjunct station plus intersection will be much higher than that of a station alone.

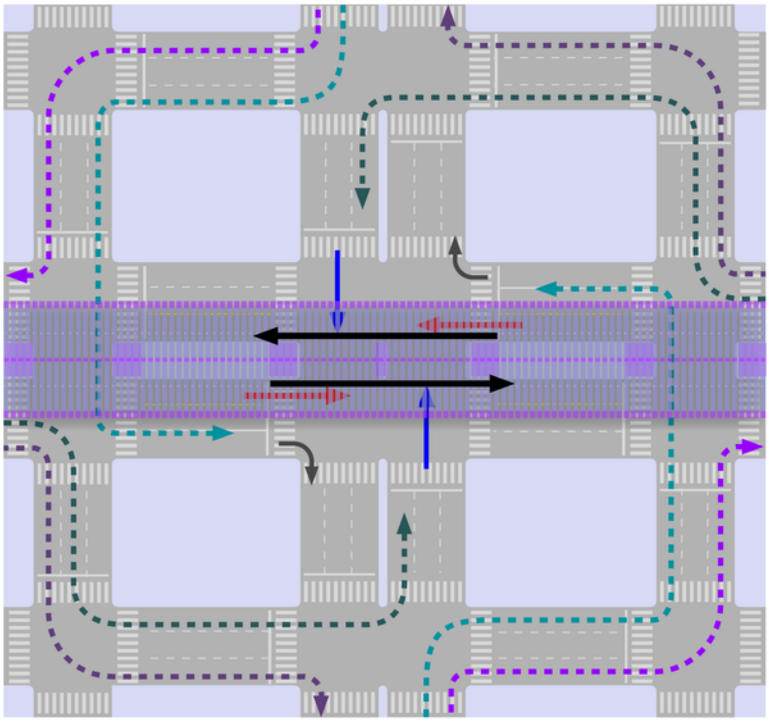

Figure 24.87. Curbside detour for perpendicular flows under the flyover. *Elebeta.*

Applying the same scheme, but using the flyover (Option I2, Figure 24.88), moves all the conflicts to the secondary intersection, which ends up being the capacity limiting element for the conjunct. As there are only two lanes in the flyover to handle the straight flow plus the cross-traffic flow from both directions (i.e., double flow in two-thirds of lanes), its result is worse than some alternatives without a flyover.

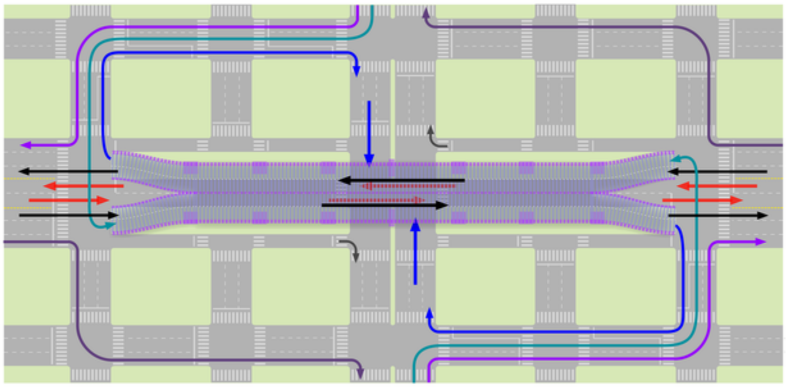

Figure 24.88. Curbside detour for perpendicular flows above the flyover. *Elebeta.*

For the clovelike alternatives (Options K, K1, K2), adding the flyover and maintaining the loops on the ground (Option K1) raises overall capacity for the system by 15 percent (comparing with option K). Making detours in auxiliary streets to take the bridge (Option K2, figure 24.89) will make it look like a "real-clove interchange" and, except for the BRT, there would be no intersection (pedestrian phase is required now). Therefore, the BRT phase would be the minimal 10 seconds and an equivalent average capacity of lanes would be 1,520 pcu/hour. Nevertheless, as all vehicles willing to do cross-traffic turns at the intersection use it twice, this is equivalent to "only" 1,216 pcu/hour.

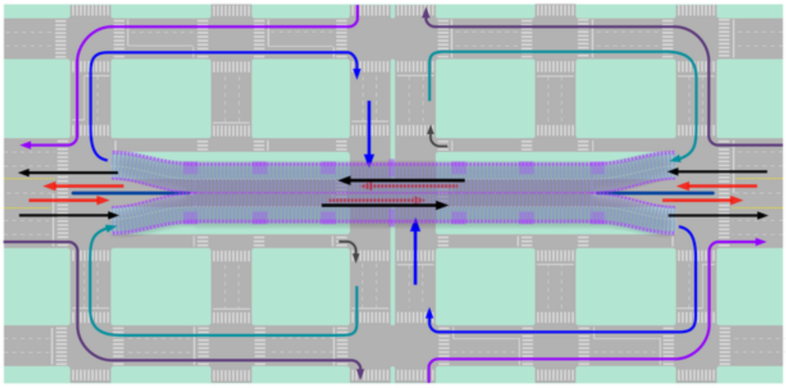

Figure 24.89. Clovelike intersection. *Elebeta.*

The fact that this situation is equivalent to a BRT cross only, the cycle time can be reduced to BRT maximum red time requirements. If this requirement is 50 seconds, then the intersection cycle can be 60 seconds (Option K3) and equivalent overall capacity is reduced to 992 pcu/hour/lane. If it is 35 seconds (maybe enough to bring the station 20 meters from the intersection and fit under the flyover), the cycle has to be 45 seconds (Option K4) and capacity is further reduced to 992 pcu/hour in our example.

Although generic, the assumptions of this exercise are quite common, so there is a strong suggestion that:

- Without grade separation, reducing signal phases to two can provide solutions as good as many grade-separated solutions in terms of capacity for mixed traffic and results in better BRT green times than grade-separated solutions.
- To prioritize BRT green times and meaningfully increase capacity, the use of separated-grade solutions must be cleverly associated with turn restrictions, and the *best solutions are obtained if the flyover is on the perpendicular road* (had that been the case of options I1 and K2, green times for the BRT would be respectively 54 and 76 seconds in a cycle of 90 seconds).

As mentioned before, an intersection cannot be analyzed in isolation. Optimum results are usually obtained when vehicle movements are analyzed along the corridor and the entire extended area surrounding the intersection.

24.10.4 BRT Turning with Grade-Separated Solutions

Separated-grade infrastructure can also be used to provide the dedicated turns for the BRT. For heavy traffic corridors where free-flow turning is required to avoid breaking down the system, the time savings certainly justify the costs.

Bogotá utilizes grade separation to provide dedicated turning infrastructure to BRT operations, such as overpasses and underpasses that link the corridors of 80th Street and Norte-Quito-Sur to an exclusive BRT roundabout (Figures 24.90 and 24.91), as well as provide an exceptional BRT-only third-floor roundabout completed in 2015 to guarantee that the interchange in Norte-Quito-Sur and Calle 6 has no delays (Figures 24.92 and 24.93).

Figure 24.90. At the major intersection of TransMilenio's Calle 80 corridor and NQS corridor is a set of underpasses and an overpass link to the exclusive BRT roundabout. *Google Earth.*

Figure 24.91. An exclusive roundabout facilitates exclusive turning movements for BRT vehicles between two corridors: the NQS corridor and Calle 80 corridor. *Eduardo Plata and Por el País que Queremos (PPQ).*

Figure 24.92. This TransMilenio interchange was carefully planned from an operational and aesthetic point of view. *Instituto de Desarollo Urbano de Bogotá.*

Figure 24.93. Exclusive BRT third-floor roundabout is an unprecedented work of art to guarantee free-flow movements for TransMilenio operation. *Instituto de Desarollo Urbano de Bogotá.*

24.10.5 BRT through Roundabouts with Grade-Separated Solutions

Constructing a busway underpass that goes below the roundabout and avoids all conflicts with mixed traffic—and thus promotes time savings for both BRT and mixed traffic—is also a possibility, as the examples from Quito with good and bad station locations show (Figures 24.74 and 24.94).

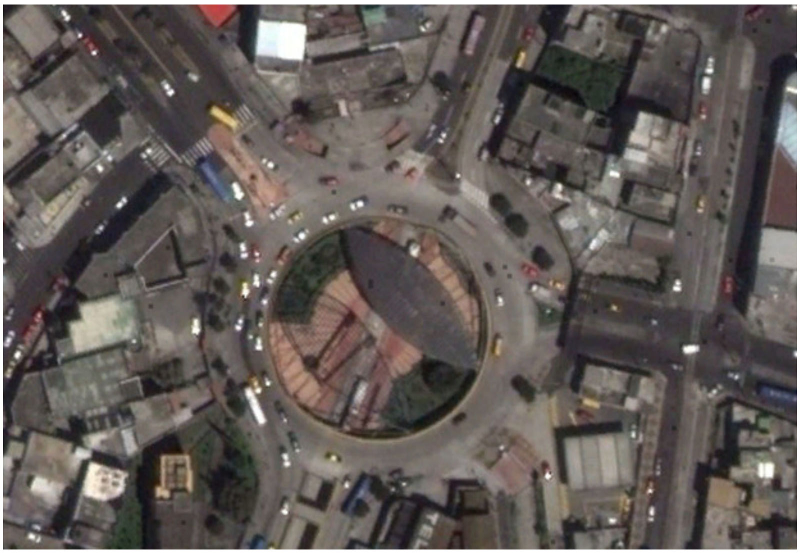

Figure 24.94. Quito's BRT avoids the Villa Flora roundabout traffic with underpasses. *Google Earth.*

A flyover is also a possibility, but the design of an aesthetically acceptable solution is very challenging. With the exception of the exceptional third-floor roundabout above mixed traffic in Bogotá as mentioned in the previous section, there are no other readily available examples of an aesthetically acceptable flyover.

25. BRT Stations

> *"In the dime stores and bus stations, people talk of situations, read books, repeat quotations, draw conclusions on the wall."*
>
> — in 'Love Minus Zero' by Bob Dylan, American singer-songwriter, 1941–

While mixed traffic capacity and performance is determined primarily by intersections, BRT capacity and performance is determined primarily by BRT stations. BRT stations are also the most visible and visceral part of the system - the main way passengers experience the BRT system. Stations are where the BRT system interacts with the city and its people. By virtue of repetition, it often becomes the symbol of the system. Between stations, BRT systems are perceived almost statical by passengers, but at stations, they board and alight, buy tickets, validate them and enter to wait. Passengers look for information. Buses have to approach and align with the correct place in the station. Stations are where everything comes together in the system and the efficiency of the station design and the technologies built into the stations are of primary importance to success of the system.

The primary purpose of a station is to allow passengers to board and alight BRT vehicles, so it must be designed to:

1. promote access to the system;
2. facilitate bus movement and minimizes bus delays, as it is the main bottleneck of the system.

The first means to serve as the main interface of the system for the users; to promote integration with the city transport system – mostly with the walking system but convencional bus, bycicle, taxi and car and eventually rail too. It also means promote integration between BRT services.

The second can be thought as 'never allow BRT vehicles to congest in a station'. It will be bad for the users of that station and for the users that don't use that station as well.

Stations are integral to the efficiency and the experience of the BRT system. As such, two components of the BRT basics – the most essential characteristics needed to qualify as a BRT according to the BRT Standard – focus on the station:

1. Off-board fare collection [8 points]: This is a BRT basic. Off-board fare collection is one the most important factors in reducing dwell time at the station and improving the customer experience. It also reduces potential conflict on the bus as people negotiate payment with conductor or driver.
2. Level boarding [7 points]: This is a BRT basic. Having the bus-station platform level with the bus floor is one of the most important ways of reducing boarding and alighting times per passenger. Passengers climbing even relatively minor steps can mean significant delay and an increase in safety hazards, particularly for the elderly, disabled, or people with suitcases or strollers.

The BRT Standard also has a subsection devoted to stations that totals 10 points and includes the distance between stations [2 points], having safe and comfortable stations [3 points], number of doors on the bus that facilitate rapid boarding and alighting at stations [3 points], the number of docking bays and sub-stops at the stations [1 point], and having sliding doors at the station to protect passengers from the elements and prevent fare evasion [1 point].

All these issues are addressed in this chapter. Facilitating seamless and efficient customer movements directly affects travel times, convenience, and ultimately customer satisfaction. This chapter provides an overview of key aspects of the planning and design of BRT stations.

25.1 Principles of Station Design

> *"I am going to design in a great hurry, and I believe to build, a Station after my own fancy; that is, with engineering roofs, etc. It is at Paddington..."*
> — Isambard Kingdom Brunel, English mechanical and civil engineer, 1806–1859

Main general principles of station design are:

- *Design for people:* It is easy to think of stations as part of an infrastructure project and focus on the engineering, but stations are islands within or next to a sea of tarmac, concrete and major motorized traffic flows. Outside the stations, different rules apply and that is the realm of civil and transport engineering. The inside is a realm for humans; the pace is slower, architects need to design for human senses, movement and behaviour patterns.
- *Design for the public:* Stations are part of the civic and public space of the city, and as such, should be designed from that perspective as well. Stations are landmarks and blic buildings, and the more public a building, that is the more people gather there, the more it needs to reflect the dignity and sacred nature of public space and the image and experience that the city wants to give its citizens. This may call for a larger scale of spaces, not only horizontally in order to accommodate the flow of large numbers on a large floor area, but also vertically. Being in crowds becomes less stressful if there is ample height above. This goes hand in hand with the need for good air, which is easier to maintain if used and warm air can rise to the top of the space in order to be removed from there.
- *Design for standardization and scalability:* A BRT station is typically made up of a series of standardized components that allows for easy scalability, ease and speed of construction, more cost-effective maintenance, and ease of passenger experience. It also helps with the branding of the system – an iconic and repeated image and experience of the system.

The guidelines to approach a particular station design (station sizing) are:

- *Gather data:* the design must be done over usage requirements, this must come from real data.
- *Design for time horizon:* Stations should be designed within a 10 – 20 year planning horizon, given that infrastructure will be assumed to have that lifespan.
- *Size for peak conditions*: size for the peak, consider expansion in phases for the near/far future: Pedestrian crowded stations lead to an uncomfortable and potentially dangerous situation. Bus crowded stations lead to the ruin of the system.
- *Understand the passengers movements:* inside and outside the station, understand the estimated demand over the day, if it is very tidal (meaning lots of people going only one direction at certain times of the day – coming in and out like the tide) or if people are traveling in both directions. This will be useful to design the internal and vertical (if level changes are needed) circulation, external connections, the need for what type of fare gates, etc.
- *Understand the bus movement:* think peak, 20 years from now, consider phasing and expansion.
- *Understand queue formation process:* operate near capacity means that eventual/accdiental queues will last, that will affect every passenger and every bus regardless of using the given station.

- *Minimize delay for buses:* This can be achieved by looking at the location of station in relationship to the intersection, the number of docking bays and sub-stops at the station, having level boarding so that passengers can get on and off the bus quickly, having multiple doors that allow passengers to both board and alight, having passing lanes, having guidance to drivers to help them align better and more quickly to the stations, and having off-board fare collection.
- *Maximize passenger comfort and experience:* create enough area for waiting, circulating and accessibility are as essential as proper ventilation and ilumination; having good wayfinding information about the system, have safe, comfortable, and clean stations are all important to achieving this principle.
- *Minimize walking distance for passengers – both inside the station and outside the station to major nearby activities – is secondary:* it is certainly always desirable to use zebras to access the station, instead of fly-overs that add stairs or hundred-meter long ramps; it is certainly desirable to transfer across platform, but not if that will cause buses to queue, or walking in narrow crowded corridors and waiting areas. More often than not people defend station location to minimize walk distances without effective walking data.

25.2 Basic Concepts

> *"Almost always, great new ideas don't emerge from within a single person or function, but at the intersection of functions or people that have never met before."*
>
> — Clayton M. Christensen, author, 1952–

A station typically has the following standardized components:

1. **Access and arrival areas**: is where people access the station (ramp, stairs, elevators), ideally at grade from a crosswalk, but can also include from a bridge or tunnel. This is how the station integrates into the urban environment.
2. **Entrance areas**: are the areas that are not directly spaces for boarding and alighting but can include kiosks for buying tickets, seating areas, etc. These are areas where passengers can find information about the system. This area can be demarcated with fare gates or turnstiles where customers enter the system; and
3. **Platform**: this is the main area where passengers wait to board and to where they alight. Circulation space and waiting space will need to be planned for, as well system information and wayfinding. This is also where the bus pulls up to the station.

Station platforms can also be described as sub-stops with docking bays for the buses.

1. **Docking bays**: this is where the bus pulls up to in order to let passengers on and off – the platform – vehicle interface. It may have doors, platform extenders, and/or guide rails. Typically there are two docking bays per sub-stop. The docking bay must be long enough so that all the doors of the bus (including articulated busses) can open simultaneously. ; and

2. **Sub-stops**: also known as station subdivisions or modules. A station may be composed of one or multiple sub-stops. Typically sub-stops are organized so that busses can pass each other while docked at a station. A sub-stop should have passenger information, wayfinding, and seating (or *perching* in constrained locations). Usually a sub-stop will have two docking bays per direction. . If more docking bays are needed due to demand, another sub-stop should be added. Thus, passing lanes are also part of the station footprint to be considered.

BRT stations also serve different purposes, that affect design, including size of the station:

1. **Standard -** typical station along BRT corridor. It is the workhorse of the system, and by virtue of repetition, it often becomes the symbol of the system. The macro-location will be determined by the operations plan. The exact location will be determined by a site analysis with pedestrian access as the foremost concern.
2. **Transfer -** stations where transfers occur between BRT lines, feeder (non-BRT) bus routes, and/or other transit modes (LRT, taxi, pedicab). The typical defining characteristic is that the transfers occur within a defined, controlled space, where the services are co-located or linked.
3. **Terminal -** larger facility typically located at the end of a BRT line or in important destinations. They are usually considered anchors of the system. They serve as interchange points between various modes and will become important destinations in their own right. Hence, there are opportunities to construct a significant building, similar to city's main train station or airport. Space is can be made available for busses to park (layover) for driver breaks, minor servicing, and schedule adjustments.

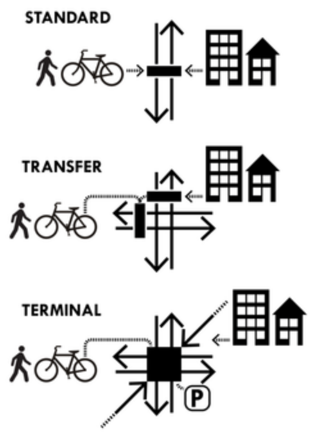

Figure 25.1. Graphic of BRT station types. *Nelson\Nygaard.*

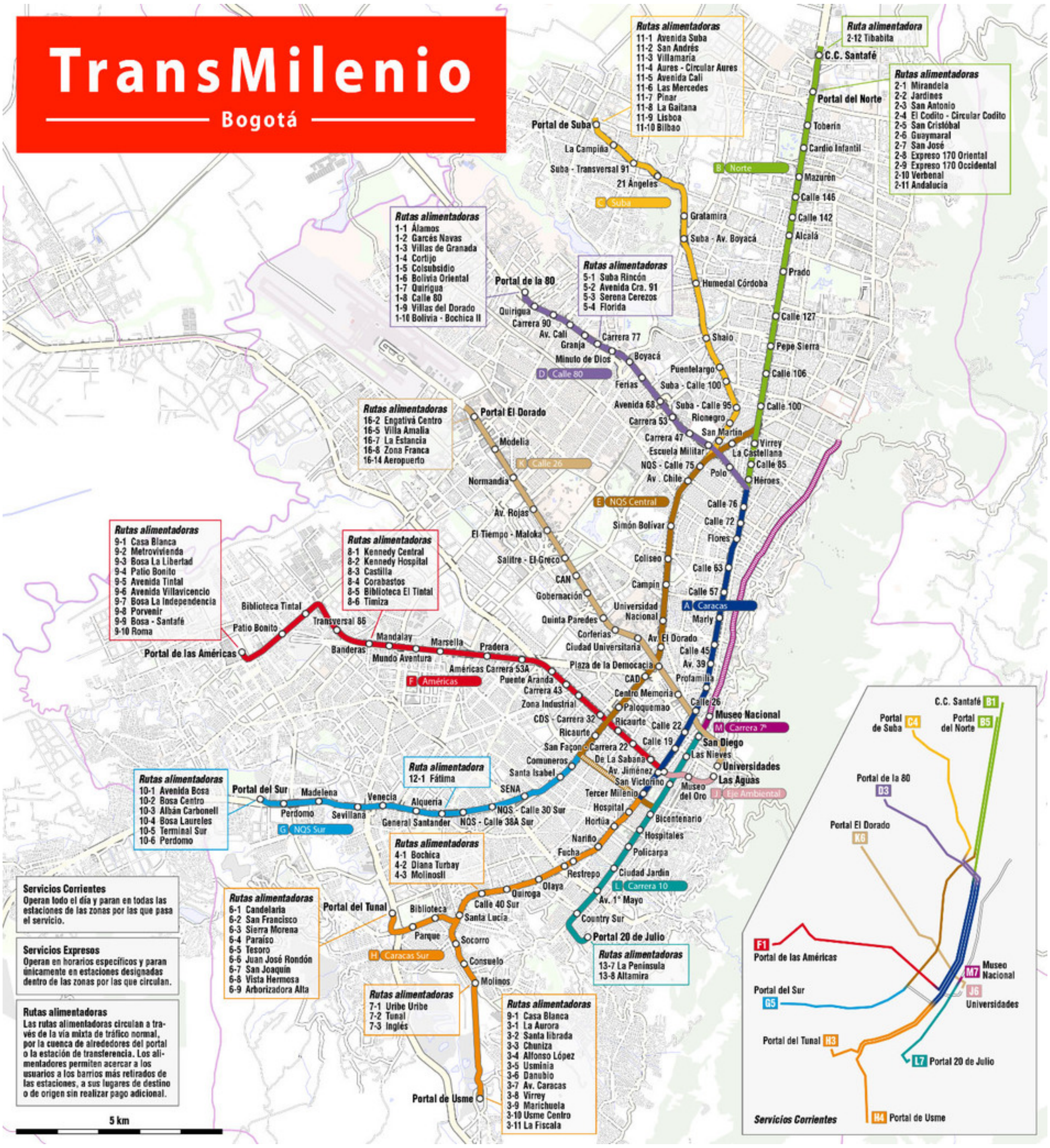

Figure 25.2. Corridors, terminals, transfer stations (at all locations where feeder routes or 'Rutas alimentadora' are indicated), and regular stations in TransMilenio as of September 2013. *Wikipedia and produced by Maximilian Dörrbecker*

One key difference between systems and conventional bus systems is the nature of the transfer between different routes and services. Within a system, all trip service and routing options are integrated both in terms of fare structure and physical proximity or preferably do not require a transfer at all.

Systems employing direct services will likely not utilise either intermediate transfer stations or terminals. Instead, vehicles operating in a direct services system will proceed directly from trunk corridors into lower-density areas.

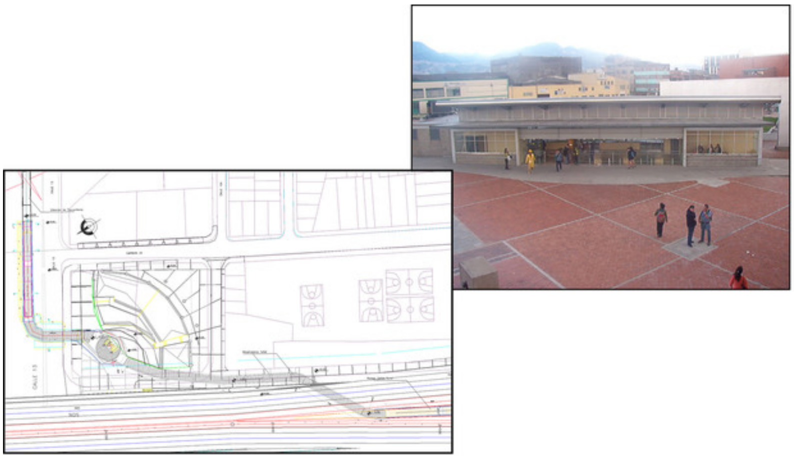

Figure 25.3. A schematic and external view of the Ricaurte interchange station in Bogotá where customers walk through a pedestrian tunnel to access the different corridors. The Ricaurte station also includes customer amenities such as restrooms, an information centre, and quality public space. *ITDP.*

Feeder connections to the trunk lines do not necessarily occur only at major terminal facilities. Feeders can also intersect the trunk corridors at what are known as intermediate transfer stations. These stations are a hybrid facility between ordinary local stations and terminal facilities.

The options for facilitating transfers can be divided into open transfers and closed transfers. As the name implies, an open transfer takes place in an open environment in which it is not necessary to physically combine the feeder and trunk sub-stops into an enclosed environment. By contrast, a closed transfer takes place in a fare-controlled environment.

There are several options for facilitating transfers between corridors. These options include:

- Platform transfers: the most desirable for the customer, because it is easiest – to transfer from one service to another is just a walk across or along a platform.
- Underground tunnels / overhead pedestrian bridges: In some instances, it may be necessary to for transfers to take place by customers walking from one corridor to another. To maintain a "closed" environment with paid customers only, a segregated tunnel or pedestrian bridge is required; and
- Interchange facility (multi-bay or multi-story facility): when different services are located in the same space, but at different levels. These facilities often take a lot of space.

Figure 25.4. Customers transfer from trunk services to feeder services by crossing a platform in Quito, Ecuador. *Lloyd Wright.*

Figure 25.5. Customers arriving by the green feeder vehicles transfer over a pedestrian bridge to enter the trunk service in Bogotá, Colombia. *TransMilenio SA.*

Figure 25.6. BRT station in Cleveland, Ohio, USA. *Michael King.*

Figure 25.7. The architectural design of terminal facilities in Quito, Ecuador. *Lloyd Wright.*

Figure 25.8. The terminal facility of Bogotá, Colombia. *Lloyd Wright.*

Figure 25.9. Station in Guadalajara, Mexico. *Michael King.*

Figure 25.10. The terminal facility in Guayaquil, Ecuador. *Lloyd Wright.*

Figure 25.11. Station in Buenos Aires, Argentina. *Michael King.*

25.3 Station Capacity

> *"Strength does not come from physical capacity. It comes from indomitable will."*
>
> — Mahatma Gandhi, leader of the sucessful Indian independence movement against British rule, 1869–1948

BRT station saturation is discussed in more detail in *Chapter 7: System Speed and Capacity*. The discussion of capacity in this section should be considered as a supplement to that chapter. This section introduces some specific concepts of capacity related to the configuration of BRT stations, whereas *Chapter 7* provides a more detailed and comprehensive coverage of BRT routes and overall operational capacity.

Stations have two nominal capacities that are dependant of each other:

- *Station Local Capacity:* it relates to the number of passengers that use the station (as transfer point, or initial or fina destination in the system; it can be referred as *Boarding Capacity (at Station)* and it could be defined by the maximum number of passengers that can possibly enter the system thru that station during one hour and not allow queue formation.
- *Station Global Capacity:* it relates to the: number of passengers that enters or exits the station, regardless of boarding and alighting there (i.e. we are also counting passengers that are entering and exiting inside the BRT vehicle ; it can be referred as *System Capacity (at the Station)* and it could be defined by the maximum number of passengers that can possibly leave (or arrive) at the station inside a BRT vehicle during one hour, without queue formation.

The *no queue formation* part is important, because if queue formation was allowed, the number of passengers would increase, but the speed of service for all users would decrease. When the context is not defined by "boarding passengers per hour" or "passengers per direction per hour" one

Once the station is the bottleneck of the system, the lowr global capacity station in a corridor defines the corridor (system) capacity.

BRT stations can be broadly divided according to global capacity by whether or not they have passing lanes and sub-stops, and whether the stations have more than one bus docking bay in each direction and sub-stop. High capacity systems feature BRT stations with passing lanes and multiple sub-stops. Medium capacity systems do not have passing lanes, but have multiple docking bays. Low capacity BRT systems have stations with no passing lanes and only one docking bay in each direction.

Considerable fluidity exists in each of the categories below, especially in cases where features such as passing lanes, sub-stops, and multiple docking bays are provided but do not actually function properly due to design shortcomings.

Using the criteria mentioned above and explained further later in this chapter, Table 25.1 categorizes BRT systems as either high, medium or low capacity. The categories in Table 25.1 are based on BRT station design capacity rather than the actual operating capacity. (BRT system capacity is also influenced by factors other than BRT stations, including the operational and intersection design, as discussed in *Chapter 7*.) Table 25.1 also lists the actual operating capacity measured in field surveys by ITDP. In general, the higher-capacity stations correspond to the higher throughput systems, though there are exceptions. From Table 25.1 it can be seen that the Los Angeles Silver Line has a high design capacity but a very low throughput, meaning the corridor can handle more demand easily and that could be obtained through densification around the corridor or using direct services to bring more people to the system. Conversely systems with a low- or medium- design capacity but relatively high throughput – such as Istanbul, Xiamen, Mexico City, Zhengzhou, Urumqi, Chengdu, and Quito – are likely to suffer from overcrowding, delays and bus queuing at some stations during peak hours. More critically, especially in cities which are still growing, these systems are likely to be already operating at or above capacity limits and hence have little capacity to take on extra ridership or growth.

The fact that a station is classified as 'high' capacity in Table 25-1 does not mean that stations do not suffer from overcrowding. Some of Bogotá's BRT stations suffer from severe overcrowding despite the fact that stations have a high-capacity design. A major problem in this regard is that most station sub-stops in Bogotá have only one bus docking bay that serves several routes. This results in crowding passengers for one route obstructing alighting passengers as well as passengers waiting to board a different route at the same sub-stop. Table 25.1 includes a listing of the high-capacity stations which have only one docking bay at each sub-stop: Bogotá, Lima, Peru, and Cali, Colombia. Cape Town, South Africa, despite having passing lanes, has BRT stations predominantly with neither multiple sub-stops nor multiple docking bays. For this reason despite having passing lanes, the design capacity is classified as low.

Figure 25.12. Crowding in a Bogotá station impedes peak hour circulation and is exacerbated by the presence of just one docking bay at each sub-stop, in many stations. *Karl Fjellstrom.*

With regard to Table 25.1, the design capacity of the station is only one factor in the system performance and overall capacity. Other key factors include the use of larger buses, express services, the number and width of doors in the buses, off-board fare collection, the level of crowding in stations and buses (extreme crowding can lead to extra delays in boarding and alighting), operational configuration (including the number of transfers), intersection design along the BRT corridor, and the stopping distance between the bus and the platform. Closer distances between the bus and the platform may take longer for drivers to execute, having the effect of reducing speed and capacity, but will enable passengers to board and alight more quickly, which has the effect of increasing speed and capacity.

Table 25.1. Classification of selected BRT systems into high-, medium- and low- capacity stations

City	passing lanes & sub-stops > 75% of stations	>1 docking bay >75% of stations	design capacity*	>1 docking bay per sub-stop	actual throughput (pphpd)	year of through-put count
Bogotá	Yes	No	HIGH	No	37,700	2013
Guangzhou	Yes	Yes	HIGH	Yes	27,400	2014
Istanbul	No	Yes	MEDIUM		18,900	2012
Lima	Yes	No	HIGH	No	13,950	2011
Cali	Yes	No	HIGH	No	11,100	2013
Xiamen	No	No	LOW		8,360	2012
Brisbane	Yes	Yes	HIGH	Yes	7,700	2014
Mexico City	No	Yes	MEDIUM		7,550	2013
Zhengzhou	No	Yes	MEDIUM		7,230	2014
Urumqi	No	Yes	MEDIUM		6,950	2013
Chengdu	No	YES	MEDIUM		6,650	2014
Lanzhou	Yes	Yes	HIGH	Yes	6,550	2013
Quito	No	No	LOW		6,000	2008
Jakarta	No	No	LOW		3,400	2013
Beijing	No	No	LOW		2,750	2013
Changzhou	No	No	LOW		2,650	2013
Jinan	No	No	LOW		2,050	2014
Leon	No	No	LOW		1,950	2013
Ahmedabad	No	No	LOW		1,200	2012
Bangkok	No	No	LOW		1,200	2011
Nantes	No	No	LOW		1,200	2011
Paris	No	No	LOW		1,200	2010
Los Angeles	Yes	Yes	HIGH	Yes	1,000	2013
Cape Town	No (OT yes, SS no)	No	LOW	No	750	2012
Nagoya	No	No	LOW		500	2013

* Note that this is an overall estimate of capacity. In some cases cities have a combination of "low" (with only one docking bay per direction) and "medium" (with two docking bays per direction) stations.Source: data from www.worldbrt.net, accessed 8 October 2014. Throughput counts are all based on actual ITDP field counts.

Actual system capacity is determined not only by stations, but by a range of operational factors described in the chapter on BRT capacity and speed.

25.3.1 Station Sub-stops

A sub-stop is a station subdivision or module. When equipped with passing lanes, one BRT station can be divided into multiple sub-stops. In order to function, sub-stops require passing lanes or a functional equivalent such as in the directional BRT stations used in Lanzhou and Yichang, China. Calculation of the capacity of station sub-stops is covered in more detail in *Chapter 7*.

Figure 25.13 shows an example of Dongpu BRT station in Guangzhou, China, which has three sub-stops in each direction. Each sub-stop is forty meters long, with docking bays for two 18-meter buses or three 12-meter buses. Fare collection space is 15 meters, though in more recent designs ITDP uses a more compressed 10-meter space for fare collection.

Figure 25.13. Dongpu BRT station in Guangzhou shows the station divisions including the access and arrival areas, the entrance area including the space for fare collection, and the three sub-stops, which can be identified by the different roof material and variation in elevation. At each sub-stop, multiple docking bays are seen and the station includes passing lanes. Between sub-stops is space for buses to pull into or out of the station around other buses already docked. *Karl Fjellstrom.*

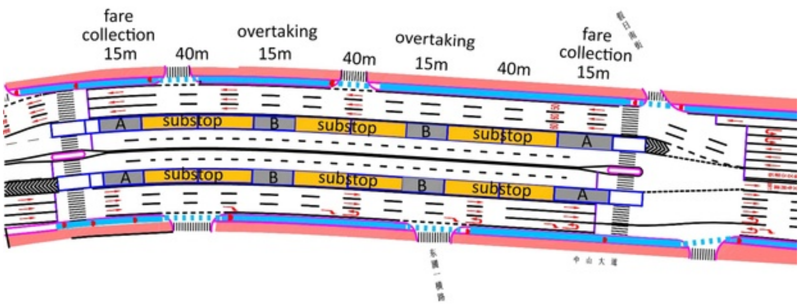

Figure 25.14. Dongpu BRT station in Guangzhou in plan view shows more clearly the parts of the station, which consists of 3 sub-stops in each direction, with a total length of 180m. Each sub-stop consists of 2 docking bays for 18m BRT buses, or 3 sub-stops for 12m BRT buses. A = fare collection and B = passing area. The platform is 5m wide. *ITDP China and GMEDRI.*

25.3.2 High-capacity System Stations

High-capacity BRT stations are those with functioning passing lanes and multiple sub-stops. There are, however, exceptions. Istanbul's BRT is one of the world's highest capacity BRT systems, with nearly 20,000 passengers per hour per direction (pphpd) but without passing lanes or sub-stops. Istanbul, however, is a very special case based on an expressway right-of-way with no traffic lights and contra-flow traffic operation which ensures zero encroachment of other vehicles, no defined docking bays inside the station, and particular demand and road network conditions that are difficult or impossible to duplicate elsewhere.

High-capacity BRT – with the exception of Istanbul's particular circumstances, which like Brisbane does not clearly define bus docking bays – requires passing lanes with sub-stops.

Figure 25.15. High-capacity station: Bogotá, Colombia. *Karl Fjellstrom.*

Figure 25.16. High capacity station: Guangzhou, China. *ITDP.*

Figure 25.17. High-capacity station: Lima, Peru. *Karl Fjellstrom.*

Figure 25.18. High-capacity station: Cali, Colombia. *Karl Fjellstrom.*

Figure 25.19. High-capacity station: Brisbane, Australia. *Karl Fjellstrom.*

Figure 25.20. High-capacity station: Lanzhou, China. *ITDP.*

Figure 25.21. High-capacity station: Belo Horizonte, Brazil. *Cristiano Machado.*

Figure 25.22. High-capacity station: Yichang, China. *Aimee Gauthier.*

25.3.3 Medium-capacity System Stations

Medium-capacity BRT stations are those without passing lanes, but with more than one bus docking bay in each direction.

Figure 25.23. Medium-capacity station with high-capacity operation due to large buses, no defined stopping berths in Istanbul, Turkey. *Karl Fjellstrom.*

Figure 25.24. Medium-capacity station: Zhengzhou, China. *Karl Fjellstrom.*

Figure 25.25. Medium-capacity station: Urumqi, China. *Karl Fjellstrom.*

Figure 25.26. Medium-capacity station: Pontal station in the TransOeste corridor in Rio de Janeiro, Brazil. *ITDP.*

Figure 25.27. Medium-capacity station: Mexico City. *Karl Fjellstrom.*

25.3.4 Low-capacity System Stations

Low-capacity stations have neither passing lanes nor sub-stops, and have only one docking bay for BRT vehicles.

Figure 25.28. Low-capacity station: Chengdu, China. *Xianyuan Zhu, ITDP.*

Figure 25.29. Low-capacity station: Quito, Ecuador. *Karl Fjellstrom.*

Figure 25.30. Low-capacity station: Jakarta, Indonesia. *Karl Fjellstrom.*

Figure 25.31. Low-capacity station: Ahmedabad, India. *ITDP.*

Figure 25.32. Low-capacity station: Leon, Mexico. *Karl Fjellstrom.*

Figure 25.33. Low-capacity station: Nantes, France. *Karl Fjellstrom.*

Figure 25.34. Low-capacity station: Rio de Janeiro's Transcarioca Station in Galeão International Airport. *Luc Nadal, ITDP.*

25.3.5 Modularity and Scalability

In situations where expansion may be necessary within ten to twenty years, BRT stations should be designed accordingly. Modular BRT stations can be expanded through the addition of station sub-stops. Bogotá's TransMilenio provides an excellent example where space was provided for expansion, as was done at the Calle 100 station. The station had two sub-stops in 2005, but another was added as demand increased, so that by 2013, the station had three sub-stops.

Figure 25.35. The image on the left is the Calle 100 station in 2005 with just two sub-stops, but space for more. The image on the right is the same station in 2013 with an additional sub-stopn having been added due to increased demand. *Google Earth.*

Cali has also added station modules at some crowded stations. The Chiminangos BRT station originally has only one sub-stop, but again space for expansion was left, so that another sub-stop could be added, as it was, when demand required it. Although it would have been preferable to build a larger station from the beginning, the modular approach to station design makes it possible to fairly easily add station modules at particular overcrowded stations. It is much more difficult, or usually impossible, to achieve the same expansion in stations which have not been designed with a modular approach to sub-stops. But space must also be reserved for expansion in the roadway.

Modularity also may help with fabrication and construction costs and impacts. By fabricating most of the station off-site, it hopefully can reduce the construction impacts of the corridor, as the station can have the foundation laid directly in the corridor and then then station can be placed on that.

Figure 25.36. Chiminangos station in Cali in 2008 with one sub-stop (left) and the station in 2013 with two sub-stops. *Google Earth.*

Figure 25.37. Prefabricated Bogotá BRT station module at the roadside, ready to be placed in position. *Karl Fjellstrom.*

25.4 Types of Stations

> *"On buses and trains, I always think about the inexhaustible variety of human genes. We see types, and occasionally twins, but never doubles. All faces are unique, and this is exhilarating, despite the increasingly plastic similarity of TV stars and actors."*
>
> — Antonia Susan Byatt, English novelist and poet, 1936–

25.4.1 Island Stations

Island stations are a single central platform serving two directions of traffic. Well known examples include Bogotá and Cali.

Figure 25.38. Island stations in Bogotá, Colombia. *Karl Fjellstrom.*

Figure 25.39. Island stations in Cali, Colombia. *Karl Fjellstromi.*

25.4.2 Split Stations

Split stations, usually located in the center of the roadway, consist of separate platforms serving each direction of traffic. Well known examples include Guangzhou and Brisbane.

Figure 25.40. Split stations in Guangzhou, China. *Karl Fjellstrom.*

Figure 25.41. Split stations in Brisbane, Australia. *Karl Fjellstrom.*

Figure 25.42. Offset central platforms in Bogotá with passing lanes and sub-stops. *Karl Fjellstrom.*

Figure 25.43. Offset central platforms in Lima with passing lanes and sub-stops. *Karl Fjellstrom.*

25.4.3 Offset Stations

Offset stations are longer, but requires less overall road width: typically around 3.5 meters of width is saved while the length of a standard central platform is doubled. Both island and split stations can be offset in this way.

Figure 25.44. Offset central station in Chengdu without passing lanes or sub-stops. *Xianyuan Zhu, ITDP.*

Figure 25.45. Two-sub-stop, offset split station in Guangzhou. The break in station roof coverage is due to the canal passing under the station at that point, and the access bridge has subsequently been covered. *ITDP.*

25.4.4 Directional Stations

The most striking difference between Lanzhou's BRT, which opened in 2013, and other high-capacity systems is a new split-station concept that allows for BRT buses traveling in the same direction to stop on both sides of a boarding platform. This new design, applied to multiple stations in a BRT corridor for the first time in Lanzhou, offers roughly the same capacity as that of a traditional offset BRT station, but with half the station length and only around one meter in extra width. This design is being applied in the planning and design of several BRT systems currently under development, including in Yichang (opened in 2015) and Tianjin, China, and Kuala Lumpur, Malaysia.

The main limitations of this new station configuration are firstly that it is limited to two sub-stops in capacity terms, and secondly that it renders express routes less effective, especially at stations nearing the two-sub-stop capacity limit. The configuration also misses out on the advantages of a single central platform compared to split platforms. In order to get around the two-sub-stop limitation, in the two station platforms requiring more than two sub-stops in Lanzhou (the east platform of Xi Zhan and the south platform of Peili Guangchang station), a different configuration was used to enable three sub-stops. In Tianjin, in the few very high demand stations requiring three sub-stops a more traditional central platform with three sub-stops was used. Most cities and corridors require a maximum of two sub-stops, which with articulated buses can accommodate more than 15,000 passengers per hour per direction, suggesting that this new configuration has wide potential application.

Figure 25.46. Directional BRT stations in Lanzhou. *Karl Fjellstrom.*

Figure 25.47. Directional BRT stations in Yichang; the buses can go on either side of the station while the opposite direction has a lane to travel past the station. *Aimee Gauthier, ITDP.*

A traditional offset two-sub-stop station in this location would be 240 meters in total length. This would make the station very hard to fit into the distance available between the two intersections. The new design on the other hand requires only 130 meters in total length. These two designs provide roughly the same BRT station capacity, subject to the limitations described above, yet the new design is only slightly more than half as long. The advantages of the new design were recognized by Yichang officials and implemented in the Yichang BRT system.

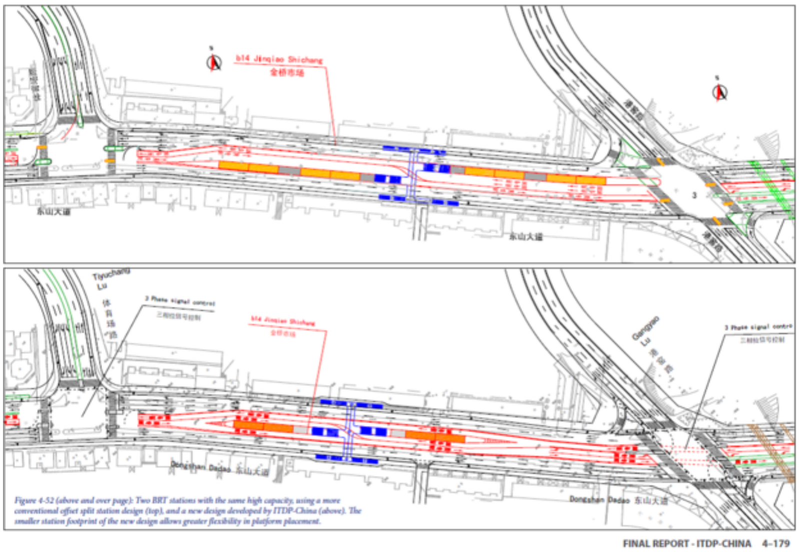

Figure 25.48. Comparison of a traditional two-sub-stop station and the new directional design applied in Lanzhou and Yichang. *ITDP-China.*

25.5 Station Location

> *"To get the right word in the right place is a rare achievement."*
>
> — Mark Twain, American writer, 1835–1910

This section covers the location of a station along a BRT corridor. BRT stations are generally spaced 300 meters to 800 meters apart. In an urban area, spacing optimizes at around 450 meters. Beyond this, more time is imposed on customers walking to stations than is saved from higher bus speeds. Below this distance, bus speeds will be reduced by more than the time saved with shorter walking distances. See *Chapter 6: Service Planning* for more details.

Outside of overall system requirements, the exact location of a station is highly site-specific. The goal is to make the station as easy to access as possible and as close to nearby origins and destinations as possible. No one wants to see a station and not be able to get to it. Following are general consideration for locating stations.

- Existing bus stops may be prime locations and already ingrained in the public's mental map of the area.
- Locate traffic signals, pedestrian crossings, bridges and tunnels to facilitate direct pedestrian access.
- Where possible, place the station at least 26 meters (85 feet) but ideally 40 meters (130 feet) from the intersections to minimize delays to the bus.
- Where the bus operates in mixed traffic, locate stations to ensure that the bus maintains its place in the traffic queue, can depart when ready, and does not have to re-merge into traffic.
- Map nearby origins and destinations, walking and cycling network, then adjust the station location to facilitate direct pedestrian access.
- Integrate stations into nearby buildings, plazas and commercial streets.
- Modular station units can be arranged to fit various sites.
- Stations may be separated by direction or serve both direction depending on space available and operation requirements. Transfer stations should serve both directions simultaneously.
- At signalized intersections, stations should be *near-side* so that boarding and alighting time can overlap with the traffic signal red phase. Provide traffic signal priority for the BRT.

- At unsignalized locations, stations should be *far-side* (in the direction of travel) so that passengers exit and cross behind the bus.
- Where blocks lengths are short, the station can be placed mid-block and accessed from both ends.
- Allow for additional platforms within a 20 year horizon. It is better to plan for and reserve the space before additional development occurs.
- Avoid placing stations simply where land is available. In the long run, these locations may not be optimal and will just frustrate passengers. Stations should not be located in the places of least resistance, but close to the places where people want to go.

One of the most common mistakes made during BRT planning is to place stations too far apart. As a rule of thumb, BRT stations should be spaced around 450 meters apart in urban areas; or 600m-700m for stations with multiple sub-stops. Outside built-up areas stations may be further apart, though should rarely be more than 800 meters apart. Yichang's BRT in the map below shows one particularly long gap between stations, of 1.7 kilometers between Pinghu and Sanxia Chacheng, due to a cliff alongside a riverfront that has no passenger demand or space for a station, yet still achieves an average station spacing of less than 650m. In the lower capacity system designed by ITDP in Vientiane, stations are smaller and this is reflected in an average station spacing of 500m (Figure 25.49).

Figure 25.49. The proposed medium capacity BRT system in Vientiane averages one station every 500 meters. *ITDP-China.*

Figure 25.50. The high capacity BRT system in Yichang, with larger stations, averages 645 meters between stations. *ITDP-China.*

The best guide to BRT station location is the location of existing bus stops. Usually, though, especially where high capacity BRT stations are being implemented, placement is heavily constrained by local physical conditions of the corridor including the locations of intersections.

Figure 25.51 top locations were used to guide the BRT station locations in Lanzhou and Yichang. In the case of Lanzhou, the BRT stations largely corresponded with the current bus stop locations, though with selected variations. In Yichang, station planning also took into account existing bus stops for most of the corridor, but for the central area the BRT station coverage is much denser than the bus stops. This is due to the fact that the central area bus stop coverage in Yichang prior to the BRT system implementation was inadequate, with stations spaced too far apart.

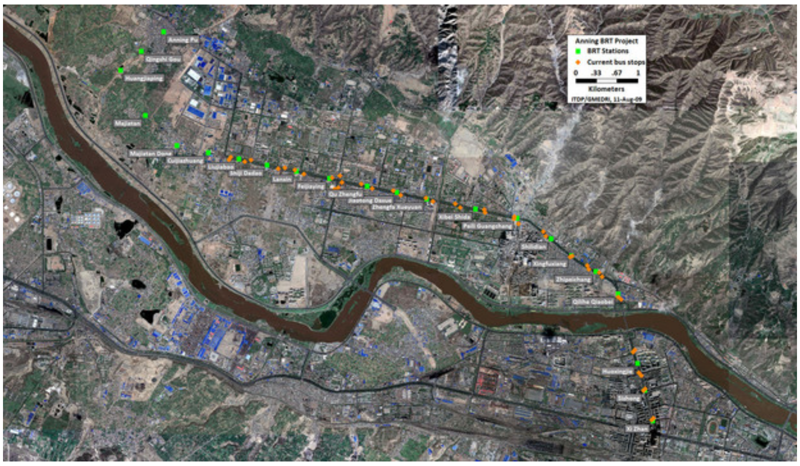

Figure 25.51. Bus stop and BRT station locations during the BRT planning in Lanzhou. *ITDP-China*

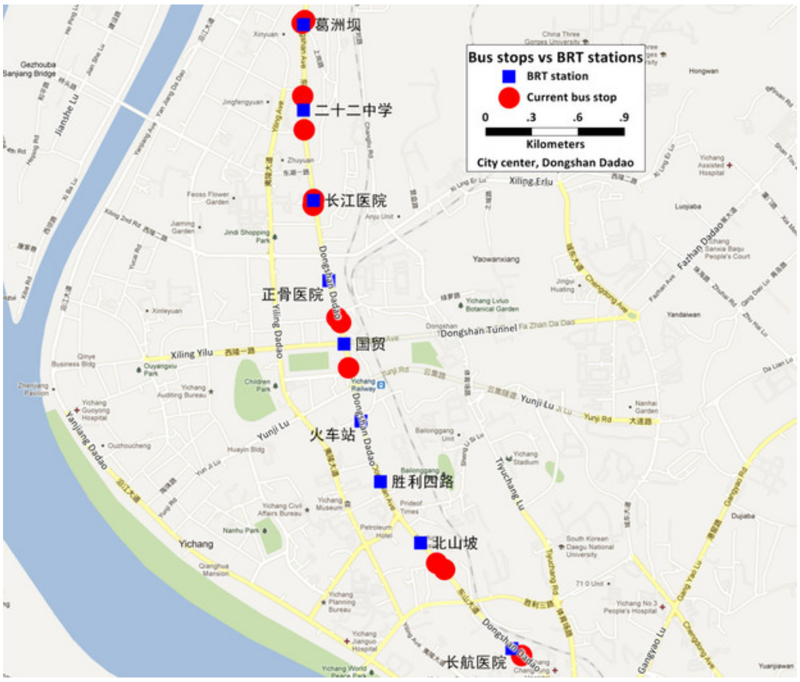

Figure 25.52. Current bus stops and proposed BRT stations by ITDP-China in the Yichang center area. *ITDP-China.*

25.6 Station Dimensions

"I refuse to accept other people's ideas of happiness for me. As if there's a 'one-size fits all' standard for happiness."

— Kanye West, musician, 1977–

Station length and width have minimuns to work well; the influential factors are discussed in the following sections but in order to create proper circulation and wait area, one may compensate for the other, as usually right-of-way is an imposing restriction.

25.6.1 Station Length

In order for multiple sub-stops to function properly, vehicles must be able to overtake buses stopped at sub-stops. In general, the absolute minimum distance required for one vehicle to pass another is one-half the bus length. For example, an 18-meter articulated vehicle requires at least nine meters of separation between docking bays. This minimum distance should only be used at stations with fairly low frequency, or where right of way constraint is a significant issue. Normally, systems require more space because:

- Entering and exiting docking bays with such limited space increases the time it takes to pull into the docking bay, which reduces speeds and adds to saturation levels;
- If a vehicle using the same docking bay is directly behind another, the waiting vehicle should be able to wait behind the first vehicle without blocking the docking bay behind it.

Based upon this criteria, the minimum spacing should be approximately 1.7 times the length of the vehicle. In the case of an 18-meter articulated vehicle, this distance would be approximately 30 metres.

If the vehicle to platform interface does not utilise a boarding bridge, then greater precision is required to align the vehicle to the platform.

As stated in Chapter 7, section 7.6, while boarding bridges allow buses greater room for error in docking to the station and allow passengers greater confidence when boarding and alighting, there are a few disadvantages. The added cost of the boarding plate and the pneumatic system to operate it entails a modest increase in vehicle costs, as well as an increase in maintenance costs. As a moving part, the boarding bridge also introduces additional maintenance issues and the potential for malfunction. The deployment of the bridge itself takes about 1.5 seconds. Likewise, the retrieval of the boarding bridge at departure also requires about 1.5 seconds. While this deployment and retrieval roughly coincide with the opening and closing of the doors, they introduce a slight delay to the boarding and alighting process.

Unless saturation is very low, room should be left for a second vehicle to stop at each sub-stop, both to avoid queues interfering with the operation of the adjacent sub-stop and also to help disperse waiting passengers within the sub-stop. Generally, it is optimal to provide two boarding and alighting spaces, though in a few exceptional circumstances three queuing spaces maybe be optimal. Table 25.2 outlines the conditions favouring one or two bus docking bays.

Table 25.2. Sub-stops and queuing spaces required

Saturation level (X) From	Saturation level (X) To	No. of sub-stops	No. of lanes	Bus docking bays (vehicle lengths)	Extra queuing positions (vehicle lengths)	Total station length (metres)
0	20%	1	1	1	0	19
20	40%	1	1	2	0	19
40%	70%	2	2	2	0	104

70%	80%	2	2	2	1	142
80%	100%	3	2	2	0	156
100%	140%	4	2	2	0	208
140%	180%	5	2	2	0	260
180%	200%	5	2	2	1	355

Notes:

- Saturation refers to the percentage of time that the station is occupied by BRT buses entering the stopping area, opening doors, passengers boarding and alighting, doors closing, and leaving the stopping area.
- The total station length is based on 18m BRT buses. 12m or smaller buses will be correspondingly smaller
- Total length = (19 m *number of docking bays) + 33 m 19 m = space for extra vehicle in queue33 m = 19 m + 14 m (space for docking bay + passing distance)Station length excludes fare collection, typically 10 meters per entrance*

As can be seen in Table 25.2, multiple sub-stops add considerable overall length to a station.

Box 25.1. TransMilenio stations

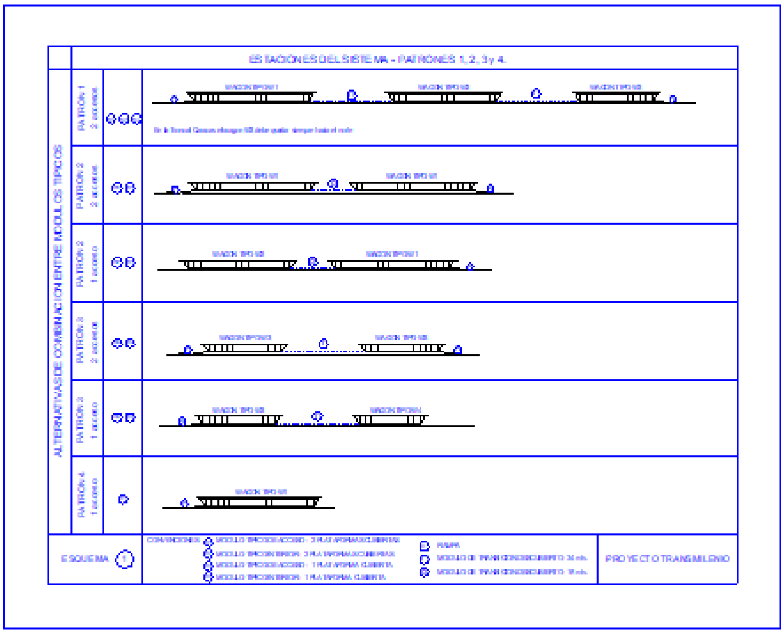

Figure 25.53. TransMilenio stations *TransMilenio, SA*

198 metres (3 sub-stops, 5 docking bays)
124 metres (2 sub-stops, 4 docking bays)
112 metres (2 sub-stops, 4 docking bays)
94 metres (2 sub-stops, 2 docking bays)
53 metres (1 sub-stop, 2 docking bays)
62 metres (1 sub-stop, 2 docking bays)

25.6.2 Station Width

for passengers to enter and exit the area, and enough space for the infrastructure itself. If length is determined, and access is made by the extremes of the stations, which is a good idea for easy of access, one must leave a width for circulation and a with for the waiting area, lateral infrastructure may demand some width as well.

- People avoid walking too close to walls, fences and the curb. Thus a 0.3-0.5 meter shy distance is included in any width calculation.

This reasonaing can be transformed in the following formulas (the concepts of vehicles flow on chapter 24 may assist).

Equation 1: Calculation of platform width

$$W_p = W_i + W_u + W_c + W_{opp}$$

Where:

- W_p: Total platform width;
- W_i: Width required for basic station infrastructure, usually equal to *1 meter*
- W_u: Width required for waiting passengers in one direction;
- W_c: Width required for circulating passengers;
- W_opp: Width required for passengers waiting for vehicles going in the other direction (value = 0 when the station serve only one direction or are staggered);

Equation 2: Width required for circulating passengers

$$W_c = \frac{\text{Flow}_{\text{pax}}}{\text{saturationflowperwidthunit}}$$

Where:

- W_c: Width required for circulating passengers;
- Flow_{pax}: Number of circulating passengers expected per hour using peak hour numbers.
- saturationflowperwidthunit: Number of pedestrians that can walk along a unit of width (for instance, 1 meter) path per hour and still provide a reasonable level of service. Usually 2,000 pedestrians crossing a meter wide section in one hour is used as the basis for determining width needed for circulating passengers.

Equation 3: Area required for waiting passengers

$$S_u = \frac{Q_u\text{pax}}{Dw_{\text{max}}}$$

$$S_{opp} = \frac{Q_{opp}\text{pax}}{Dw_{\text{max}}}$$

Where:

- S_u and S_{opp}: Minimum area required for waiting passengers. This is a function of the maximum number of passengers projected to queue divided by the capacity of an area (for instance, a square meter) to hold waiting passengers.
- $Q_u\text{pax}$: Maximum number of passengers projected to queue in one direction of a substop;
- $Q_{opp}\text{pax}$: Maximum number of passengers projected to queue in opposite direction of a substop;
- Dw_{max} Acceptable number of passengers waiting per area unit (the maximum is 3 people per square meter).

Equation 4: Width required for waiting passengers

$$W_{opp} = \frac{S_{opp}}{L_{opp}}$$

$$W_u = \frac{S_u}{L_u}$$

Where:

- S_u and S_{opp}: Minimum area required for waiting passengers
- L_u and L_{opp}: Platform lenght (usually corresponding to the extension of the vehicle on the outside plus length the vehicle has to maneuver. It can be longer if required in narrow stations, by increasing distannce between platformas, but if much longer will require operators to organize the queues in peak hours.
- S_u and $_{opp}$: Minimum width required for the area of waiting passengers in the platform. It's calculation derives from area formula $S = L * W$

Equation 5: Estimate of total boarding passengers at a sub-stop

$$Q_{\text{pax}} = \sum_{i=1}^{N_{\text{routes}}} \frac{Pb_i}{F_i} = \sum_{i=1}^{N_{\text{routes}}} pbv_i$$

Where:

- Q_{pax}: Maximum passenger queue expected; represents the sum of all boarding passengers in the given direction, i.e. how many passenger will board the bus is when it gets to the station (this is used for calculating Q_u and Q_p above).
- Pb_i: Passengers boarding on BRT route i (per hour. during peak);
- F_i: Frequency of line i (BRT vehicles per hour, during peak);
- pbv_i: Average number of passengers boarding per BRT line i vehicle (during peak)

Box 25.2. Example of station width requirement calculation

A simplified application of this formulas, would be as follows, assuming an off-set station, given:

- station infrastructure consumes 0.5 meters on each side for a total of 1 meter
- waiting areas for the two directions are offset ($W_opp = 0$)
- 18m long BRT vehicle ($L = 18m$)
- 4 routes will stop at this platform, serving 1000 passenger altogether in the peak ($\sum Pb_i = 1000$) in a balanced way
- Each route has a headway of 12 minutes, which means in average one vehicle arriving every 3 minutes, or 20 vehicles/hour at the platform.
- number of passengers expected to cross this platform in the peak to reach exit or other platforms is 4,000/hour

If we assume boarding passengers arrive at a constant rate at the platform, and the proportion of passengers boarding in each route being similar, as proposed:

- each route would have 250 pax/hour
- with one vehicle every 12 minutes there are 5 vehicles arriving per hour
- in average 50 passengers would board each vehicle of each route
- if all 4 routes arrive close to each other, 200 people might add up waiting to borad the vehicles ($Qp_U = 200$)

$$Q_{\text{pax}} = \sum_{i=1}^{N_{\text{routes}}} \frac{Pb_i}{F_i} = \sum_{i=1}^{N_{\text{routes}}} pbv_i$$

$$Q_{\text{pax}} = \frac{250}{5} + \frac{250}{5} + \frac{250}{5} + \frac{250}{5} = 200$$

200 waiting passengers divided by 3 the maximum accepted occupancy of space: three passengers per square meter ($Dw_max = 3pax/m^2$) implies 66.6 square meters are required as waiting area.

$$S_u = \frac{Q_u\text{pax}}{Dw_{\text{max}}}$$

$$S_u = \frac{200pax}{3pax/m^2} = 66.6m^2$$

The BRT vehicle is 18 meters long, if we consider 2 extra meter of lenght for the internal side of the station, corresponding to the space a BRT vehicle uses outside: To total 66.6m^2 in 20 m of extention, the waiting area needs to be 3.33 8m wide (Wu = 3.33m).

$$W_u = \frac{S_u}{L_u}$$

$$3.33\frac{66_u}{20_u}$$

The width for circulation of passengers coming and going from and to other platforms will be 2 meters

$$W_c = \frac{\text{Flow}_{\text{pax}}}{\text{basicpax saturationflowperwidthunit}}$$

$$W_c = \frac{4000}{2000} = 2m$$

And finally to total width of the station results in 6.33 metres.

$$W_p = W_i + W_u + W_c + W_opp$$

$$1m + 3.33m + 2m + 0m = 6.33m; \text{add } 0.5m \text{ shy distance} = 6.83m$$

Round up to 7.0m

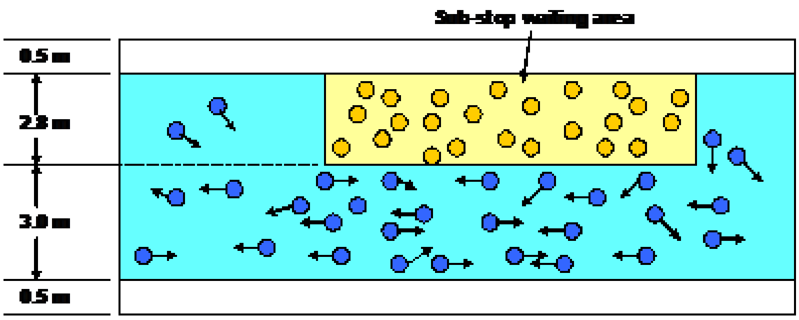

Figure 25.54. Platform width example *ITDP*

25.6.3 Station Height

Station height from floor to ceiling should be at least 3.5m in a partially enclosed station, and at least 4m in a fully enclosed station. Beyond these minimum dimensions, station heights can vary according to the particular design. An example of BRT station dimensions provided by architect Derek Trusler with ITDP for a study in Malaysia is provided in Figure 25.55.

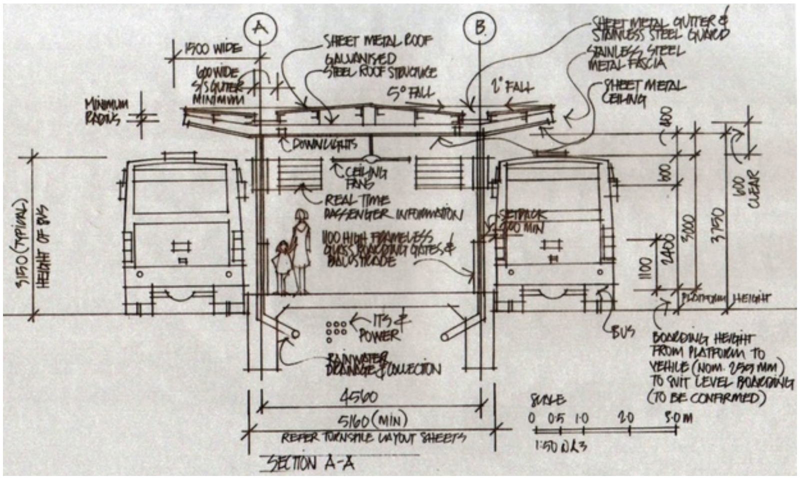

Figure 25.55. Proposed station dimensions for a BRT conceptual design by ITDP in Malaysia. The BRT door height is 1.1 meters. For fully enclosed stations an extra height of at least 0.5 meters is recommended. *ITDP and created by Derek Trusler.*

Figure 25.56. BRT station interior and exterior in Chengdu, which features stations with several different architectural styles. The skylight helps to ensure a bright interior and the walls curve downward. *Karl Fjellstrom, ITDP*

25.6.4 Station and Road Cross-sections

Station and road cross-sections will vary according to the conditions of each urban corridor and the demand and operational characteristics of the system. However, the following general guidelines can be applied:

- BRT stations can be as narrow as 4 meters but should preferably be at least 5 meters wide, and preferably at least 6m wide where passengers are boarding and alighting on both sides of the platform.
- Space is often most constrained at the station area. Since the station area is the critical point for BRT operation, this may mean that other modes are partially "sacrificed" in order to allow for excellent BRT operation. Mixed traffic lanes can be as narrow as 2.8 meters at the station area. Walkways can be narrowed to 2 meters or even 1.5 meters (if the walkway is unobstructed). Bike lanes can be narrowed to 1.5 meters or even 1 meter in low volume locations.
- Where the BRT has passing lanes, the stopping lane can be narrowed to 3 meters if necessary.

ITDP's station section for Wangzhougang Station in Yichang, illustrated in Figure 25.57, is an example of the need to reduce the width of non-BRT lanes at the BRT station in order to retain in this case a minimum 5-meter BRT station width. Between stations, where space is less constrained, mixed traffic lanes are 3.5 meter, the bike lane 1.5 meter (plus a 0.5-meter divider), and the walkway 3.5 meter. At the station the mixed traffic lanes are reduced to 3.2 meter, the bike lane to 1 meter (without a divider), and the walkway to 3 meter. Yichang is a high-capacity BRT system. Reducing space for pedestrians should be the last resort as with customers going to and from the station, pedestrian traffic may be higher in these station areas.

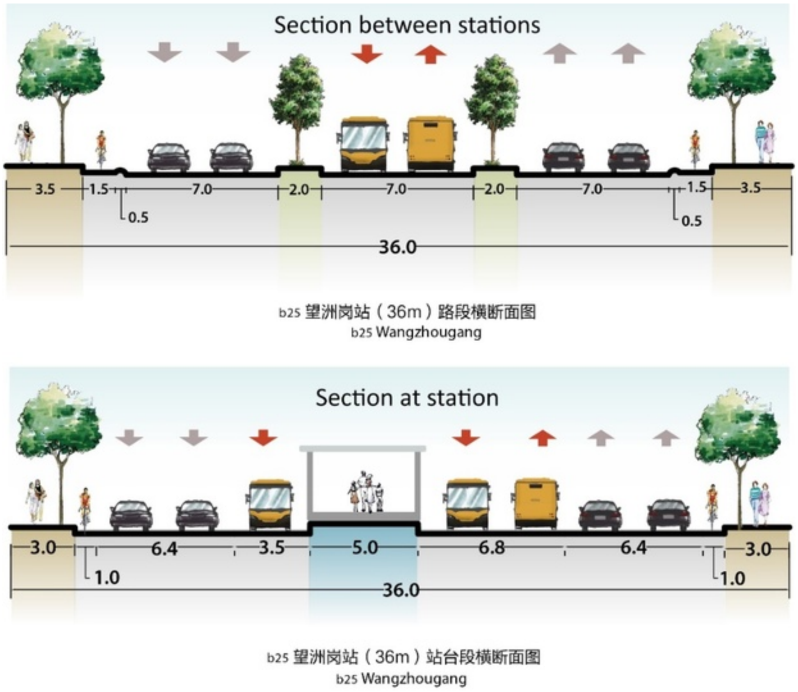

Figure 25.57. Cross-section at and between stations at Wangzhougang BRT station in Yichang. *ITDP*

Figure 27,58 provides an example of a cross-section for a medium capacity BRT system: the design in Vientiane, Lao PDR. Note that in the proposed cross-section between stations, mixed traffic has 7 meter of space per direction, which at the BRT station is reduced to 6 meter. Since BRT vehicles are stopping on both sides of the platform, the BRT lane width is also reduced to 3 meter at the station. A rendering of the same station is provided in Figure 25.59.

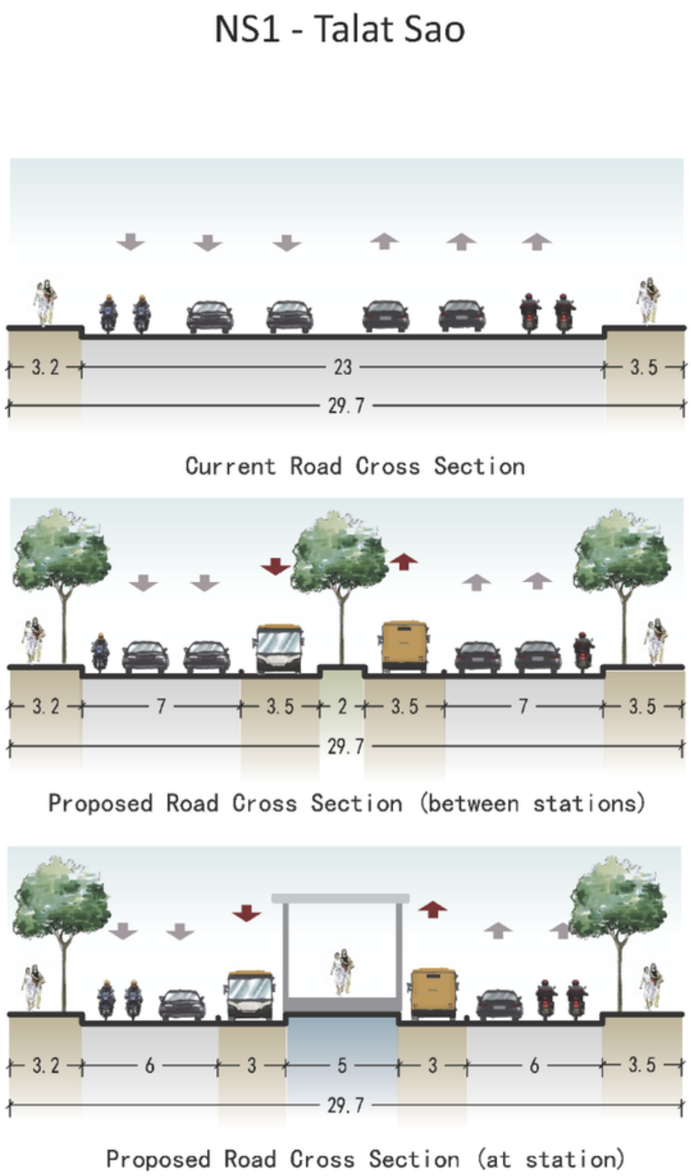

Figure 25.58. Proposed road cross-sections at Talat Sao station in Vientiane. *ITDP*

Figure 25.59. Rendering of Talat Sao BRT station in Vientiane. *ITDP*

The following table lists typical cross section widths at BRT stations. It is organized from the outside-in (from the building line to the center line). Priority is shown for each element. Use the prioritization scheme to guide the assemblage of the cross-section.

Table 25.3. Typical elements in a cross-section at a BRT station

–	**Pedestrian Zone**	**2 - 5.0m**	**• Includes Paved Accessible Route • Includes landscaping, sidewalk furniture, sidewalk cafes, bicycle parking • Can be wider if incorporated into building, plaza or other urban design elements**
1	Paved Accessible Pedestrian Route	2 - 3.0m	• Clear and free route for people walking or using wheelchairs • Wider based on level or service
3	Bicycle parking	2.0m	• Locate in pedestrian zone or on median at BRT station
2	Trees and landscaping	1.0m or wider	• Narrower tree pits must be longer to provide sufficient arable soil. • Combine with buffers, parking, sidewalk furniture, etc.
3	Pedestrian-bicycle buffer	0.0 - 1.0m	• Can be landscaped • Narrower if fenced
2	Bicycle lane	1.5 - 5.0m	• 2.5m for cycle rickshaws • 3.0m for two-way • 0.5m shoulders • Wider based on level or service
3	Bicycle-auto buffer	0.3 - 1.5m	• Can be landscaped • Narrower if fenced
–	Auto parking	n/a	• Typically not located at station or along BRT corridor
4	Auto lane	2.7 - 3.3m	• Narrower inside lanes • Wider outside lanes for trucks • Narrow lane width at the station • Minimize number of lanes • Provide intermediate pedestrian refuge islands if greater than three lanes per direction
–	Auto turn lane	n/a	• Typically not located at station
–	Auto lane shoulder	n/a	• Typically not located at station
2	Auto-BRT buffer	0.2 - 0.5m	• Narrower if fenced • 1.5m minimum as pedestrian refuge (wider based on level or service)
2	BRT passing lane	3.5m	• May be used by emergency vehicles
1	BRT lane	3.0 - 3.5m	• Based on vehicle type and station interface • Narrow lane width at the station where the bus is stopping
1	BRT station	5.0 - 10.0m	• Width based on space availability, BRT operation, and construction techniques

25.7 Station Components

"Oh, here it is. The instructions to fit in, have everybody like you, and always be happy! Step one; Breathe... Okay, got that one down. Step two; Greet today's smile and say: Good Morning City!"

— Emmet Brickowisk, as voiced by Chris Pratt in *The Lego Movie*, 2014

25.7.1 Access & Arrival Area

The access and arrival area is the front door of the station. It is where people arrive via ramp, stairs or elevators from a crosswalk, bridge or tunnel. An at-grade crossing is preferred. As discussed above, it is critical to locate crossings along desire lines in order to maximize utility. An important consideration is that people may use the crosswalk, bridge or tunnel simply to cross the street, not to access the stations. Those volumes and need for queuing space must be included in any calculation. Bicycle parking may also be located here. See *Chapter 29: Pedestrian Access*, *Chapter 30 Universal Access*, and *Chapter 31 Bicycle and Pedicab Integration* for more detail.

The key priority in planning and designing the access and arrival areas to the BRT station is to ensure as direct and convenient access as possible.

In the Urumqi station pictured in Figure 25.60, the poor station access design means that passengers can only access the station from one side of the road, leading to large unnecessary additional walking trips for many passengers. In this figure, a passenger traveling between points A and B would first need to walk to the intersection (C), then cross the street-level crossing to D, then go through the pedestrian tunnel to E, and then walk along the walkway (trying to avoid the cars also parking on the walkway) to B. The total actual walking distance that the passenger would need to traverse is 400 meters. The straight line distance between A and B is twenty-three meters. Although since this photo was taken a footbridge has been built which reduces the walking distance from A to B to a mere severnty-five meters, this still compares poorly to the twenty-three meters straight line distance.

Similarly BRT expert Pedro Szasz's analysis of the Transjakarta Busway and how to improve various problems showed that the measure which would have the single biggest benefit in terms of passenger time savings was to add stairs or ramps to reduce the unnecessarily long walking distance to access the BRT stations (Figure 25.61). Poorly designed station access can impose a penalty of hundreds of meters of extra walking distance for BRT passengers, and this 'access penalty' will deter many passengers from using the BRT system. In the case of Jakarta, pedestrian access was the worst deficiency of the system according to the summary in Table 25.4, because it occurs at most of the stations and during all eighteen operational hours.

Figure 25.60. Station access in Urumqi. *Karl Fjellstrom, ITDP, www.transportphoto.net*

Figure 25.61. Passengers are forced to double back and walk up to 200 meters further than would be required with a better station access design. *Karl Fjellstrom*

Table 25.4. Summary of problems and consequences identified in the Transjakarta Busway from December 2008

Problems	Equivalent travel time delay per trip (minutes)	Description
Pedestrian access	11	Lack of stairs and additional bridges or at-grade crossings with pedestrian signals. Bridges double-back, adding walking distance
Passenger transfers	3.5	No routes interchange corridors, so most passengers lose time walking to and waiting for the second route
Lack of buses	3	Buses are less than needed to attend demand, especially during the evening peak
Low velocity	1.5	Buses on some stretches and hours travel at low speed
Bus access on bus station	0.2	Drivers stop far from the bus stop, especially at some stations on curves
TOTAL	19.2	

25.7.2 Entrance Area and Fare Collection

The entrance is composed of the fare collection area including sales kiosks for purchasing tickets and validation, the fare collection equipment such as fare gates and turnstiles, and system information including maps. Ideally it is weather protected and lockable after hours.

The fare collection area will require:

- ways for staff to communicate with passengers, both visual and through speech: grills, speakers, microphones, induction loops, and lip reading for the hearing impaired
- cash trays, cash drawers, a drop safe, and possibly credit card readers
- to be protected to secure money transactions
- ergonomic design, and air conditioning and/or heating subject to climate
- storage facilities for supplies, including cleaning supplies, and a water tap
- storage facilities such as lockers for the staff, as well as (in some cases) a staff toilet.

Because this is the electronic nucleus of the station, considerations for power supply and back-up power will need to be put here, and cables included in the station foundation design. The sales information and the ticket validation equipment will all need electricity to power it and transmission equipment to communicate that information to a control center. A local server may need to be stored here with proper ventilation. If there is a real time passenger information system, it will need power as well and be linked to the system to give that information. Power may also need to be supplied to the doors at the entrances and the where the buses dock, as well as the interior lighting. Fire detection and alarm systems will also need to be incorporated. At a minimum, an extinguisher is to be stored in the kiosk.

Point of sale (POS) Terminals

There needs to be sufficient point of sales (POS) terminals at each station to handle the level of customers. With an insufficient number of POS terminals there can be major queuing problems at high volume stations.

It is not recommended to sell tickets or cards at the station platform, because with sales, comes queues. Queueing on the platform presents many problems because of space limitations and the challenges to circulation. Therefore, selling and recharging cards / tickets at shops or at POS kiosks on pedestrian access bridges is better than selling them on the platform and should be encouraged as much as possible.

To avoid any queuing, there should be one POS terminal for every 500 boarding customers. To minimize the system costs and maximize profits, however, one POS terminal for every 2,000 customers is closer to optimum. The personnel costs are expensive, and a certain amount of queuing at the beginning is normal and will create an incentive for customers to buy multi-trip tickets. For this reason, we recommend one new POS terminal should be added for each 1,000 boarding passengers per peak hour, unless the level of usage of smart cards is very high and the cash payment in the station does not allow change to be given. In this case, where smart card usage is very high and where change is not provided in the station, one POS terminal for every 3,000 passengers can suffice.

This figure is derived as follows. One selling operation normally takes about 6 to 10 seconds, averaging 8 seconds. Thus, on average a POS terminal will have a capacity 450 customers per hour. Not everybody will be buying tickets, however, as many will already have multi- trip tickets. It is difficult to predict how many tickets the average customer will ultimately buy in any given system. In TransMilenio the average ticket buyer buys 4.2 trips. So, a POS terminal is really only necessary for every 450 * 4.2 or 1,890 passengers boarding per hour. However, this figure may be different in other cities, so to be reasonably sure that serious queuing will not result, one POS terminal for every 1,500 boarding passengers per hour per station is suggested. While at least one of the POS terminals should be manually operated, some of the additional ticketing system POS terminals can be automated.

Entry and Exit Turnstiles

At the BRT stations along the corridor, normally the turnstiles have higher capacity than the POS terminals, but they are used by all the customers. Normally the gates have a capacity of 900 to 1,200 customers per hour, or 3 to 4 seconds per customers. Because sometimes the ticket gates fail, it is usually good to have one or more back up turnstiles to plan for redundancy in the system. For systems with a flat fare, to keep open the possibility of a distance-based fare, there needs to be a minimum of one gate per every 1,000 boarding passengers and one gate per every 1,000 alighting passengers, but with a minimum of at least one additional gate per direction in case of a turnstile failure.

The following are rules of thumb for processing rates:

- 2,000 people per hour can move within a meter of space.
- 900 people per hour (PPH) can enter a station through a single smart-card turnstile. The number rarely is that high as machine and human error can drop that rate to 600 PPH, if not lower. This is also contingent on the technology. This can be used as a rule of thumb, but then should be verified against real counts of the actual technology.
- 1,500 PPH can exit a station through a single turnstile if they do not have to scan a card, but just pass through.
- 3,300 PPH can enter or exit a station with no barrier. The older the population, the slower the speed, the lower the rate.
- Two people will wait in one square meter of space, while three people will wait in queues in a square meter of space.
- People avoid walking too close to walls, fences and the curb. Thus a 0.3-0.5 meter shy distance is included in any width calculation.
- Processing rates for ticket vending also need to be accounted for. There will always be lines for ticket procurement and the processing rates depend on whether machine kiosks are used, if you can buy multiple tickets or fares at once, or if you have to buy a ticket from a person.
- Always have a contingency or redundancy plan for broken equipment, staffing issues, etc.

Space on station is precious and every function that can be done in other places should be avoided and removed, including rest rooms, ticket selling, and equipment that is not directly related to operation.

25.7.3 Number of Gates, ticket machines or boots

The equation bellow is general for detemine the required number of units of boots, turnstiles, gates without queue formation:

$$N = integer(\frac{Q}{C} + 1.5) + R$$

- N: Number of units needed
- Q: Quantity of required peak hour operations
- C: Average Capacity per unit (operations/hour)
- 1.5:
  - 0.5: Spare capacity to avoid random queues
  - 1.0: Rounding up, to never have less than 0.5 of spare capacity
- R : Reserve for failure, minimum of 1. If reversible gates are used, R can be added after adding entry and exit gates.

In case of two entries and no information about flows adopt 0.70 of total for each side.

Parameter for number of operations and capacity for gates, ticket machines

Ticket machine:

- $Q = \frac{Max(Pb, Pa)}{Nt}$, where
  - Nt: average number of ticket trips bought per sale operation. In absence of data adopt 4
  - Pa: total alighting passengers on peak
  - Pb: total boarding passengers on peak
- C = 180

Ticket boot:

- same as ticket machine
- but $C = 400$

Entrance gate: turnstile with contactless card

- Q: total boarding
- $C = 900$

Exit gate: turnstile with contacless card

- Q: total alight
- $C = 900$

Exit gate: turnstile without card (free exit)

- Q: total alight
- $C = 1800$

Exit without turnstyle

- Q: total alight
- $C = 3000/m^2$

Exit gate without turnstile but with contact point to discount

- Q: total alight
- $C = 1400$

Compute separately morning and evening peak and adopt maximum for each.

However, in case of reversible gates (which may provide economy of space and equipment), compute the maximum required gates for each period without considering reserves for failure:

$$G_{\text{TOTAL}} = max(\text{G}_{\text{ENTER MORNING}} + \text{G}_{\text{EXIT MORNING}}, \text{G}_{\text{ENTER AFTERNOON}} + \text{G}_{\text{EXIT AFTERNOON}})$$

Then, compute the maximum of entrance gates (M_{EXIT}) of all periods (without reserve for failure R) and the maximum of exit gates (of all periods except reserve for failure R):

$M_{\text{ENTER}} = max(\text{G}_{\text{ENTER MORNING}} + \text{G}_{\text{ENTER AFTERNOON}})$ $M_{\text{EXIT}} = max(\text{G}_{\text{EXIT AFTERNOON}} + \text{G}_{\text{EXIT AFTERNOON}})$

Then, the number of entrance, exit and , will be as follows:

$G_{\text{REVERSIBLE}} = \text{M}_{\text{ENTER}} + \text{M}_{\text{EXIT}} - G_{\text{TOTAL}}$ $G_{\text{ENTER}} = \text{M}_{\text{ENTER}} - \text{G}_{\text{REVERSIBLE}}$ $G_{\text{EXIT}} = \text{M}_{\text{EXIT}} - \text{G}_{\text{REVERSIBLE}}$

Reserve gates, computed over total, should be reversible

Box 25.3. Finding out how many gates are required

Table 25.5. Example of number of required gates computation

period and number of gates needed

peak	boarding	alighting	total
morning	3	7	10
evening	5	3	8
maximum	5	7	10

$G_{\text{REVERSIBLE}} = \text{M}_{\text{ENTER}} + \text{M}_{\text{EXIT}} - G_{\text{TOTAL}}$ $G_{\text{ENTER}} = \text{M}_{\text{ENTER}} - \text{G}_{\text{REVERSIBLE}}$ $G_{\text{EXIT}} = \text{M}_{\text{EXIT}} - \text{G}_{\text{REVERSIBLE}}$

$G_{\text{TOTAL}} = 10$ $M_{\text{ENTER}} = 7$ $M_{\text{EXIT}} = 5$ $G_{\text{REVERSIBLE}} = 7 + 5 - 10 = 2$ $G_{\text{ENTER}} = 7 - 2 = 5$ $G_{\text{EXIT}} = 5 - 2 = 3$

Ten operating gates are required, with one resversible as reserve

$$Total = 10 + 1 = 11$$

25.7.4 Layout and Placement of Turnstiles

Turnstiles can be offset or placed directly across the entry of the station. Offsetting the turnstiles allows for more turnstiles but requires more station length. Figure 25.62 provides examples of various turnstile/gate configurations.

Figure 25.63. Straight row of turnstiles in a Bogotá BRT station with a segregated bike lane passing under the station. *Karl Fjellstrom*

Figure 25.62. Straight row of turnstiles in a Zhongshan BRT station. *ITDP*

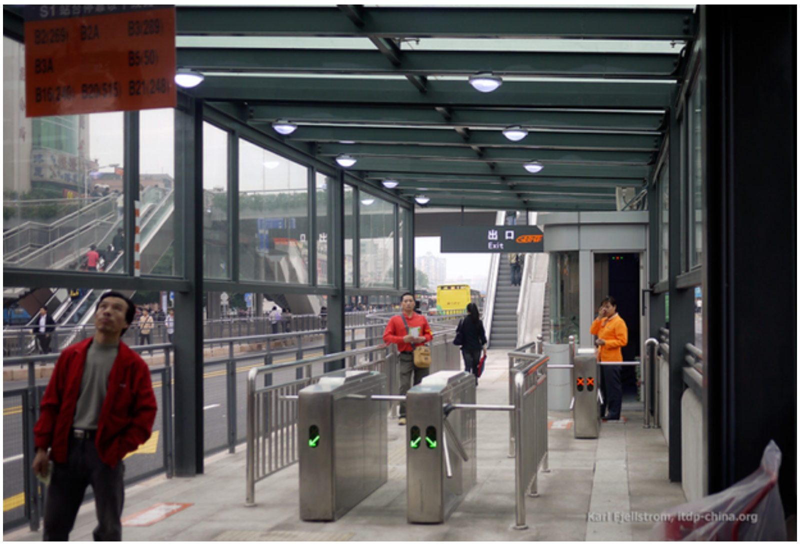

Figure 25.64. Offset turnstiles in a Guangzhou BRT station. *Karl Fjellstrom*

Figure 25.65. Straight row of turnstiles in a Bogotá BRT station. *Karl Fjellstrom*

Figure 25.66. Offset turnstiles in a Bogotá BRT station. *Karl Fjellstrom*

Since space inside the station is limited, fare collection can sometimes take place outside the BRT platform. Examples of off-platform fare collection and POS location are provided in Figure 25.67.

Figure 25.67. Fare collection on bridge: Bogotá. *Karl Fjellstrom*

Figure 25.68. Fare collection in tunnel/mall: Jakarta. *Karl Fjellstrom*

Figure 25.71. Fare collection in tunnel: Guangzhou. *Karl Fjellstrom*

Figure 25.69. Fare collection on bridge: Chengdu. *Xianyuan Zhu, ITDP*

Figure 25.70. Fare collection in tunnel: Bogotá. *Karl Fjellstrom*

Figure 25.72. POS kiosk on walkway: Bogotá. *Karl Fjellstrom*

Figure 25.73. POS machine in station vicinity: Mexico City. *Karl Fjellstrom*

Figure 25.74. POS machine in station vicinity: Lima. *Karl Fjellstrom*

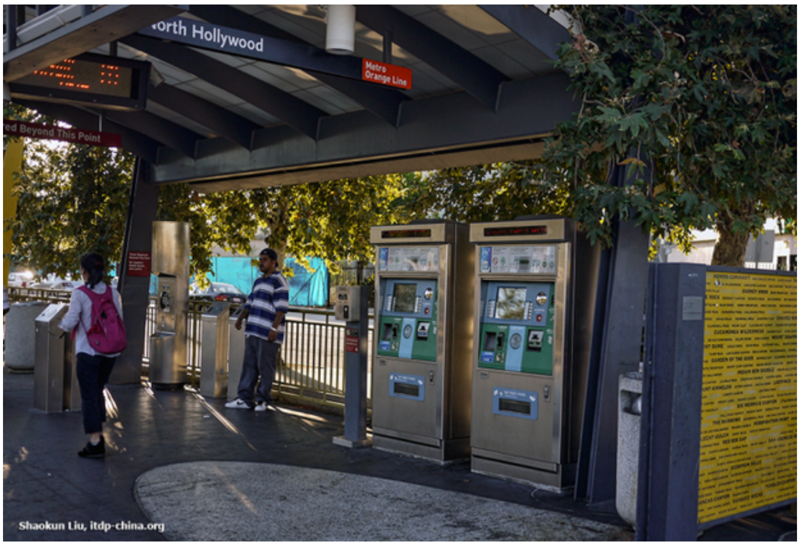

Figure 25.77. POS machines inside BRT station in Los Angeles. *Karl Fjellstrom*

Figure 25.75. Fare collection in tunnel: Istanbul. *Karl Fjellstrom*

Figure 25.76. Fare collection on bridge: Istanbul. *Karl Fjellstrom*

Figure 25.78. POS machines inside BRT station in Nantes. *Karl Fjellstrom*

25.7.5 Platform Waiting and Circulation Areas

Waiting areas in stations with doors in both sides of the station should generally be offset so that boarding doors do not directly face each other. Otherwise, waiting as well as alighting passengers can come into conflict as they try to crowd into the same space.

Figure 25.79. BRT station interior in Cali. The doors are offset so that passengers waiting for buses in one direction do not conflict with the passengers waiting for buses in the other direction. *Shanshan Li, ITDP*

25.7.6 Wayfinding

A station wayfinding strategy is necessary to help people quickly and intuitively identify where they are and where they are trying to go, how and where to get on the bus or make transfers, and where to access station services. The most effective wayfinding strategy is achieved through a combination of station design and signage (see *Information and Customer Service* below and *Chapter 28: Multi-modal Access*).

Four principles of wayfinding are:

- Intuitive;
- Legible;
- Consistent; and
- Extensive.

Wayfinding is typically provided via static signage, but may also utilize real-time information screens. Increasingly, passengers use their own hand-held devices for navigation. At transfer stations in particular, signage should be sufficiently sized and eye-catching in order to effectively lead customers to the right location. System designers should walk through the likely steps of a prospective customer in order to place the signage at the correct point. For example, signage directing customers to transfer points may be best placed directly across from the exit points of alighting customers.

In addition to providing directional and location information, other informational signage in and around stations should also be provided to help customers readily understand the system. This signage could include:

- Station entry and exit points;
- Waiting location for particular routes (if multiple docking bays);
- Directions for making transfers;
- Directions to station services (tickets, bicycle parking, restrooms); and

- Actions required in the event of emergencies (instructions for call boxes, fire suppressing equipment, etc.).

Signage allows the customer to immediately identify the system and can be an important element of the wider marketing effort.

The height of the signage post will be a principal factor in creating a sight line that is visible from a great distance. The color and letter size on the post will also determine recognition levels (Figure 11.64). Typically, the name and logo of the system will be prominently displayed on the sign-post, along with the name of the particular station.

An image related to the particular station may also be displayed on the sign-post. Such visual imagery helps passengers to quickly recognise their destination. The name of a hospital, university, or zoo may not mean anything to some passengers (especially occasional visitors), and thus a representative drawing may provide more immediate recognition.

The sign-post may also include other pertinent information. However, at the same time, designers must avoid placing too much information on the posts. Visual clutter will reduce the overall objective of allowing customers to quickly recognise a station's location.

Figure 25.80. The colour, shape, and form of this station sign-post in Brisbane allows customers to quickly recognise the presence of a station. *Queensland Transport.*

Figure 25.81. In Quito, station sign posts reflect the local character of the station area. The image of children on the sign-post indicates that the Baca Ortiz children's hospital is located near this station. *Lloyd Wright.*

Figure 25.82. In Quito, station sign posts reflect the local character of the station area. The stadium station sign-post is represented by a stadium image. *Lloyd Wright*

Figure 25.83. Station sign posts in Bogotá include the system name and logo, and the name of the particular station. *Karl Fjellstrom*

25.7.7 ITS Components

In-station intelligent transportation system (ITS) components at minimum will usually include:

- Operating and dispatch system. This includes cameras connected to the control center, broadcasting announcements, screens showing the next-bus arrival information, and some of the equipment inside the ticketing kiosk;
- Automated fare collection (AFC) system. This consists of the turnstiles or gates and related cables, as well as equipment in the ticketing kiosk; and
- Sliding door system for the station. This consists of the sliding doors themselves, plus controls from inside the ticketing kiosk and related cabling.

All of these components rely on or interact with various subsystems, such as clock synchronization, UPS power supply, IP digital broadcasting, vehicle localization, dispatch management, and so on.

One of the most important technological developments for transit riders in recent years has been the availability of real-time arrival information. This information helps to reduce customer “waiting stress,” which affects passengers when they do not know when or if a particular bus is going to arrive. A monitor can be mounted adjacent to the waiting area. Besides arrival information, other important news such as route changes, system delays, and scheduled maintenance can also be displayed. Vehicle-arrival status can be displayed outside the BRT station as well. Passengers who know that they have sufficient time until their vehicle arrives may choose to run an errand in the meantime.

Sliding doors are also increasingly used in BRT systems. The height of the sliding door is normally 1.1 - 1.3 meters, and the opening width of the door is 1.35 - 1.8 meters depending on the type of vehicles needing to stop at the station. The sliding door is activated by a sensor which is installed inside the vehicle, and when the driver stops the vehicle at the station and opens the door, the related sliding door at the station will automatically open for passengers boarding and alighting. The second level of control is in the control room of each station to open the sliding door in case the sensor in the vehicle fails to activate the sliding door. And as third level of control, if the sliding door cannot be activated by the other ways, the station attendant can use a remote controller to activate the sliding door. Maintenance and upkeep of sliding doors has proven to be a problem. The more technology or moving parts introduced, the more likely that they will need to be fixed.

25.7.8 Seating

Seating provides a resting space while customers wait, particularly the elderly and disabled. Seating can range from formal benches to simple leaning posts. The need for benches may vary based on the headways - if vehicle headways are infrequent, then more people will want to sit. In direct service systems, customers tend to wait for longer periods in the station as they wait for a particular route, in contrast to trunk-feeder systems. Some form of station seating or at least leaning is essential in such systems. The leaning bars and seating are effective ways of encouraging passengers not to wait in front of the gates, which can impede boarding and alighting. This is especially important in Lima and Cali, which have only one stopping area per sub-stop.

Figure 25.85. Station seating in Guangzhou (right). *ITDP-China*

Figure 25.84. Station leaning bars in Cali. *Shanshan Li*

25.8 Vehicle Interface

"Even if you're on the right track, you'll get run over if you just sit there"

— Will Rogers, actor, 1879–1935

Having the platform level with the vehicle floor is one of the most important ways of reducing boarding and alighting times per passenger. Customers climbing even relatively minor steps can mean significant delay and an increase in safety hazards, particularly for the elderly, disabled, or people with walking aids, suitcases, or strollers. This is also true with horizontal and vertical gaps between the station and the bus. As mentioned previously, *the BRT Standard* includes level boarding as one of the BRT Basics, the essential elements of BRT. Having one of the highest points awarded to this indicates how important this element is to both operational efficiency and passenger experience.

Having the platform and vehicle at the same level speeds up alighting and boarding, and with it, reducing dwell time and improving overall performance.

- Level boarding is 0.2 to 0.7 seconds faster per passenger and alighting times 0.3 to 2.7 seconds faster per passenger compared to a buses where you have to go up steps.
- Stepping up or down to the vehicle renders the system unusable for persons in wheelchairs and problematic for others (using walking aids, persons carrying packages, children, etc.).

25.8.1 Doors and Boarding Area

Sliding doors can provide a more professional impression and improve safety by deterring fare evasion through station doorways (Figure 11.60). Station doors can also help protect the customers from the weather – whether it be rain or hot or cold. If a station is heated or air conditioned, doors keep in the conditioned air. These doors may be controlled electronically from the vehicle or station, but should have a manual override, in case like in Figure 25.87 the door does not function. As mentioned above, this introduces a maintenance challenge and can lead to the doors not functioning and the system not having the capacity or resources to fix them.

Figure 25.87. Without sliding doorways, customers may evade fare payment and endanger their safety by entering and exiting through the platform doorway. In Quito, station doors are left open. *Lloyd Wright.*

Figure 25.86. In Johannesburg, the sliding door malfunctioned and did not open as the bus pulled up, leaving the passenger stranded between the bus and station. The station attendant quickly came to manually open the doors with a remote control. *ITDP*

Station doors need to be aligned with the vehicle types using the station, and within the station according to the space available on the BRT station structure. Where boarding and alighting takes place on both sides of the station, the doors should ideally be offset, so that waiting passengers in one direction do not impede boarding & alighting passengers in the other direction.

Figure 25.88 shows the proposed BRT station configuration in Vientiane. Note:

- The stations have been designed to accommodate a variety of vehicle types; namely 9-meter, 12-meter,
- and 18-meter BRT buses. In the short to medium term the 18-meter buses are not needed and are not recommended.
- The 18-meter BRT bus option is included only so that if needed capacity can be added in future.
- The doors of the vehicles align with the doors in the stations.
- The boarding and alighting areas for the two directions are offset, except for the middle set of doors. In the case of the middle doors, since this is the second docking bay and is not used at all for the initially proposed fleet of 9-meter buses, the likelihood of passengers in different directions impeding each other is low.
- Each direction has two docking bays for each direction.
- A 'reserved' space has been identified allowing the future installation of additional sliding doors, in case in the long term there is a need to use many 18-meter buses.
- The preferred station width is 5-meter or 6-meter, not 4-meter.
- A manned ticket selling booth is provided at one end of the station. The other end will have either exit-only functionality or provision only for smart-card entry.

Figure 25.88. Location and alignment of sliding doors in proposed BRT stations in Vientiane. There are other types of stations; this 55-meter station is the standard one. *ITDP-China*

25.8.2 Platform-vehicle Alignment

The goal is to create a level boarding experience so that people using wheelchairs or walking aids, pushing strollers or carts, or jut carrying packages can easily and safely board and alight. To do that, the gap between the bus and station needs to be 10 centimeters or less, especially at the front of the bus where it is easier to bring the bus closer to the station. Below are some of the more common ways systems have used to minimize the gap:

- Boarding bridges: These are mechanical bridges that extend from either the bus or the station (such as in Yichang) to cover the gap between the bus and the station;

- Alignment Markers: Most BRT systems use alignment markers on the busway surface, in combination with markers on the vehicle windscreen, to assist drivers to dock with a minimal vehicle-to-platform gap. Some BRT systems also utilize a painted “guide strip” that lines up with a guide line on the bus’s windshield that aids drivers in docking the bus closely to the station;
- Platform Edge Treatment: It is a common practice to provide a protective edge on the platform, typically matched by a protective strip opposite the platform edge that runs along the length of the vehicle; and
- Beveled Curbs: The BRT in Nantes uses beveled curbs to assist vehicles in docking near the edge of the platform. The curb is hardened and smoothed to reduce wear on vehicle tires. The Cape Town BRT uses special curbs to assure that the vehicles can dock near the platform without risk of damage to the vehicle. This increases confidence in drivers that they may safely reduce the gap for boarding passengers. The Kassel curb allows the wheel of the vehicle to make contact with the curb so the driver can “feel” where to position the vehicle correctly through the steering system. It helps the driver and vehicle align with the curb for seamless boarding and alighting. See Figure xxxx.

If the vehicle to platform interface does not utilise a boarding bridge, then greater precision is required to align the vehicle to the platform. While a boarding bridge only requires a vehicle to be within 40 centimetres of the platform, the lack of a boarding bridge requires that the vehicle be aligned within 10 centimetres or less, if the station is to be wheelchair accessible, especially at the front of the bus where it is easier to closer to the platform. This degree of precision will require a longer approach distance in order to maintain an effective speed. Ahmedabad has door sensors and the door cannot be opened if the gap exceeds an allowable width. The driver then has to re-align the vehicle.

To ensure close docking without the use of boarding bridges, a combination of the following are needed:

- Driver training, as well as monitoring of driver performance in this regard;
- Adequate approach distances, especially where stations have passing lanes;
- Kassel curbs or sloping curbs that enable buses to stop close to the platform without actually striking the platform; and
- Especially for high floor systems where closer docking is more critical, some form of padding is often utilized (see Figure 25.89).
- Visual aids to drivers so they know exactly where to stop the bus (Figure 25.90).

Figure 25.89. Cali’s BRT stations feature padding to allow drivers to dock closely to the station. *Shanshan Li, ITDP*

Figure 25.90. In Johannesburg, bus drivers line up the yellow line on the dashboard to the yellow line on the pavement to dock closely to the station. *ITDP*

Figure 25.91. Pauline Froschauer standing next to Phase 1B construction of Johannesburg's BRT system. The curbs here are rounded and made of steel so that buses can pull up to them without damaging their tires. *Aimee Gauthier, ITDP*

Figure 25.92. Smooth, hard, bevelled curb in Nantes to reduce tire wear. *Karl Fjellstrom*

Figure 25.93. Smooth, hard, bevelled curb in Amsterdam to reduce tire wear. *Karl Fjellstrom*

Figure 25.94. Cape Town uses Kassel curbs, a sloped curb that minimizes the wear and tear on the tires of the bus by curving up. *ITDP*

Box 25.4. Solutions to Minimizing the Gap: A case study

Using a beveled curb allows drivers to pull up close to the station by using the curb to guide the bus. This means added wear and tear to the tires as they rub against typically the concrete curb surface, even if those curbs are bevelled or smoothed. To compensate for this that results in excessive tire side wall wear, many tires are reinforced with thicker rubber, which increases the weight of the tires by a third more. This added weight means more fuel consumption.

Figure 25.95. Image of the precision docking curb that shows the slope downward to the station, the rounded curb, and the idea of the stepping back the top of the curb. *Bridgestone.*

In an effort to address this, Bridgestone has been experimenting with both the curb and the tire to reduce the wear and tear of the tire, as well as its weight, while helping getting a closer alignment. It is a mix of redesigning the idea of a beveled curb to better work with buses and drivers to get closer to the station, while redesigning the tire for that type of approach.

Figure 25.96. The tire reside technology reinforces the side of the tire that rubs against the curb without adding extra weight to the tire and making the tire last 25 percent longer than a conventional tire. No color on the tire – color in image is for illustration. *Bridgestone.*

In what they are calling the "Precision Docking Curb," Bridgestone builds on the idea of the beveled curb with two additional features which help buses align to the station better. The first is the gently slope the roadway toward to the station curb, which enables buses to naturally approach curbs with minimal steering. This serves as a means of controlling the angle of approach to the curb without rely on to the driver's skills. The second big change this introduces is to step back the curb to avoid the curb hitting the body of the buses when approaching the station. In a study testing the performance between existing beveled curbs and the precision docking curb, the precision docking curb performed significantly better with less variation (see Figure 25.97) To address the wear and tear to the tire, Bridgestone has developed the tire reside technology. This allows the tire casing to be replaced, but the internal tube can be reused over and over again. This technology also slows down the speed with which the tire sides wear, meaning these tires last 25 percent longer than a conventional tire.

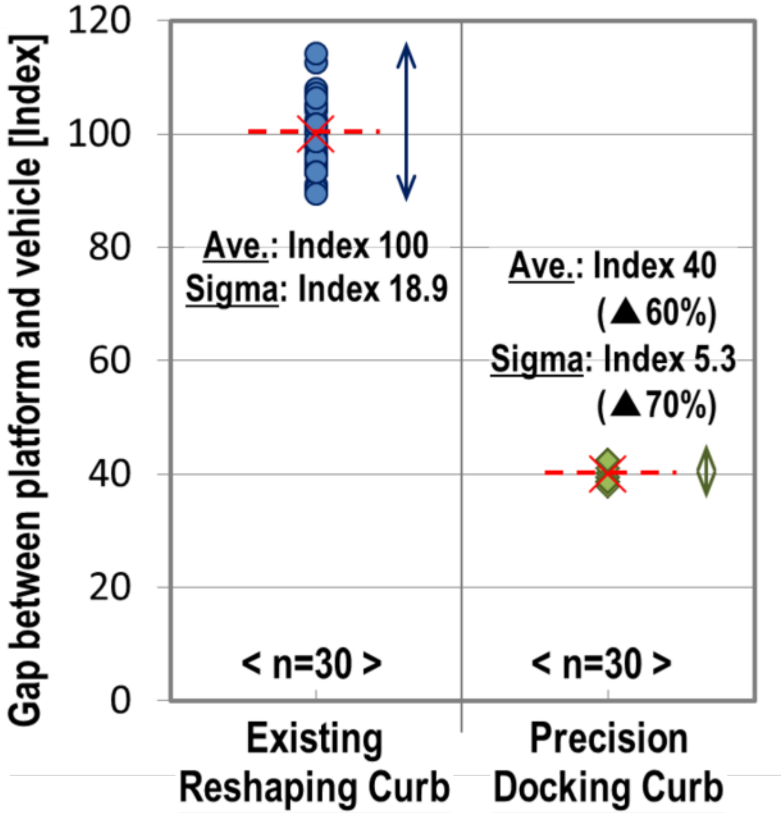

Figure 25.97. The gap improvement from using the precision docking curb method. *Bridgestone*

These both improve the platform-vehicle interface with narrower gap and less variances, which significantly affect accessibility for a variety of users.

Various electronic systems are used to ensure proper platform-vehicle alignment, though these are much more expensive than visual alignment markers guiding the drivers at a fairly marginal additional benefit, especially in cases where capacity issues mean that rapid docking is more important to overall system performance than precision docking.

- Optical Guidance - a video camera detects the position of the bus relative to the station and helps guide the vehicle. Optical guidance systems are used in Rouen, France, Castellón, Spain, and Bologna, Italy; and
- Magnetic Alignment - a path is laid magnetically using a loop, wire, or permanent magnetic studs that are read by sensors underneath the bus to guide the vehicle. Magnetic alignment technology is employed in Eindhoven, The Netherlands.

25.9 Station architecture

"It is not the beauty of a building you should look at; it's the construction of the foundation that will stand the test of time."

— David Allen Coe, musician, 1939–

25.9.1 Architectural Style

Modern architectural styles often deliver relatively clean look within a sort of minimalistic framework (Figures 11.47 and 11.48). The station designs in Brisbane epitomize this type of approach. The excellence of the design has resulted in the designers receiving various architectural awards. Likewise, stations in cities such as and have likewise utilised simple, clean designs to evoke a modern appearance.

Figure 25.98. Clean and simple design in Brisbane gives the system a look of modernity and sophistication. *Queensland Transport.*

25.9.2 Weather and Enclosure

BRT stations need to protect passengers from adverse weather including rain, wind, and sun. A comfortable customer will be more likely to use the system. Comfort is also related to efficiency, as passengers will tend to wait where they are out of the elements. As such, the design and location of waiting areas can enhance efficiency of space utilization and passenger flows.

Any area where passengers are queued or stationary (ticket vending, turnstiles, waiting area) needs to be roofed. Areas with equipment are to be enclosed. Transfer locations, such as ramps and bridges should also be roofed, if not enclosed. Apart from comfort, enclosure assists with security and access (keeping out fare dodgers).

In general, stations in areas with warm and humid weather are preferably designed with more open structures, which usually means partially open walls and door heights of 1.1 meters, to enable air circulation. Stations in cold climates may be fully enclosed.

25.9.3 Lighting and Power Supply

Based on specifications used in Guangzhou and Yichang, suggested minimum design illuminance levels are 75 lux in stations and 300 lux in control and machine rooms. Stations should use more energy-efficient fluorescent lighting or electronic energy-saving lamps with energy-saving inductance ballasts or electronic ballasts, and a single lamp power factor not less than 0.9.

Platform security doors, turnstiles, ticketing system and emergency lighting is based on secondary load, with general lighting, advertising lighting, fans, air-conditioning and others based on tertiary load. The secondary load is eleven kilowatts, and tertiary eight kilowatts. Primary and secondary loads use a dual power supply to ensure supply security. Main power supply is provided by the platform box, with backup power from the adjacent platform dedicated box. Particularly important electrical equipment such as the fare system has an extra accessory set UPS, and emergency lighting comes with batteries.

25.9.4 Signature and Iconic Stations

Memorable BRT stations can have iconic value. Prominently located in the median and repeated multiple times along a corridor, BRT stations can redefine that corridor.

A city's investment in a BRT system is a major investment, and many BRT corridors are the most prominent urban transport projects that cities have ever undertaken. Such commitments are not made lightly, and are expected to significantly better the lives of its citizens and visitors.

Signature stations are a useful concept in BRT station planning. Signature stations can be selected based on usage or prominence within the city, and can include additional elements. For example, signature stations may include escalators instead of stairs, and may be wider, or have trees and plantings and public art, or other special characteristics not present in most stations in the system.

Figure 25.99. The Johannesburg station design was meant to be iconic and indicative of a quality public space, visible in the neighborhood. *ITDP*

Figure 25.100. Each station in the Rea Vaya system has a unique character in the locally produced artwork that is on the glass of the station as the customers enter. *ITDP*

25.9.5 Supervision During Construction

Many key decisions are made during the detailed engineering design and construction of a BRT system. Both stages require supervision and technical input by BRT experts experienced with high-quality BRT implementation. Changes to system features such as any aspects of the station design or configuration, any aspect of the intersection design, and aspects of the physical design or the corridor can have potentially disastrous implications for the later operation. Operational decisions are also extremely important, but provided the physical design is correct, can be fixed after the system starts operation. Physical mistakes, on the other hand, are usually either difficult or impossible to fix, short of demolition.

Institutional and contracting decisions made during the construction period are also important, and should not be taken without input by BRT experts with experience with high-quality BRT implementation. While theoretically the institutional and regulatory matters should be well advanced even during the period before construction starts, in reality it is the appearance of the corridor and physical station structures that often spurs the relevant regulatory authorities to take action.

Experts with experience with BRT implementation should be hired separately to supervise key technical aspects of the implementation, especially during the construction period. This does not refer to the typical procedures regarding supervision of matters like administration, contracting, bidding, and auditing. Rather, this refers to the need for an additional contract for supervising the technical aspects of the BRT implementation, in order to ensure that the designs are properly implemented. Without this supervision, there is a substantial risk that local contractors and engineers, inexperienced with BRT implementation, will make errors that will undermine the later project operation.

25.9.6 Ensuring High Quality Construction

Poor workmanship can result in unresolved building details, causing misaligned station parts, unfortunate junction of materials and components and substandard finishing off of the BRT station works.

A qualified, independent architect should be engaged to provide detailed design information, including working drawings and technical specifications. Because of the scale of BRT projects and the number of stations, it is recommended that during the critical construction period weekly inspections are undertaken and monthly reporting on the quality and the progress of the works be made to the project management team.

Station construction requires the care and workmanship of a skilled contractor for such important BRT infrastructure, especially considering the high levels of financial investment in BRT stations. Inadequate construction supervision with limited architectural information and below-average workmanship will adversely impact on the overall functional and visual quality of the stations. Substandard workmanship reduces the life expectancy of the station works and may require later remedial work to improve the stations.

New station designs should be coordinated with other supporting building design professionals, including structural and civil engineers, electrical engineer, hydraulic engineers, landscape architects and signage designers. This must be undertaken to reduce the risk of poor workmanship, less than satisfactory quality, and the possibility of budget overruns for BRT stations.

The planning and design of new stations requires the engagement of a qualified architect to lead the station architectural design process. This standard building industry practice is needed for the production of architectural design information that accurately indicates the technical detail needed by a building contractor to construct new BRT stations.

25.9.7 Demonstration Stations

An approach successfully used in Johannesburg, Guangzhou, and Yichang is to build a single demonstration station first, before the remaining stations are built. This initial demonstration station can be used to test and make adjustments for all aspects of the station architecture, as well as for components such as road pavement coloring. It can also help build excitement and buy-in to the new system.

Figure 25.101 shows the demonstration station completed in Yichang in late 2013. This station, Wuyi Guangchang, was thoroughly reviewed by ITDP-China working with the Guangzhou Municipal Engineering Design and Research Institute (GMEDRI) in late 2013, and a number of adjustments were made for application to the station architecture and construction of subsequent stations.

Figure 25.101. Yichang BRT demonstration station (Wuyi Guangchang station) under construction in December 2013. Wuyi Guangchang is in a wide, relatively lower demand section of the BRT corridor, far to the south of the highest demand city-center stations. *Shanshan Li, ITDP*

In Guangzhou, a demonstration station was finalized in 2009 before the other stations at Huangcun, in a relatively lower demand location along the corridor. Various pavement colorings were also tested at this station prior to application throughout the entire BRT corridor later in 2009. The system opened in February 2010.

25.9.8 Materials

The best BRT stations are constructed with materials that are highly durable, weather-resistant, vandalism-resistant, and easily maintained.

- **Steel** is commonly used for shelters, ramps, bridges, benches, bicycle racks, and trash receptacles. It resists everyday wear, tear, and graffiti;
- **Concrete**, an excellent non-slip surface, is commonly used for the station base, ramps, and walkways. Concrete panels can be used for walls;
- **Tempered glass** is primarily used for side panels on station shelters. Visually, the material is more pleasing that plastic and withstands environmental demands better than plastic. Unlike plastic, the material is not damaged by repeated cleaning;
- **Plastic** is used for paneling and roofing on stations. The material is lightweight and can be installed with minimal effort. Clear plastic permits the interior of the shelter to be visible from a distance, which enhances security. Depending on the desired effect, plastic can be frosted to reduce the amount of sun entering the station or left clear to allow for exposure to the sun;
- **Aluminum**, although fairly inexpensive and easy to work with, is easily scratched. Its high recyclable value makes it a target for theft; and
- **Wood**, oftentimes used for benches, is rarely used to construct other elements because it weathers poorly and is easily vandalized.

A BRT station needs to be designed to counteract wind loads, snow loads, seismic activity, and storm water. Wind loads are especially problematic for stations surrounded by tall buildings. It is also advisable to include as much sound-absorptive material as possible to make the station quieter (given that it exists in the middle of the road).

Stations need to withstand occasional scrapes from buses or other vehicles without suffering visible damage. For this reason, the sides of the platform are often designed similar to highway barriers.

The station and its passengers must be protected from vehicles crashing into the station. This can be accomplished using a series of perimeter barriers. The first would be the verge and merge areas, which can be designed so that any errant BRT vehicle is shunted away from the station. The second is a barrier between the regular vehicle lanes and BRT lanes. This would deflect errant vehicles approaching from the side, for example swerving cars and trucks or those approaching from side streets. Bollards and other structural material atop the platform provide a third layer of protection, stopping any vehicles or vehicle parts that pass over the barriers. Through the use of perimeter barriers, the station does not have to look like a fortress.

25.9.8.1 Passive Heating and Cooling

To be consistent with sustainability principles, BRT stations should be passively heated and cooled as much as possible. This also reduces operating expenses. Passive design techniques include:

- Roof overhangs to block the sun (must be high enough to not interfere with bus traffic);
- Horizontal louvers to shade the sun (can be mechanized to adjust to the sun angle);
- Horizontal or vertical louvers which allow prevailing breezes to pass through (but do not obstruct visibility);
- Performance glasses to reduce heat gain;
- Reflective colors that absorb less heat;
- Ventilation systems where hot air is vented out the top of the station and fresh air is drawn in at the bottom;
- Cross ventilation; and
- Green roofs (vegetated to absorb radiant heat and reduce heat-island effect).

25.9.8.2 Mechanical Heating and Cooling

Some locations are simply too hot, humid, cold, or windy to passively heat and cool. Here mechanical systems are required, but efforts should be made to utilize passive techniques as much as possible. For example, a BRT station can have a passive ventilation system in the summer and heaters in the winter. With high bus frequency, wait times are low, and the need to heat and cool less. Some mechanical heating and cooling options are:

- Ceiling and high-speed fans;
- Exhaust fans;
- Water-fans and misters;
- Area heaters;
- Ground source heat pumps; and
- Air-conditioning - recommended only where the station is fully enclosed and connects to the vehicles via doors. Alternatively, certain sections of the station can be enclosed and either air-conditioned or heated. Attendant booths/kiosks, offices, and electrical equipment should be air-conditioned.

25.9.8.3 Electricity

BRT stations require electricity for lighting, ticketing, fare collection, surveillance, and other ITS elements. Utilize energy-conserving devices such as LED lights and automatic switches. Power is typically obtained from the same lines that power traffic signals and street lighting. Underground cables are preferred. Include additional power for future services. Where the power grid is unstable, it is necessary to install a generator or backup power supply.

A station may be fully solar powered, especially one with an open-fare system and passive ventilation. The station roof is a prime place for solar panels.

25.9.9 Greenery

Addition of greenery can alleviate the concrete jungle impression imparted by large expanses of road and station infrastructure.

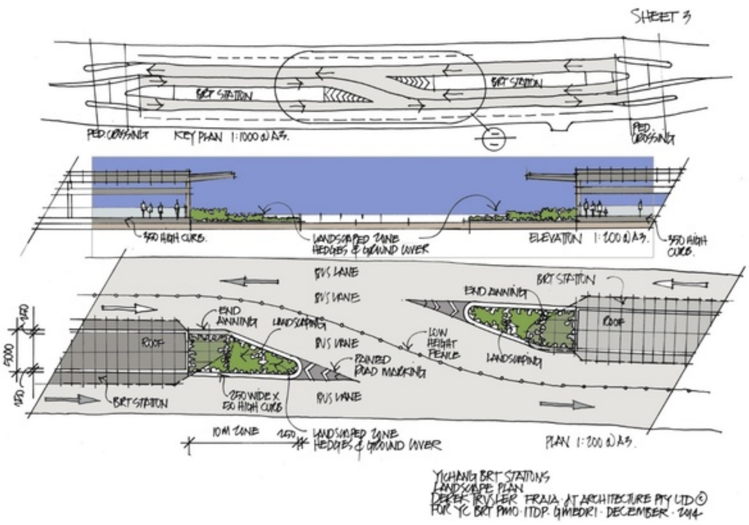

Figure 25.102. Yichang BRT station landscaping plan. *ITDP-China*

Figure 25.103. Yichang BRT station landscaping in reality. *ITDP-China*

Figure 25.104. Trees retained in a BRT station in Mexico City. *Bernardo Baranda, ITDP*

Figure 25.105. Greenery at a BRT station in Mexico City. *Karl Fjellstrom*

Figure 25.106. Cape Town planted trees in the station on the walkway connecting sub-stops. *ITDP*

25.9.10 Station Amenities

> *"A river is more than an amenity, it is treasure."*
>
> — Oliver Wendell Holmes, author, physician, poet, humourist, 1809-1894

Toilets

In general, BRT systems rarely provide toilets at stations because it requires additional space, cost, utilities (electricity and plumbing), and maintenance. Larger stations and terminals are often equipped with restrooms for customers, which staff can use, with proper security. It is essential to have restrooms for drivers at terminal facilities, so they can be comfortable while driving during their shifts. These facilities may be separate from customer restrooms. Toilets are essential for staff located at stations full time for maintenance and/or customer service; however, it may be sufficient to establish a relationship with nearby businesses to use their facilities. Another option is paid, self-cleaning toilets located nearby the station.

As noted, toilets need to be provided for station staff, though not necessarily at every station. A toilet every few stations can suffice, allowing staff to access toilets during breaks. Toilets for station staff should preferably be located near rather than in BRT stations.

Commercial Space

BRT stations provide commercial opportunities to generate revenue and provide passengers services. Proximity to destinations, such as shopping centers, sports arenas, or entertainment districts, may provide opportunities for joint development with adjacent retail. This may not only lead to opportunities for on-site retail and passenger amenities, it may also help seamlessly integrate the station into the surrounding environment.

Different station configurations may determine the commercial potential. Larger intermodal and terminal stations may be destinations in themselves, providing gateways to grocery stores and shopping malls. These stations may also host smaller vendors, such as newspaper stands or retail kiosks. Stations may have similar types of development, but these stations typically have smaller footprints and therefore less space for commercial development. The smaller retail shops could be planned in coordination with ticket sales outlets or information centers. Regardless of configuration, stations have opportunities to generate on-site revenue through advertising, vending machines, and newspaper boxes.

Public transport stations also represent great value from the perspective of vendors and shop owners. The high volume of public-transport customers through stations and terminals provides vendors with a concentration of potential clientele. The value of commercial property near stations often is representative of the high value that merchants place upon potential customer volumes. The needs of the commuters are met both by the services provided by the street vendors and the formal establishments like kiosks, shops, and large commercial centers.

From an infrastructure standpoint, it is possible to integrate commercial enterprises into the station and/or terminal sites. The availability of space is the prime determinant, along with the ability to design the shop to avoid conflicts with passenger movements. If a system has an underground tunnel connecting interchange stations, then an underground shop location could be feasible.

The Lanzhou BRT includes elements of transit-oriented development and public-private partnership financing in the form of six underground shopping malls underneath the BRT corridor, constructed as part of the BRT project. The largest, called Fifth Avenue, connects with two BRT stations, Feijiaying and Taohai Shichang. These shopping malls were implemented by the government in the form of the Lanzhou ADB loan Project Management Office, with one sold to a private company and the other five rented to tenants. The Fifth Avenue mall is 496 meters long with a 16,000 square meter operational area, which includes shopping areas, public space and pedestrian passageways. It has eight entrances and 16 escalators, along with 24-hour camera monitors, three public plazas and exhibition spaces, and its own system control center. Gansu Dacheng Investment Ltd. invested in and will operate this shopping mall for 50 years. In addition to the original fee which was used to offset the BRT corridor construction cost, the company builds and maintains the public facilities, including BRT passenger tunnels and escalators.

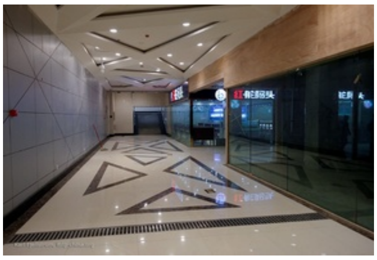

Figure 25.107. Lanzhou's Fifth Avenue shopping mall connects two BRT stations and is pictured here in May 2013, a few months before opening. The mall has proven very successful. *Karl Fjellstrom*

25.10 Station Operation

> *"In the end, all business operations can be reduced to three words: people, product, and profit. Unless you've got a good team, you can't do much with the other two."*
>
> — Lee Iacocca, businessman, 1924–

25.10.1 BRT Station Staffing

For the Guangzhou BRT, the BRT Operations Management Company, fully owned by the Communications Commission of the City Government, is responsible for BRT station management, monitoring of corridor, scheduling of the BRT buses, the fare collection and sorting, station maintenance, and design and production of the signs, lighting, and electronic displays. Departments of the BRT Operations Management Company are: administration, finance, information engineering, operations, and stations. The company has more than six hundred employees, and is funded by the city government. There are eight to ten staff per station at all times, and about five hundred station staff in total.

25.10.2 Maintenance of BRT Stations

Regular maintenance for BRT stations is required for the long-term performance of stations structures.

BRT stations are a significant investment in transport infrastructure. The operation, function, aesthetics, and quality of BRT stations represent the city's standards. The BRT stations, if respected and valued, will continue over time to contribute significantly to the mobility of residents and the livability of a city. The stations will help to build confidence and support the future investment in placemaking developments along important integrated transport corridors.

A yearly program and annual budget for regular maintenance of key station parts must be established for the critically important long-term operational life and ongoing performance of BRT stations. Thousands of people will benefit from the infrastructure, moving in and out of the stations every day. Many stations will experience a high level of wear and tear that will increase as services are added to the network to meet demand. Residents will become increasingly dependent on the reliability and assured transit services accessed at stations.

Keeping the infrastructure in a good state of working order will ensure station parts all function optimally and is an important obligation of operators and regulators.

Critically important station parts include:

- Glazed passenger screen doors;
- Any manually or automatically operated louvers for ventilation;
- Electrically operated turnstiles;
- Electrically and manually operated roller doors for station security; and
- Station lighting, station signage and passenger information displays.

It is recommended that key parts of the stations be serviced weekly and that any worn, defective, or damaged parts be replaced immediately. A supply of station components should be kept in store so that should breakages occur or parts need to be replaced, they are on hand immediately. This allows removal of defective parts from the stations and installation of new parts without disrupting services. This maintenance could be undertaken at night when the stations are closed and no services are running.

25.10.3 Cleaning of BRT Stations

The regular cleaning of BRT stations both externally and internally, to present the space in a clean, tidy, and fit state for use has many benefits, not only in attracting passengers to services, but also ensuring the parts continue to function.

BRT stations should be adequately cleaned of dirt, dust and stains. If not, within even a short space of a year or so the stations will begin to look unnecessarily worn, shabby, and tired. The station buildings will quickly deteriorate, significantly affecting public transport services, reducing attractiveness to passengers and imposing future financial costs in expensive repair. Regular cleaning will ensure that deterioration and other problems can be detected immediately rather than dealt with in crisis maintenance, or being forced to undertake extensive cleaning due to diminishing public support.

The stations should be washed down and thoroughly cleaned every two weeks or monthly. The government must establish a program and a budget to employ a cleaning contractor to thoroughly clean and present the stations as fit for use. This should be undertaken irrespective of the regular build-up of dust and dirt brought to the stations by the prevailing weather patterns or environmental conditions. Owners of BRT infrastructure must commit to regular cleaning and maintenance of stations. This is because they are the primary message of the bus rapid transit services. The owners of the assets recognize the immediate and long benefits thorough cleaning brings to the bottom line of bus operating companies. The BRT stations set the standards and expectation for public infrastructure in a city.

A systematic cleaning schedule for stations and terminals serves to keep a system in near pristine form. One option is to clean after system closing times; however, in highly frequented systems, it is likely that stations will also need cleaning during the day. Therefore, scheduling station cleanings after peak periods can address litter accumulation without interfering with the free flow of customers.

Rubbish and recycling receptacles are necessary to minimize litter at BRT stations, as riders have food and drink containers and other items to dispose of before boarding a vehicle. They should be anchored to the floor and not in direct sunlight (so they do not smell).

Rubbish receptacles may be considered a security issue, and thus specially designed rubbish receptacles may be required . Alternatively, locating rubbish bins just outside the station is generally a safe and viable option.

25.10.4 Security and Vandalism

Fear of crime and assault is a motivating factor in the movement towards more private modes of transport, especially for women, the elderly, and other vulnerable groups. The close confines of crowded conditions provide the ideal environment for pick-pocketing and other assaults on person and property.

Visibility is the single most important attribute of security. The station itself, as well as the approaches to it, should be well-lit. Ideally, walkways extending five hundred meters around the station would be similarly lit. Lighting should be resistant to vandalism.

In addition to visibility and lighting, crime and insecurity can be deterred with the strategic use of design features, policing, and information technology. The presence of uniformed security personnel at stations and on buses can dramatically limit criminal activity and instill customer confidence. Security cameras and emergency call boxes can both allow for more rapid responses to potential threats and can also deter crimes from happening in the first place.

Closed Circuit TV (CCTV) can go a long way to minimize the incidence of vandalism. It allows for uninterrupted views of all public areas, both inside and outside the station. CCTV monitoring provides numerous benefits, including the recording of criminal activity and crowd management in stations. Used overtly, it can act as a deterrent to crime and reduce fear of crime in stations, on the street, and in vehicles. Placed discreetly, cameras leave nighttime users with a feeling of safety while allowing for maximum surveillance as well as a deterrent for vandalism.

Vandalism typically occurs when stations and the surrounding properties have little or no surveillance. The use of durable materials that deter vandalism allows for the ease of maintenance and repair and helps to deter crime. Graffiti-resistant materials and finishes should be used to facilitate the easy cleaning and removal of graffiti. Tamper-proof materials minimize maintenance or repair.

25.10.5 Emergencies and Evacuation

All stations need to consider potential emergency situations so that customers can remain safe. Typically, local jurisdictions have regulations related to safety, security, fire, and other potential hazards. Examples of emergency and evacuation components include:

- Fire detection, protection, and suppression systems, including alarms, fire hydrants, fire extinguishers, sprinkler systems;
- Emergency exit doors with automatic (magnetic) locks. Manually operated doors (push bars or levers) are to be avoided as they tend to be misused by passengers and fare evaders. Providing an auditory signal when these doors are opened, thus alerting staff, is usually not considered sufficient safeguard;
- Emergency telephones, so that passengers can communicate with responders;
- Video camera monitoring; and
- Public address system.

In the event of an emergency, able-bodied people would simply jump down from the station, but provisions must be made for those in wheelchairs, the elderly, etc. As such, emergency egress is required at the opposite end of a single-entry station. At high-platform stations in the median, a ramp, paved landing, and route across the road is necessary. The escape route should not look like an entrance; ramps are slightly steeper than normal and there are typically no handrails.

25.10.6 Special Events

Consideration of special events may need to be included in the design of some BRT stations, such as those near large sporting venues or in locations where there may be sometimes large crowds (see Figure 109).

Figure 25.108. During New Year's Eve and other special events in Brisbane, the Brisbane Busway operates free of charge. The heavy station usage at the Cultural Centre Station on New Year's Eve, pictured above, is alleviated by a panel being opened in the station wall allowing temporary access to the platform without going via the usual footbridge access. *Karl Fjellstrom*

26. Depots

"Maintenance is terribly important."

— Manolo Blahnik, fashion designer, 1942–

Depot areas serve an array of purposes, including bus-parking areas, refueling facilities, vehicle washing and cleaning, maintenance and repair areas, administrative offices for operators, and employee facilities.

The objective of this chapter is to describe how to design the most efficient depot for the particular operational requirements of a BRT system. The chapter deals with where to locate a depot within the BRT corridor or system, how many depots are required, and their size and layout. Various design considerations are discussed and, finally, the need for intermediate parking facilities within the system is discussed.

Contributors: Andre Frieslaar, HHO Africa; Ulises Navarro, ITDP Latin America; Karina Licea, consultant

26.1 Depot Location Considerations

Depots are generally, but not always, adjacent to terminals. Normally, the BRT vehicle will enter the terminal several times a day, but it will generally enter the depot only if it is being taken out of service, either because it is a nonpeak period, because it is the end of the day, or because it is in need of repairs. Ideally, depots will be located at or adjacent to terminal facilities so that depot parking can also be used for BRT vehicles coming out of service for off-peak periods without having to travel a long distance to return to a depot (Figure 26.1). Travel between the depot and terminal areas creates "dead kilometers," since fuel and other expenses are consumed without generating any customer revenues. These dead kilometers can considerably increase overall operating costs. Such separation can also create service irregularities, especially if the BRT vehicles are delayed in mixed traffic congestion while travelling from the depot.

However, since depots can consume considerable space, the location is often dependent on the economical acquisition of sufficient property. In some cases, sufficient land is not available near a terminal site and any site acquisition can be quite costly. Thus, for example, in TransJakarta, the depot area is located a considerable distance from the system's terminals. BRT vehicles must not only travel a long distance from the depot in the morning and to the depot in the evening, but must travel to depot parking during nonpeak periods. In Cali, Colombia, for example, the city had land acquisition problems and was not able to build a depot next to a major terminal. The depot was then built approximately five kilometers away until the city could find a closer location for it. The issue was solved in just a few months, but having the depot far away, even if just for a short period of time, generated considerable revenue reductions for operators. As an alternative to locating the depot near the terminal, it is possible to increase the amount of temporary vehicle parking at the terminal area or through intermediate parking facilities.

Figure 26.1. In Bogotá, most depots are located next to the terminal areas in order to improve operational efficiency. *Oscar Diaz and Por el País que Queremos (PPQ).*

Terminals and depots for BRT may also be integrated with other transport facilities. In Dar es Salaam, Tanzania, a terminal and depot are being planned on the site of the long-distance bus services. This co-location of urban and long-distance services holds benefits both for the customer as well as the private operators. Customers are able to easily transfer from the long-distance services into the BRT system, and private operators may also benefit in terms of sharing facilities with long-distance operators.

26.2 Number of Depot Facilities and Ownership

In many cases, it is desirable to provide enough depots so that each operator controls its own maintenance and parking facilities. Most private operators, if they own the buses, like to have control over their own depots so that they can take responsibility for the vehicles' security, maintenance, and repair. The vehicles represent the biggest corporate asset, and private protection of the long-term survival of this asset is one of the critical benefits of having private operators. The number of depots in a BRT system will therefore be partly a function of the number of private operators. In the case of TransMilenio, for instance, in Phase I there were three terminals, each one under the control of a different operator. The trunk-line vehicles were stored at these depots. The feeder buses may be stored at smaller depots under the control of the private feeder companies. These facilities are generally in fairly remote locations near the feeder routes where low-cost land is available. However, there may also be circumstances where the feeder-line operators share depot facilities with the trunk-line operators. If some firms operate both feeder and trunk services, then it can be more cost effective for such firms to utilize the same depot area (Figure 26.2). Also, depot services may be a profit center for some trunk operators who have the depot space and capacity to also provide refueling, repair, and maintenance services to feeder operators. However, the number of operators should be determined in a manner that maximizes system competition while also permitting administrative and management efficiency. For this reason, the number of operators can often exceed the realistic number of depot sites. In the extreme of a system with only one terminal and one depot, then all operators will have to share a single terminal and depot. In these cases, clear contractual language will be required to denote responsibilities at the site.

Figure 26.2. At the Usme depot in Bogotá, the green feeder vehicles are maintained at the same facility as the red trunk vehicles. *Lloyd Wright.*

Regardless of whether there is one or multiple operators at a depot facility, public authority should maintain ownership of the site. The operators may possess ownership-like responsibilities during the time of their concession, but at the termination of the concession, the public authority will wish to retain a high degree of flexibility. The next firm to gain the operating concession may or may not be the same as the existing company.

If a depot location is already owned by a private operator, then it may not be possible for the public authority to assume ownership right away. Expropriation costs may be high and the legal process can be difficult. It may be necessary to move through the first concession period with the existing operator in full control of the site.

26.3 Depot Sizing

The size of the terminals and depots depends greatly on the amount of vehicle parking needed, and the number of vehicles likely to need repairs. The configuration of the parking area can be a trade-off between parking efficiency and ease of entry. Some configurations may require some vehicles to be backed out, which can be difficult with articulated and bi-articulated vehicles. Further, a densely packed parking area may be relatively space efficient, but it can also lead to occasional damage to vehicles bumping into one another.

Table 26.1. Examples of Possible Vehicle Parking Configurations

CONFIGURATION / SPECIFICATION	CORD	ON DRUMS	DUAL DRUMS	45°	DUAL DRUM 45°		DUAL DRUM 45° IN SQUARE	
					LONG AND NARROW AREA	RECTANGULAR AREA	WIDE CIRCULATION	NARROW CIRCULATION
BUSES PER ROW	12	50	84	42	84	64	84	84
NUMBER OF ROWS	24	5	3	6	3	4	3	3
ROW LENGTH (m)	143.9	179.8	151.2	219.8	228.6	177.7	69.5	223.1
LINE WIDTH (m)	3.7	11.9	24	11	19.5	19.5	20.1	20.1
NUMBER OF CIRCULATIONS	-	6	4	7	4	5	4	4
CIRCULATION WIDTH (m)	-	16.8	16.8	13.7	13.7	13.7	13.7	6.1
TOTAL WIDTH (m)	86	160	139	162	113	146	115	85
AREA (km²)	12.4	28.9	20.9	35.7	25.9	25.9	25.6	18.9
BUS CAPACITY	252	250	252	252	252	256	252	252
AREA PER BUS (m²)	49.4	115.6	82.4	141.5	102.8	101.3	101.7	75.2
FLEXIBILITY	Bad	Excellent	Good	Excellent	Good	Good	Good	Regular/Bad
MANEUVERABILITY	Good	Regular	Regular	Good	Good	Good	Regular	Regular
SCHEMATIC								

Source: Angel Molinero and Luis Ignacio Sánchez Arellano. Transporte Público: Planeación, Diseño, Operación y Administración.

Local land prices will likely determine the flexibility available with the depot design. High land prices and a restricted depot area will necessitate some creativity in the layout of the area.

26.4 Design Layout

The internal design of the depot area should allow for a logical movement of vehicles based on their typical requirements. Figure 26.3 shows a typical layout for a depot area. This layout is for countries that drive on the right-hand side of the road, hence allowing for an anticlockwise movement of travel for the vehicles and minimizing vehicle conflicts inside the depot. For countries that drive on the left, the circulation should be in a clockwise direction to obtain the same benefit.

Table 26.2. Legend for Figure 26.3

Legend	Description
1	Gate and visual inspection area
2, 3, 6	Administrative offices for the concessioned operators
4	Refueling area
5	Vehicle washing and cleaning area
7, 10	Major repairs
8, 9	Minor repairs and maintenance
11	BRT vehicle parking
12	Private vehicle parking
Green	Operational vehicles
Yellow	Vehicles requiring minor or routine maintenance
Red	Vehicles requiring major repairs

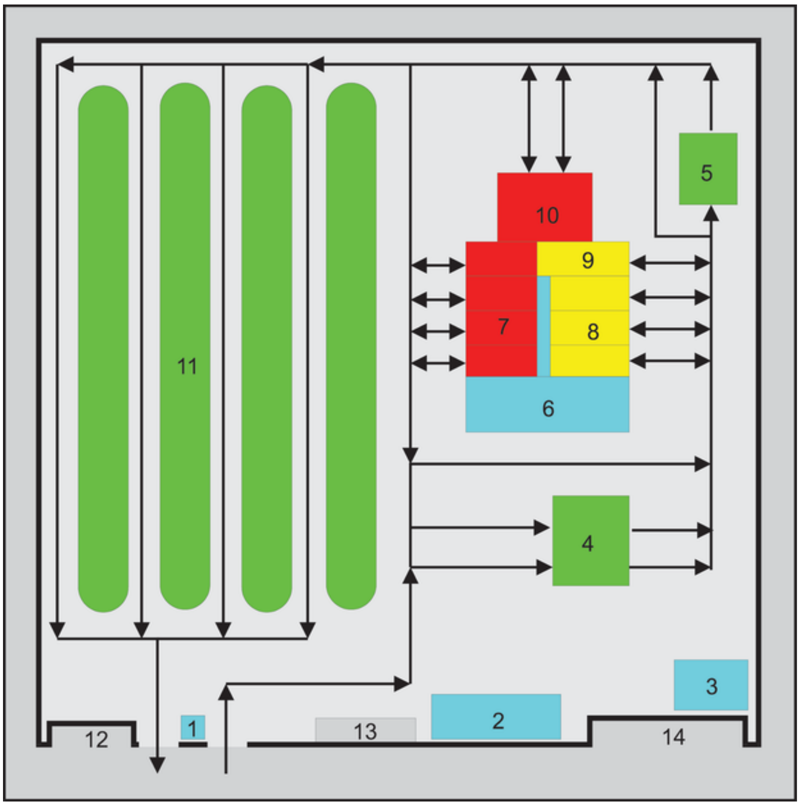

Figure 26.3. Standard layout for a depot area, with legend in Table 26.2. *ITDP.*

The following expressions hold:

- Area occupied by a vehicle, VA:

  - Articulated bus: 45 m^2
  - 12 m long bus: 30 m^2
  - 10 m long bus: 25 m^2
- Access area AP $= (2.5$ to $4.0)$ VA
- Area for visual inspection, fueling, and cleaning VI $= (6.0$ to $8.0)$ VA
- Parking area PAR $= 2 \cdot$ VA $\cdot N$, where N is the number of vehicles
- Maintenance area MA $= 0.2$ PAR

Vehicles will enter the depot area as they are instructed to temporarily come out of service by the control center. As BRT vehicles enter the depot, they are visually inspected at point 1 in Figure 26.3. The vehicle is classified as "green" (operational), "yellow" (in need of minor repairs), or "red" (in need of major repairs).

If the bus is classified as "green," it will typically first move to refueling. Here fuel levels and vehicle kilometers are checked as a way of monitoring usage and operating costs. In Bogotá, a digital monitoring device records the pertinent vehicle information upon entering the refueling area (Figure 26.4). If required, the vehicle will be refueled at this time.

Figure 26.4. Upon entering the refueling area, a digital monitoring device records the pertinent vehicle details (i.e., fuel level, odometer, etc.). *Lloyd Wright.*

Figure 26.5. Upon entering the refueling area, if fuel is required, an attendant will then refuel the vehicle. *Lloyd Wright*

From the refueling area, the vehicle will likely be either washed or placed in a parking bay. The exterior of the vehicle will typically be washed once per day. Most often, the washing occurs after the vehicle's final run of the day. The vehicle's interior may be cleaned upon each entry into the depot area, even if the vehicle is to return for the afternoon-peak period. Maintaining a pristine interior area does much to send a positive message to the customer as well as to psychologically discourage littering. In some systems, such as the Quito Ecovía corridor, the vehicle interior is cleaned after each pass through the corridor. The cleaning, in this case, is actually done at the terminal platform (as opposed to within the depot area).

The washing area should be designed to facilitate easy access to all parts of the vehicle. A channelized pit with drainage permits the washing of the vehicle's underside (Figure 26.6). Special scaffolding equipment permits washing of the vehicle's roof (Figure 26.7). Alternatively, the washing area can be contained within a building, where stairs and catwalks can be provided to gain access to the vehicle roof for cleaning purposes (Figure 26.9). Vehicle washing machines can also be installed, but this needs to weighed against the cost of these machines, the number required to meet the peak demand for washing, and the speed at which hand washing can be achieved.

Figure 26.6. A channel allows the undersides of the vehicles to be washed *Lloyd Wright*

Figure 26.7. Scaffolding permits the tops of the vehicles to be washed *Lloyd Wright.*

Figure 26.8. Bus washing area. Mexico City, CISA depot Metrobús Line 1. *Karina Licea, 2011.*

Figure 26.9. Stairs and a catwalk give access to the vehicle roof for washing purposes. *Andre Frieslaar.*

In some depots in Bogotá, water-recycling facilities have been established in order to permit reuse of the water from washing (Figure 26.10). Such recycling not only improves the environmental aspects of the system but can also reduce operating costs.

Figure 26.10. A wastewater pond helps facilitate water recycling in Bogotá. *Lloyd Wright.*

If the BRT vehicle is classified as "yellow," it is moved to the minor maintenance area (Figure 26.11). From the minor maintenance area a vehicle may return to service the same day or by the next morning. This area may also perform routine checks on the vehicle based on the total kilometers travelled.

If the vehicle is classified as "red," it goes to the major maintenance building, and is replaced by a standby vehicle. The major maintenance building includes a range of facilities, namely vehicle service bays, maintenance offices and facilities, and parts storage. A channeled work space (or pit) below each vehicle permits repair staff to easily access the vehicle chassis for inspection and repair (Figures 26.12 and 26.13). Typically, a certain percentage of vehicles (5 to 10 percent) of the fleet are held in reserve to replace vehicles undergoing maintenance. However, in other systems, a just-in-time (JIT) philosophy prevails where all vehicles are fully utilized.

Figure 26.11. Vehicles are periodically removed from service for routine evaluation and maintenance. *Lloyd Wright.*

Figure 26.12. A pit beneath the work area allows technical staff to inspect (and service) the underside of the vehicle. *Andre Frieslaar.*

Figure 26.13. Channel pit for Mexibus depot. *Karina Licea, 2011.*

Figure 26.14. Repair areas for Metrobús Line 1, Mexico City. *Karina Licea, 2011*

Figure 26.15. Repair areas for Metrobús Line 1, Mexico City. *Karina Licea, 2011*

Figure 26.16. Repair areas for Metrobús Line 1, Mexico City. *Karina Licea, 2011*

Typically, seven vehicle-service bays are required per hundred vehicles based at the depot. Of these seven bays, four bays should be equipped with service pits, two bays without service pits, and one bay should be separate and used as a spray painting bay (Figure 26.18).

- The one service bay with a pit should be equipped with brake testing equipment (Figure 26.19);
- The pit lengths should exceed the length of the longest vehicle by at least a meter on either end of the pit, to ensure access to the pit once the vehicle has been parked over it. The pits should be equipped with hydraulic lifting equipment to facilitate lifting of the chassis to do wheel repairs (Figure 26.20);
- One or both of the service bays without pits, should be equipped with stairways and catwalks, so that the air-conditioning units of the vehicles can be inspected and repaired;
- All lubricants, oils, etc., required for the maintenance of the vehicles can be piped through the building to each of the service pits (Figure 26.17).

Figure 26.17. Service bays with pits at the Gautrain bus depot, Johannesburg, South Africa. *Andre Frieslaar.*

Figure 26.18. Spray painting bay at the Gautrain bus depot, Johannesburg, South Africa. *Andre Frieslaar.*

Figure 26.19. Brake testing equipment at the Gautrain bus depot, Johannesburg, South Africa. *Andre Frieslaar.*

Figure 26.20. Hydraulic chassis lifts in service pits at the Gautrain bus depot, Johannesburg, South Africa. *Andre Frieslaar.*

Spare-parts storage is typically located near the maintenance and repair areas. The extent to which parts storage is required depends in part on the procurement practices of the particular operating company. Some firms may prefer to purchase in bulk, and thus retain a fairly substantial spare-parts inventory. In other cases, a just-in-time (JIT) philosophy may prevail, and the operating company may hold just a minimum number of spare parts (Figure 26.21). The operating company Sí 99 in Bogotá maintains a very lean inventory in order to minimize costs. In fact, the spare parts are part of the contractual arrangements with the BRT vehicle supplier who must provide on-site service. Since this type of close manufacturer-operator relationship was not foreseen at the outset of the depot construction, facilities were not provided for the manufacturer offices. Instead, provisional trailers have been set up to accommodate manufacturer offices and supplies (Figure 26.22).

Figure 26.21. Storerooms for spare parts should be planned into depot design. *Lloyd Wright.*

Figure 26.22. Makeshift trailers provide office and storage space for suppliers to the TransMilenio operators. *Lloyd Wright.*

Figure 26.23. Warehouse tools and supplies. Mexico City, CISA depot Metrobús Line 1. *Karina Licea, 2011.*

Sufficient parking space must be provided to hold the vehicle fleet during off-hour periods. The parking-area design should also maximize easy entry and departure movements of vehicles. The numbering and assignment of the parking bays can provide efficient control over the fleet (Figure 26.24).

Figure 26.24. Efficient organization of the fleet parking improves management control over the depot area. *Lloyd Wright.*

Figure 26.25. Mexibus depot. *Karina Licea, 2011.*

Figure 26.26. Mexibus depot. *Karina Licea, 2011.*

Some private-vehicle parking may also be required at the depot area. Certainly, access for emergency vehicles should be included in the design. In some cases, not all employees may be able to utilize the BRT system to arrive at work. Since the drivers, mechanics, and other employees will likely need to arrive prior to the start-up of the system in the morning, alternative arrangements should be considered. At the Bogotá Américas depot, bicycle parking is provided for the staff (Figure 26.27). Providing good pedestrian and bicycle access to the depot area helps encourage staff to utilize sustainable forms of transport to get to work (Figure 26.28).

Figure 26.27. In Bogotá, TransMilenio staff are provided with bicycle parking at the depot site. *Lloyd Wright.*

Figure 26.28. A bike lane provides direct access to the nearby Américas depot in Bogotá. *Lloyd Wright.*

It is best to locate the offices for operating companies at or near the depot. By being located at the depots, operating company officials can better monitor activities and oversee staff (Figure 26.29). The administrative offices may also include conference and training facilities.

Figure 26.29. Administrative office facilities for operating companies are provided at TransMilenio depots. *Lloyd Wright.*

Finally, the depot area should also provide facilities catering to the needs of staff, such as drivers, mechanics, and administrative workers. These facilities may include showers and lockers, luncheon areas, and recreational areas (Figure 26.30). The workplace environment should be designed to allow drivers and other employees an opportunity to relax after or in-between shifts, as well as prepare prior to the start of a shift.

Figure 26.30. Cafeteria for drivers and other staff at the TransMilenio Américas terminal. *Lloyd Wright.*

26.5 Design Considerations

"Design is not just what it looks like and feels like. Design is how it works."
— Steve Jobs, co-founder, chairman, and CEO of Apple, Inc., 1956–2011

26.5.1 Aesthetics

Although depot areas are not generally accessible to the public, there still may be many reasons to give attention to the aesthetic qualities of the space. First, depots consume large amounts of urban space and thus are typically quite visible to the general population. Thus, the visual aesthetics of the depot will affect the local residents' image of the system. It is always important to be a good neighbor with populations living near the system. Second, a well-designed work environment can have a positive impact on employee satisfaction and work effectiveness. The maintenance depots of systems such as Bogotá, Colombia, and Guayaquil, Ecuador, provide a highly pleasing appearance to both local residents and employees (Figures 26.31 and 26.32)

Figure 26.31. The architecture for the maintenance areas in Bogotá is both aesthetically pleasing and highly functional. *Lloyd Wright.*

Figure 26.32. The architecture for the maintenance areas in Guayaquil is both aesthetically pleasing and highly functional. *Lloyd Wright.*

The design should protect maintenance workers from adverse weather conditions, such as wind, rain, or strong sun. The maintenance-area ceiling height should be sufficient to allow employees to comfortably perform maintenance on the topside of the BRT vehicles.

26.5.2 Pavement Design

The majority of the surface area of depots is paved. These areas are for parking, circulating, refueling, washing, and maintenance. Due to the damage caused by engine oil and fuel on asphalt pavements, consideration should be given to constructing the majority of these surfaces in concrete. Areas where asphalt could be considered are circulation areas, where vehicles are moving and unlikely to park for extended periods of time (Figure 26.33).

Figure 26.33. Use of concrete for bus parking areas and asphalt for bus circulation areas at a BRT vehicle depot the Lanzhou, China. Image *Karl Fjellstrom.*

The external areas, if constructed in concrete, should be jointed panels to allow for expansion and contraction of the large concrete surface. The pavement should be designed according to the flexural strength required to support the vehicle. Asphalt areas should be designed taking into account the vehicle axle loads and the number of axle loads likely to be required in the pavement's design life.

26.6 Intermediate Parking Facilities

Intermediate parking facilities provide parking for BRT vehicles during off-peak periods, so that the vehicles do not have to travel all the way to the depot or the terminal to return to service in the afternoon peak (Figure 26.34). Bogotá's TransMilenio has two intermediate parking locations.

Some systems will have specific turnabouts midway along a corridor, so that operations can be more closely adjusted to customer volume. On a very long corridor, significant operational costs can sometimes be saved if, for example, half of the vehicles do not go all the way to the terminal, but instead turn around at some midpoint, so that more service can be provided on the part of the corridor with the highest demand. Sometimes an important depot and interchange facility is not located at the end of a corridor, but at a midpoint, in which case the terminal may be an important turnabout location.

Figure 26.34. Parking next to Terminal de las Americas in Bogotá. *Google Earth.*

Typical driver facilities provided at these intermediate parking facilities include an administration building, toilets, a room where drivers can wait while off duty, and lockers. A mock station platform could be provided to allow for driver docking training to take place at these venues during the off peak.

26.7 Cost

Depot facilities for an articulated bus can amount to more than US$40,000. The courtyard setting located in Poniente 152, in Mexico City, which serves the Metrobús 3 line, came at a cost of approximately US$2.5 million. Fifty buses are stored within an area of 12,000 m2 with workshops, washing areas, and offices.

It is not always necessary to build bus depots, such as in the case of the Guangzhou, China, BRT where BRT routes are based on previously provided routes and use existing depot facilities, providing a more sustainable and economically attractive option.

27. Control Center

> *"Everyone in a complex system has a slightly different interpretation. The more interpretations we gather, the easier it becomes to gain a sense of the whole."*
>
> — Margaret J. Wheatley, writer and management consultant, 1944–

A centralized management and control of the BRT system affords many advantages to optimize system efficiencies and minimize costs:

- Immediate response to changes in customer demand;
- Immediate response to equipment failures, safety, and security problems;
- Efficient spacing between BRT vehicles and avoidance of vehicle "bunching";
- Automated system performance evaluation;
- Automated linkages between operations and revenue distribution;
- Efficient response to customer queries.

In the case of many conventional bus service operators, vehicle fleets are often depleted, old, and not adequately adapted to existing infrastructure and operational needs, like accommodating the disabled.

Figure 27.1. Control Center in Lanzhou, China. *Karl Fjellstrom, Far East BRT.*

Contributors: Johann Andersen, *Techso*

27.1 Development of the Traffic Management Center Concept

> *"Life in LA is not lying in the sun for months. It is having a 4pm meeting and leaving at noon to sit in traffic for four hours."*
>
> — Billy Boyd, actor, 1968–

Initially, localized or decentralized control was implemented, but later gave way to centralized management and control of regional traffic. To facilitate this, the concept of the Traffic Management Center (TMC) was born, with the aim to reduce road congestion, to improve road safety and incident response, and to provide traffic updates to motorists and public transport services about road-related events. The regional TMC serves as the information hub for the public, the police, the traffic services, and the roadside emergency personnel, and it integrates the responses of various services to minimize response time and reduce costs. Today, TMCs worldwide leverage Intelligent Transport Systems (ITS) technologies that significantly improve the efficiency and effectiveness of traffic management and road safety.

To ensure a successful BRT system, it is important to establish a BRT Management Center (BRTMC) that can either be developed as an integrated part of a regional Traffic Management Center or stand on its own.

Figure 27.2. Chengzhou, China's BRT Control Center. *Karl Fjellstrom, Far East BRT.*

Figure 27.3. Inside Zhengzhou, China's Control Center. *ITDP*

27.2 The BRTMC

"We live in a society exquisitely dependent on science and technology, in which hardly anyone knows anything about science and technology."
— Carl Sagan, scientist and writer, 1934–1996

27.2.1 Purpose

A BRT system typically uses global positioning systems, communication systems, CCTV (closed circuit television) surveillance systems, and other technologies that enable customers to obtain information about when a vehicle will arrive to know where a vehicle is along its route. The BRTMC is the point from where the total system is managed and controlled.

The aim of the BRTMC is to ensure optimal BRT operations, to facilitate improved safety and incident response, and to provide real-time information to commuters about BRT-related events. As in the case of the regional TMC, the BRTMC can also serve as the information hub for the public, police, traffic services, and roadside emergency personnel, while integrating the actions of various services to minimize response time.

Figure 27.4. BRTMC's closed circuit television surveillance system in Zhengzhou, China. *ITDP.*

27.2.2 Functions

The BRTMC is expected to contain both real-time control and monitoring operations (in an operations room), as well as non-real-time operations like planning, scheduling, and administrative functions (which should be located in the BRTMC).

The typical functional elements of a BRTMC are as shown in Figure 27.5 and are discussed in more detail thereafter.

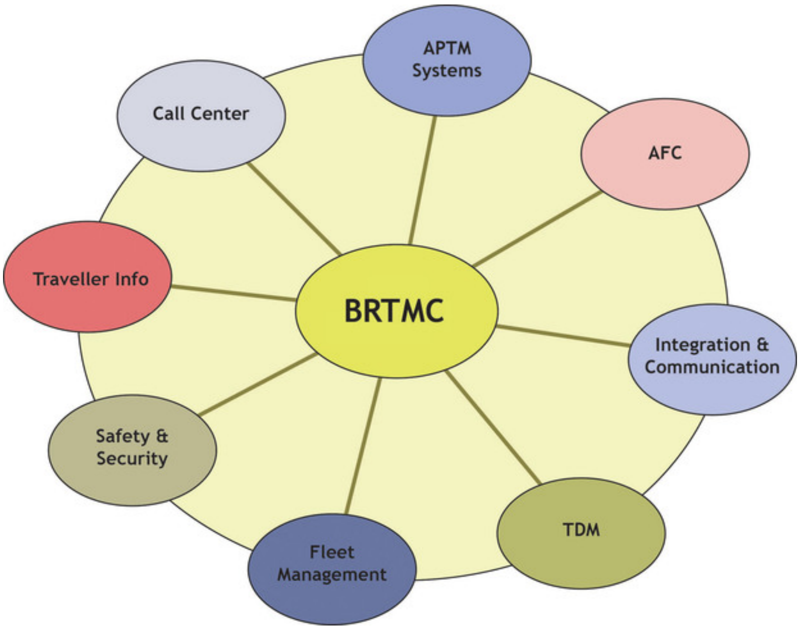

Figure 27.5. Typical functional elements of a BRTMC. Diagram *ITDP.*

27.2.2.1 Automated Fare Collection (AFC)

The AFC function in the BRTMC has two prime focus areas, namely:

1. Ensuring accurate fare collection;
2. Minimizing any occurrences of fare evasion.

The identification of system/equipment failures and monitoring for potential fare evasions are real-time operations. The identification of failures is, however, automated to some extent, while CCTV surveillance operators, drivers, and on-site staff are also expected to report equipment/system malfunctions and fare evasions.

Other personnel that are involved with the AFC system are the conductors who check for fare evasion in stations and on vehicles. While these persons may not need permanent accommodation, it might be advantageous to accommodate them in the BRTMC, the depot(s), or alternatively in a customer care facility and possibly in a shared area.

The apportionment of fees and the analysis of travel data might have to be performed according to the type of vehicle-operating contract. This task should be performed by a person in the BRTMC.

Other AFC-related functions are:

- Auditing;
- Reconciliation of fares;
- Stock management (fare media and consumables);
- Cash management (for kiosks, automated vending machines, and onboard cash boxes if applicable).

27.2.2.2 Advanced Public Transport Management (APTM)

The following functions should be performed in either the BRTMC or the depot(s):

- Driver and Vehicle Scheduling (also known as “runcutting”). These persons can be accommodated at either the BRTMC or the depot(s);
- Fleet Management and Maintenance Controller. It is recommended to localize this to the vehicle operator’s depot(s);
- Schedule Adherence. This function consists of monitoring the progress of the vehicles on the routes and taking corrective action when a vehicle deviates from the schedule. This function should be accommodated in the BRTMC;
- Performance Management. This function typically falls within the administrative environment of the BRTMC and is implemented for the vehicle operating contract(s). It entails the monitoring of the processes of the operating contract(s), particularly for such processes that are reflected in Key Performance Indicators, to ensure that the required service levels are met and if not, to take the steps necessary to ensure that the service levels are adhered to. A Performance Manager, accommodated within the BRTMC, should be appointed for this task;
- APTM Systems Maintenance Manager. This function is responsible for ensuring that the required APTM systems’ availability is maintained. It would be advisable to appoint an APTMS Maintenance Manager to identify malfunctions as soon as possible and, in the case of a malfunction, be held responsible for logging the fault and ensuring that the problem is resolved within the required time frame. Vehicle operating contracts may use the same systems. This function should be housed within the BRTMC.

The above APTM tasks do not necessarily require one person per task, but they can be combined depending on the size of the BRT system.

Figure 27.6. BRTMC staff members in Rio de Janeiro, Brazil. *ITDP.*

27.2.2.3 Traveler Information

This function is responsible for the following information systems that are controlled from a BRTMC:

- Pre-trip information systems, for example, providing schedule and route information;
- Personal information systems, for example, providing information via an SMS service, public Call Center, and website;
- In-vehicle information systems, for example, audio announcements via the Automatic Voice Annunciators (AVAs);
- In-station information systems, for example, BRT schedules, route information, and Variable Message Signs (VMSs).

27.2.2.4 Transport Demand Management (TDM)

TDM entails BRT service coordination and transport planning, and it is recommended that is also be housed in the BRTMC. This function typically also acts as an interface to the regional TMC, where applicable, on issues such as traffic signal optimization and traffic control.

27.2.2.5 Transport Safety and Security

Safety and security are crucial to the success of any BRT system. As such this function should focus on:

- Surveillance to ensure station, on board, and route safety and security;
- Vehicle safety systems;
- Incident/disaster management;
- Information and Communication Technology (ICT) systems' security;
- Law enforcement.

It is recommended that this function be accommodated in the BRTMC.

27.2.2.6 Fleet Management

The fleet management function is responsible for:

- Maintenance of management systems;
- Transportation operations systems;
- Utilization management systems;
- Fleet telemetry systems;
- Vehicle guidance.

It is suggested that this function could be housed in either the BRTMC or the vehicle operator's depot(s), or both.

27.2.2.7 Integration and Communication

Due to the diverse complex systems and different entities required to enable an effective and efficient BRT system, integration and communication play a cardinal role in its success. This function facilitates:

- Station integration and communications;
- Vehicle integration and communications;
- Roadside integration and communications;
- Back-office integration and communications;
- Regional TMC integration and communication where applicable.

It is recommended to accommodate this function in the BRTMC.

27.2.2.8 Call Center

There are two main components in the call center function, namely:

1. An internal component for BRT staff to obtain information or assistance and log issues. It is recommended to accommodate this component in the BRTMC;
2. An externally focused component facilitating public interaction and interaction with the regional Transport Management Center. This function could be accommodated in the BRTMC or elsewhere as discussed below.

A regional TMC typically already hosts a Transport Information Center (TIC), which might operate a twenty-four-hour call center that provides public transport information to commuters. The TIC normally disseminates information to motorists and commuters by means of radio reports, variable message signs, semi-dynamic message signs, websites, and SMSs. As such, the regional TIC could be used for the BRT Call Center's public interaction function if the required integration and communication infrastructure is in place or if the BRTMC is collocated in the regional TMC.

27.3 BRT Stakeholders

"Individually, we are one drop. Together, we are an ocean."

— Ryūnosuke Akutagawa, writer, 1892–1927

The stakeholders that typically require accommodation in the BRTMC are presented in Table 27.1.

Table 27.1. BRT Stakeholders, with a High-Level Indication of Roles and Responsibilities

Stakeholder	Roles and Responsibilities
Information Systems and Technology (IS&T) Contract; ;	• Operate and maintain the BRT system's IS&T infrastructure.;
Operations Control	• Monitor and control BRT operations, including vehicle tracking and scheduling, driver monitoring, and the vehicle subsystem; • Respond to customer demands.;
Automatic Fare Collection	• Monitor and take corrective action to address AFC system failure and fare evasion; • Apportion fees and analyze travel data.;
Safety and Security	• Perform surveillance of BRT routes, vehicles, stations, and customers; • Take corrective measures to negate safety and security risks and fare evasion; • Interact with regional emergency management services (EMS), ambulances, and firefighting services; • Liaise with law enforcement agencies, e.g., police and traffic police.;
Call Center	• Interface with internal BRT staff; • Interface with the public, the regional TMC (where applicable), and other government departments.;
Facility Management	• Take responsibility for the facility infrastructure, premises, security, and housekeeping.;

Other BRT stakeholders that might not require accommodation in the BRTMC itself are listed in the table below.

Table 27.2. Stakeholders Not Necessarily Accommodated within the BRTMC.

Stakeholder	Roles and Responsibilities
Financial Services	Manage assets, budget, treasury, and accounts.;
Vehicle Contract	Manage and operate vehicles.
Station Services Contract	Keep the station in good condition.
Emergency Management Services	Manage incidents and disasters.
Public Transport Regulator	Regulate with respect to public transport and the BRT system.
Road Maintenance and Civil Works	Maintain public roads and station works.
Law Enforcement Agencies	Police and control traffic.

27.4 Location of BRTMC

"I'm easy. Put me in an interesting location with good people and I'm there."

— Jane Curtin, actress and comedian, 1947–

The BRTMC functions remotely from the corridor through its information and communications systems. However, locating it near one of the trunk corridors could be desirable since such a location allows a cost-effective, direct linkage to the system through a fiber optic line at the time of construction. It is recommended that the BRTMC should be situated in a place that has highly reliable communications connections and electrical power connections. Furthermore, since the center may also be receiving information by way of satellite or infrared communications, the center should not be located where signals could be potentially blocked. Additionally, the premises should be located close to public transport amenities to ensure that the staff can easily access their workplace.

There could be some benefits to locating BRTMC staff in management facilities or in terminal facilities. These locations would allow greater interactions between the BRTMC staff and management staff or vehicle operators. This sort of interaction could lead to certain synergies in gaining further insights on system operations.

If possible, it could be advantageous to have the BRTMC collocated in the regional TMC. Such an arrangement might facilitate a better understanding of each other's areas of responsibility, improve relationships, and reduce response time. This would in turn lead to further effectiveness and efficiency enhancements for the BRT system. Such an approach will also bring cost savings through the sharing of an existing building and certain infrastructure, such as the sharing of the premise's UPS, generators, security staff, a well-managed Building Management System (BMS), etc. Also, the premises might already have dual redundant municipal electrical power feeds as well as redundant telecommunication infrastructure—for example, redundant fiber optic links and/or Microwave and Mobile Operator links.

Figure 27.7. BRT Control Center in Lanzhou, China. *ITDP.*

27.5 Staffing of the BRTMC

"Nothing will work unless you do."

— Maya Angelou, author and poet, 1928–2014

A possible organizational structure for a small-to-medium-sized BRTMC that should be able to cater to a BRT system with up to approximately 300 vehicles could be as illustrated in Table 27.3. The example assumes a BRT system that is operational to the public from 06:00 to 21:00 daily (i.e. sixteen hours per day) and a BRTMC that covers the full operating hours of the BRT system.

To comply with local labor laws, specifically where shift work is concerned (e.g., maximum hours an employee may work per month, etc.), it might be required to have staff for three shifts—that is, one team will be off while two other teams each work an eight-hour shift to cover a sixteen-hour workday. It is further important to note that for critical shift functions where a full-time human presence is required, at least two staff would be required per shift to perform these functions, as time should be allowed for a shift worker to take comfort breaks and to eat.

Table 27.3. BRTMC Organizational Structure

Group	Staff

IS&T Contract [Headcount = 9]	This group is responsible for operating and maintaining the BRT system's IS&T infrastructure-related equipment and communications infrastructure. It is suggested that this function could be outsourced to an ICT company. However, it is envisaged that the contractor would be required to have approximated the following staff based at the BRTMC: 1 x Site-coordinator/supervisor; 8 x Technicians. This group should not be required to perform shift work. However, they should be on standby after hours.
Operations Control [Headcount = 16]	Operations Control Management: 1 x Manager—manage the operations control group, plus manage the vehicle operator and the BRT IS&T contractor to key performance indicators to ensure compliance with required service-level agreements (SLAs). Driver and Vehicle Scheduling: 1 per vehicle operator contract during BRT operating hours (typically 2 x 8-hour shifts per day). Monitoring and Schedule Adherence: 1 x Supervisor (typically 2 x 8-hour shifts per day); 4 x Operators (typically 2 x 8-hour shifts per day).
Automatic Fare Collection [Headcount = 18]	AFC Management: 1 x Manager—manage the AFC group to ensure AFC system availability and accurate fare collection, as well as stock and cash management. AFC System Monitoring and Resolving AFC Problems: 1 x Supervisor (typically 2 x 8-hour shifts per day); 2 x Operators (typically 2 x 8-hour shifts per day). Auditing and Fare Reconciliation: 1 x Supervisor; 1 x Finance Officer. Cash and Stock Management: To manage the cash for kiosks, automated vending machines, and on board cash boxes if applicable, plus to manage fare media and consumables, the following staff would be required: 1 x Supervisor; 1 x Finance officer.
Safety and Security [Headcount = 10]	1 x Manager; 1 x Supervisor (typically 2 x 8-hour shifts per day); 3 x Surveillance operators (typically 2 x 8-hour shifts per day); 1 x Policeman as police liaison officer (typically 2 x 8-hour shifts per day); 1 x Traffic cop as traffic services liaison officer (typically 2 x 8-hour shifts per day).
Call Center [Headcount = 37]	Call Center Management: 1 x Manager—manage the overall activities and staff of the call center. BRT Internally Focus Call Center: This center should serve BRT staff members who call in to obtain information or assistance and also log issues reported. It would typically require the following staff: 1 x Supervisor (typically 2 x 8-hour shifts per day); 2 x Call center agents (typically 2 x 8-hour shifts per day). BRT Externally Focused Call Center: This center should serve as the interface with the public, the regional TMC, if applicable, and other government departments. It is proposed that the center's public interaction function should be handled by the transport information center (TIC) normally housed within a regional TMC. If this is not possible, the following is suggested as an initial requirement: 1 x Supervisor (typically 2 x 8-hour shifts per day); 4 x Call center agents (typically 2 x 8-hour shifts per day); 1 x Web administrator (typically 2 x 8-hour shifts per day).
Facility Management [Headcount = 4 staff, plus 20 staff from companies performing work that is outsourced. Thus: Total Headcount = 24]	To manage the overall facility, including the building management system (BMS) and outsourced security, housekeeping, and catering services, the following staff is recommended: 1 x Facility Manager; 1 x Electrician; 1 x Administrative Officer. The following should be added for the mentioned outsourced services whose personnel will also be on site: 8 x Security guards (2 at the main entrance, 2 at reception, and 4 for perimeter and premises protection, as well as designated staff entrances); 8 x Cleaners to perform housekeeping duties; 4 x Personnel from a catering service provider.

The suggested total BRTMC staff headcount for operating this small-to-medium-size BRT system thus works out to ninety-two, plus twenty for outsourced security, housekeeping, and catering services. It does not, however, imply that office and seating capacity for one hundred and twelve staff would be needed, as seventy-two of the ninety-two aforementioned members are shift workers of whom only a third will be on duty at any given time. Therefore, it is recommended that sufficient capacity be allowed to accommodate at least forty-four BRTMC personnel plus the twenty outsourced service providers at any given time (i.e. a total of sixty-four personnel). It would, however, be advisable to bear any planned future BRT growth in mind and to provide for it from the outset. To prevent a disruptive move to larger facilities at a later stage, it is recommended that implementation agencies should work through a requirements list, use a checklist, and adapt the implementation according to the specific needs.

Functions that are not listed above are Fleet Management and Maintenance Controlling. However, it is reasoned that it would be better to accommodate these roles at the vehicle operator's depot and that one person should be sufficient to perform both of these functions.

Further, the contracting model chosen for the BRT system has a direct impact on the personnel requirement. In the above suggested organizational structure, only one vehicle operating contract and one outsourced BRT IS&T contract were assumed.

Table 27.4 provides an indication of other personnel involved with the BRT system that do not need to be accommodated in the BRTMC itself.

Table 27.4. Other Personnel Involved with the BRTMC.

Group	Roles and Accommodation
Financial Services	Manage assets, budget, treasury, and accounts. Accommodation: These staff may be accommodated in a regional head office environment and do not necessarily need accommodation in the BRTMC.
Vehicle Contract	Manage and operate vehicles. Accommodation: Accommodated in the vehicle depot(s).

Station Service Contract	Keep the station in good condition. Accommodation: Own premises.
Emergency Management Services	Manage incidents and disasters. Accommodation: Own premises.
Public Transport Regulator	Regulate with respect to public transport and the BRT system. Accommodation: Own premises.
Local Roads and Transport and Civil Works Departments	Maintain public roads and station works. Accommodation: Own premises.
Law Enforcement Agencies	Police and control traffic. Accommodation: Own premises.

27.6 Floor Space Requirements

"Are you really sure that a floor can't also be a ceiling?"

— M.C. Escher, graphic artist, 1898–1972

The BRTMC area itself requires specific spatial features. Sufficient space should be allowed for the following areas: control room; open-plan environments; offices; meeting rooms; rest and recreation areas and a cafeteria; ablution facilities, storage space; server and telecommunications room, staging area, vault space, UPS and generator rooms, and walkway space.

27.6.1 Control Room

This area should accommodate the following groups:

- Operations control operators and supervisor;
- Surveillance operators and supervisor;
- Call center agents and supervisor.

The size of the area depends on the number of workstations required. As a BRT system is likely to be developed in phases, the control room will most likely be only partially utilized during the initial years. However, it is imperative to plan for future requirements where applicable.

Each BRTMC operator will require space for a computer terminal, voice communications equipment, and additional work space. The number of operator workstations required for the total system is a factor of the size of the system and the number of vehicles each operator can safely control. The nature of the controller software package will also play an important role in determining the number of vehicles a BRTMC staff member can effectively oversee. However, under normal conditions each operator should be able to manage an average of eighty to one hundred vehicles. Additionally, since the Operators should be able to clearly communicate with the drivers, the acoustic arrangement of the workstations should be considered. If noise from one workstation interferes with the communications in another workstation, there could be a potential for lost or misinterpreted communications, which might be problematic.

By using a video wall displaying critical junctures in the system and the positions of the various vehicles, these staff members would be provided with a visual understanding and assessment of the system's operations. A video wall would also help in circumstances where multiple staff members need to resolve a complex issue together.

Figure 27.8. A large-screen display and vehicle tracking board can help staff and supervisors quickly assess the situation. *Los Angeles County Metropolitan Transportation Authority.*

Figure 27.9. Multiple small-screen displays of each critical juncture in the system give the control team a visual understanding of the system's operation. *Queensland Transport.*

27.6.2 Open-Plan Environments

Open-plan work spaces, separate from one another, are recommended for the following areas:

1. AFC Operators and Supervisor;
2. Safety and Security Officers and Supervisor, plus Law Enforcement Representatives;
3. BRT IS&T Contactor;
4. Facility Management.

27.6.3 Offices

A separate office for each manager is recommended.

27.6.4 Meeting Rooms

There should be at least two meeting rooms that can accommodate approximately ten people and one that can accommodate twenty people. Furthermore, to assist with public relations as well as interactions with the Media, it is recommended to have a visitor viewing area—that is, an auditorium, overlooking the control room environment with a clear view of the video wall. Additionally, it is suggested to allow space for a Joint Operations Center (JOC) where in the event of an emergency situation key personnel from the BRT team can meet with key staff from various other disciplines, like traffic, police, and emergency service, to plan and direct emergency operations and recovery. Additionally, this can be a space where any required media interaction can be conducted to assist in keeping the public informed about the state of affairs with respect to the emergency situation.

27.6.5 Rest and Recreation Areas and a Cafeteria

Control room operators can become fatigued by long hours of looking at monitors and tracking vehicles. Holding focused concentration for long periods of time can be mentally exhausting. Typically, operators should have frequently scheduled breaks in order to maintain their alertness. It is therefore recommended that there should be a relaxation area or break area that allows operators to refresh themselves. Furthermore, it is recommended that space be allowed for a cafeteria environment.

27.6.6 Ablution Facilities

It is recommended to not only provide toilets but also shower facilities.

27.6.7 Storage Space

It is recommended to provide a secure room for the storing of equipment and materials.

27.6.8 Server and Telecommunications Room

It is suggested that two environments should be provided for, separate from one another, to accommodate the following:

1. IT data processing equipment, e.g., servers, Storage Area Network (SAN) equipment, data backup devices, etc.;
2. Local Area Network (LAN) and PABX equipment.

It is further recommended that these two server rooms should comply with international standards such as the TIA 942 Data Center Standard.

27.6.9 Staging Area

An environment should be provided where computer and telecommunications equipment can be configured and set up before they are placed into production.

27.6.10 Vault Space

It is recommended to make allowance for vault space where high-value items and computer/data backup media can be stored.

27.6.11 UPS and Generator Rooms

Separate areas for housing the Uninterruptable Power Supply (UPS) and generator equipment, respectively, are recommended.

27.6.12 Other Utility Rooms

It is proposed that separate areas for the following might also be required:

1. Municipal power connection to the building's high-voltage plant;
2. Telecommunication service provider's equipment—Wide Area Network (WAN) connection point;
3. Fire suppression room to house gas bottles (e.g., FM 200 gas cylinders) and related equipment;
4. Air-conditioning plant.

27.6.13 Walkway Space

Walkway space should constitute approximately 25 percent of utilized space.

27.7 Layout and Site Planning

"A goal without a plan is just a wish."

— Antoine de Saint-Exupéry, writer and pilot, 1900–1944

The premises should have easy and unrestricted access twenty-four hours a day. Selection of the site is of critical importance and should take the following into consideration.

27.7.1 Site Selection

The following items should be considered when choosing a site for the BRTMC.

- The role of the precinct where the BRTMC will be located;
- Terrain:
  - When flat, avoid excavation to prevent potential problems with a high water table and/or unstable bedrock;
  - If located on a slope, maximize the terrain's potential when designing the building.
- It should to be close to freeways and transport facilities, for example, a BRT station.

27.7.2 Parking

Parking requirements should be determined based on location relative to a BRT station and on parking spaces already available in the surrounding area. Secure bike parking should be provided.

27.7.3 Boundary Walls and Fencing

Depending on the site configuration, it is recommended that there should be three sides with 2.1-meter high brick walls with security measures/obstacles on top—for example, electrical fencing—with the street facade and parking preferably not fenced off with a brick wall to increase visibility for the public as well as ideally "undercover" controlled access with a guard building. The street boundary should be made from standard transparent fencing.

27.7.4 Ergonomics

Ergonomics plays a very important role in the layout and design of the BRTMC. The job of the operator can at times be highly demanding. The consequences resulting from inappropriate operator actions, such as acts of omission, incorrect timing, or following incorrect sequences, could potentially have a grave impact on the BRT system. Therefore, international standards, like the ISO 11064-1 Standard for the Ergonomic Design of Control Centers, should be considered to assist in eliminating or minimizing the potential for human errors.

Figure 27.10. BRT Control Center in Bogotá, Colombia. Workstations should provide a comfortable environment within easy reach of all telecommunications equipment Image *ITDP.*

27.8 Building Requirements

> *"If I have to move up in a building, I choose the elevator over the escalator. Because one time I was riding the escalator and I tripped. I fell down the stairs for an hour and a half."*
>
> — Demetri Martin, comedian and actor, 1973–

Due consideration should be given to the aspects listed in Table 27.5 below.

Table 27.5. Recommended Building Considerations

Item	Comment
Design Approach	• Internationally accepted guidelines for energy efficiency should be taken into consideration; • The building should comply as much as possible with internationally accepted green building guidelines and standards; • Way-finding and signage outside and inside the BRTMC should be integrated in style, appearance, and communication with the rest of the BRT system as part of the branding; • The building should comply with all universal access requirements for an office building; • The building should comply with all local authority bylaws, regulations, and policies and procedures.
Materials	• Material selection, both external and internal, should be performed with an emphasis on low maintenance along with a balance between cost and longevity. Material selection should be subject to the life-cycle costing model, which should in turn form part of the Quantity Surveyor's deliverables and reporting.
Landscaping	• Landscaping should be performed on a low maintenance and low water consumption basis with a good balance between hard landscaping and plant-scapes.

Services

- All ceiling voids should be designed in horizontal zones to make sufficient provision for all the various services, i.e., electrical, sprinkler, HVAC, air-conditioning, drainage pipes, sewer lines, light fittings, data cabling, BMS, etc.;
- Ceiling voids need not be plastered but should be finished neatly, and, where applicable, concrete soffits should be painted and the void area be made as dust free as possible;
- Ceiling voids should have proper access to all equipment that needs maintenance. Give special attention to detailing of service hatches where plastered bulkheads or flush-plastered ceilings are proposed for installation;
- Vertical reticulation shafts should provide enough room for maintenance and installation staff to get in and work in the shafts. Preferably installing a full height door to the shaft area;
- The shafts should have proper lighting and should be plastered and painted inside to control dust and should be ventilated sufficiently;
- Service ducts should be provided between male and female toilets. The service ducts should be a minimum of 900 millimeters wide with screed and waterproofed floors with at least 110 millimeters Ø floor drains to accommodate for flooding emergencies;
- Service ducts should be plastered and painted with proper lighting for maintenance purposes and proper ventilation;
- All geysers should be installed inside the service duct areas with drip trays and proper access to elements and valves;
- Each toilet bench, male and female separate, should have its own shut-off valve for maintenance purposes. This valve should be close to the duct entrance;
- Equipment rooms should have proper vertical and horizontal cable rack layouts and should have a dust-free finish on the floors for proper cleaning. In the case of trenching, e.g., in a plant room or substation/HT/LT room, checker plate finish should be installed flush with the floors;
- The server rooms, UPS rooms, and the control room floor should have access flooring of approximately 350 millimeters in depth, and the under floor finish should be a dust-free area. It is suggested to finish this with a power float/steel trowel finish and a high-quality epoxy paint;
- Antistatic floor finish should be provided for access flooring in the server and UPS rooms, but for the control room floor it should be finished with carpet tile.

Signage

- As part of way-finding, care should be taken regarding statutory signage to service-related rooms and room identification of boardrooms, management offices, staff rooms, etc.

Vertical Transportation

- The elevator should comply with the universal access requirements. The elevator should be a full stretcher lift, which will also service emergency situations.

General Access, Access Control, and Internal Surveillance Systems

- Access should be site specific but preferably such as to avoid congestion at morning and afternoon peak hours;
- The service entrance, specifically for diesel generator refueling, should be separate from the main entrance;
- The Access Control system should preferably use biometric fingerprint readers;
- A CCTV system should be used to monitor all access and perimeter walls and fencing;
- Surveillance security cameras inside the building are also recommended.

Control Room

- The control room should require a double volume or at least a one and one-half volume floor to ceiling space to accommodate the height of the video wall (if installed) and services in the ceiling void area as well as the access flooring. The access flooring should provide for sufficient flexibility to allow the operational managers to move staff and furniture on the floor in the shortest possible time with the least possible disruption. It is recommended to use access floor panels with flush-mounted power sockets that connect with fly-leads below the floor to the main backbone of the electrical and data cable feeds;
- Space should be allowed in the front of the control room to enable comfortable sight lines from the floor personnel, i.e., they should not have to bend their heads backward to see the top of the screen. They should be able to do so with eye movement.

Electrical

- Due consideration should be paid to the load requirements, emergency generator sizing and provisioning, and lux levels—or the amount of light illuminating the surfaces—inside the standard offices, control center, lobbies, etc.;
- Lamp specifications should comply with the green building requirements and carbon footprint context as well as low energy consumption.

Air-conditioning

- Acceptable indoor temperatures should be provided for in server rooms, UPS rooms, control room, meeting rooms, and offices.

Electronics

- Consideration should be paid to the data requirements, e.g., wireless, security, audio visual, communications, etc.

27.9 Costing

"Money often costs too much."

— Ralph Waldo Emerson, essayist and poet, 1803–1882

Cost of the BRTMC would be directly related to the facility's size, the quality of finishes, the level of security and control, the number of services housed in the building, and the size of the BRT system. Cost items for establishing the BRTMC include:

- Initial design, implementation, and project management;
- Land;
- Building;
- Boundary walls and fencing;
- Parking requirements;

- ITS/ATPMS equipment and applications;
- Data processing equipment (e.g., servers, SAN equipment, backup devices, etc.);
- Telecommunications equipment (e.g., LAN infrastructure, PABX);
- Workstations and video wall(s);
- UPS and generator;
- Access control and internal surveillance systems;
- Air-conditioning plant;
- Training costs;
- Staff remuneration;
- Additional costs: furniture and fittings, signage, outsourced service providers, plus other operational costs like electricity, water, etc.

Figure 27.11. Guadalajara, Mexico BRT control center with surveillance system. *ITDP.*

27.10 Operational Requirements

> *"The world is not to be put in order. The world is order. It is for us to put ourselves in unison with this order."*
>
> — Henry Miller, writer, 1891–1980

For a BRT system that operates for a longer period than normal office hours, it might be required to implement a shift system. In this case there would, however, still be some groups in the BRTMC that would not be required to work outside normal office hours.

27.10.1 Shift Systems

As discussed earlier, to comply with local labor laws—that is, maximum hours an employee may work per month, etc.—it might be required in the case of a BRT system that operates from say 06:00 to 21:00 (i.e., for sixteen hours per day) to have staff for three shifts. One team will be off while two teams each work a shift. Also, for critical shift functions where a full-time human presence is required, at least two staff would be required per shift to perform these functions, because time should be allowed for a shift worker to take breaks and to eat.

It is recommended that the following staff should perform shift work (two shifts per day should be adequate for a BRT system that operates for sixteen hours per day as mentioned above, i.e., 05:30 to 13:30 and 13:30 to 21:30):

1. Operations Control: Driver and Vehicle Scheduling Officer; Monitoring and Schedule Adherence Operators and Supervisor;

2. Automatic Fare Collection: AFC Monitoring, Scheduling, and Schedule Adherence Operators and Supervisor;
3. Safety and Security: Surveillance Operators and Supervisor, plus Police and Traffic Police Liaison Officers;
4. Call Center: Call Center Agents, Supervisors, and Web Administrator.

It is recommended that the managers of these groups work standard office hours.

Additionally, it is proposed that the outsourced security service should provide the required on-site security personnel on a 24 x 7 x 365 basis.

27.10.2 Operational Procedures

For the BRTMC to function optimally, it is imperative to not only provide the staff with the necessary equipment, but also clear instruction on what to do, when, where, and why. Clear operational procedures that empower the staff to perform their jobs are therefore vital to the success of the BRTMC.

The BRTMC workflow specification should detail the collective flow of actions over four main functions.

The four main functions of the BRTMC are:

- Collect data/info;
- Configure the data/info;
- Share data/info with all the relevant stakeholders;
- Monitor performance, safety, and security.

Operational procedures are required to explain how events would trigger specific actions by certain stakeholders to enable the flow of data and information through the system. It would also specify how reports are to be generated. Operational procedures and protocol would provide instructions on how the operator would act when receiving calls, where to find information, and what to do with it. From a management perspective, workflow would detail how informational meaning may be derived from certain views of data and what options could be followed to ensure it flows through the communication system to its proper destination(s).

The general Standard Operating Procedures (SOPs) that should be developed include:

- Incident detection;
- Incident response management;
- Incident confirmation;
- Maintenance request generation;
- Performance management monitoring;
- Station monitoring;
- Vehicle monitoring;
- Safety and security monitoring;
- AFC monitoring;
- Power failure;
- Smoke/fire in TMC actions;
- Security in TMC;
- Request for video footage;
- BRTMC evacuation plan;
- BRTMC disaster recovery and business continuity.

27.10.3 Operational Scenarios

Three operational scenarios of how the BRT system should work once operational are sketched below to provide a better understanding of the role that the BRTMC plays in the operations of the BRT system.

27.10.3.1 Customer Scenario

Sipho needs to use the BRT system, because he has a meeting in town A's central business district (CBD) at 09:00. Sipho logs on to the Internet and views the BRT website, which is administered by the BRTMC's call center, to determine if the vehicle schedule is on time. The website indicates that all vehicles are running on time.

Sipho uses a feeder bus to trunk station Alpha. Arriving at the trunk station, Sipho realizes that his BRT smart card does not have enough money in order for him to make a trip. At the ticket kiosk, Sipho reloads his smart card with enough credit to travel the rest of the week. At the gate, Sipho touches his card and gains access to the station.

Figure 27.12. A customer uses the fare system at a BRT station in Bangkok, Thailand. *ITDP.*

Sipho looks at the time and sees that the Verbal Message Sign (VMS), which is also administered from the BRTMC, indicates that the next express vehicle traveling to town A's CBD will arrive in five minutes. Sipho decides to buy a newspaper at the newsstand while waiting for the vehicle.

Figure 27.13. A message board shows departure times of vehicles in Chengdu, China. *ITDP.*

The Automatic Voice Annunciator (AVA), again administered from the BRTMC, announces that the vehicle has arrived. Sipho boards and finds a comfortable seat. The VMS on the vehicle and the AVA announcing each station provide Sipho with the comfort to read his newspaper. The vehicle priority allows the vehicle to clear slow-moving traffic at the intersection. The VMS display and the AVA annunciator warn Sipho that his station is up next. Sipho gathers all his belongings and disembarks the vehicle at the station.

Figure 27.14. Customers leave a BRT station in Bogotá, Colombia. *Karl Fjellstrom, Far East BRT.*

Sipho exits the station again through the gate and walks the two blocks to where his meeting is scheduled. Sipho arrives at his meeting on time, relaxed, and without the morning stress of traffic. Figure 27.15 illustrates the movement of the customer scenario as sketched above.

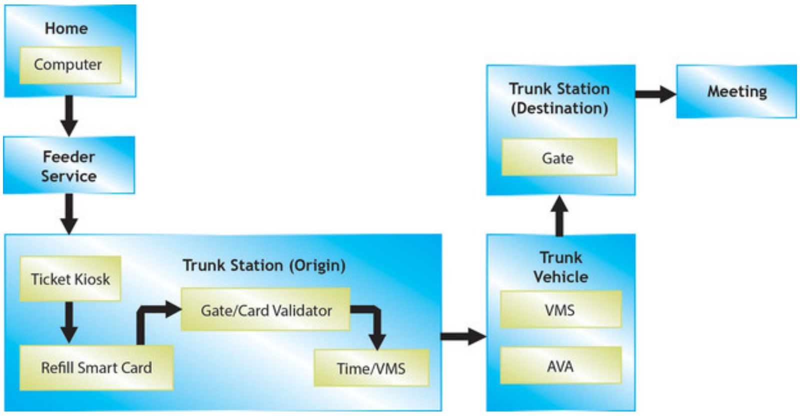

Figure 27.15. Customer scenario. *TECHSO.*

27.10.3.2 Maintenance Scenario

Vuzi is the station officer at one of the trunk stations. One of Vuzi's duties is to check all equipment at the station before operations start and determine if anything is broken and needs to be repaired.

Vuzi arrives at the station and starts to check the equipment. Vuzi first assesses the gates and finds that one of the card readers at the gates is faulty. Vuzi makes a note and continues the inspection. Vuzi checks the Passenger Display Units (PDUs) and AVA and all of them are functioning correctly. Vuzi continues with the assessment of the ticketing kiosks and finds that all is in order as well. Vuzi checks the automatic doors that allow access to the vehicles and finds that they are faulty. All the other equipment is in order.

Figure 27.16. Station officer at the card readers in a Bogotá, Colombia, BRT station. *Karl Fjellstrom, Far East BRT.*

Vuzi then contacts the BRTMC immediately and reports to the call center agent that one of the card readers at the gate is not working and that the automatic doors are faulty.

Gareth is the call center agent on duty and logs the call received from Vuzi. Gareth immediately dispatches the card reader and automatic door maintenance teams. They indicate that the problem will be fixed within the hour.

The respective maintenance personnel arrive at the station where Vuzi shows them the problems. They fix the problems and report to Vuzi who goes to inspect the card reader and automatic doors and finds them fixed.

The maintenance staff and Vuzi report back to Gareth at the BRTMC that all faulty equipment has been fixed, and Gareth completes the logged call with a short report.

Figure 27.17 illustrates the maintenance scenario as described above.

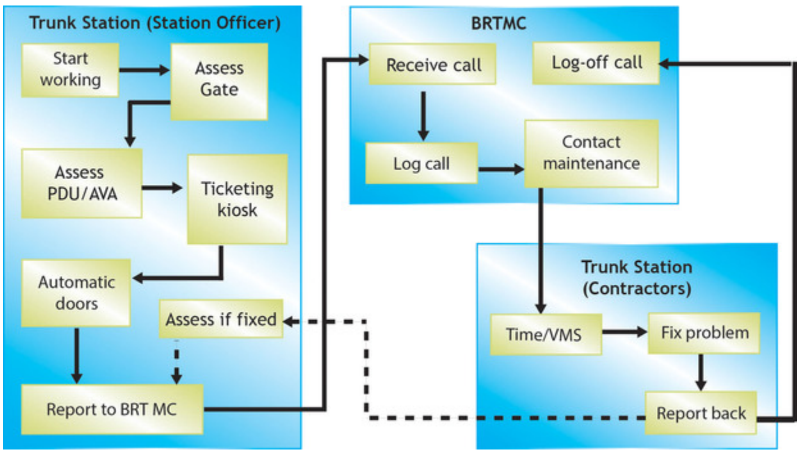

Figure 27.17. Maintenance process. *TECHSO.*

27.10.3.3 Emergency Scenario

Dillon and Cynthia are operators working for the Safety and Security group in the BRTMC's control room. Both of them have been on duty for only two hours, and they are comfortably watching the monitors.

Dillon sees on one of the monitors that something has happened that is out of the ordinary. There is an accident at an intersection involving one of the BRT vehicles and a car. Dillon immediately logs a call to fire and rescue stating that an accident has occurred at the Nelson and Main Street intersection and that it involves a BRT vehicle and a car. While Dillon is logging the call to the fire and rescue, Cynthia logs a call to the police in case there are any fatalities. The fire and rescue department and the police immediately dispatch vehicles to the accident scene.

Once Dillon has completed his call to fire and rescue, he contacts the Traffic Department to dispatch personnel to manage the other traffic. Cynthia has the responsibility to inform the Operations Control group in the BRTMC to reschedule/relocate vehicles and update all VMS at stations. Operations Control informs all station officers and the depot manager of the current standings and contacts the web administrator at the call center to update the information on the website.

The entire time that the accident cleaning process is under way, Dillon and Cynthia review the CCTV cameras. Once the clean-up operation is complete, the vehicles are rescheduled, and operations can continue normally.

Figure 27.18 illustrates the emergency scenario as described above.

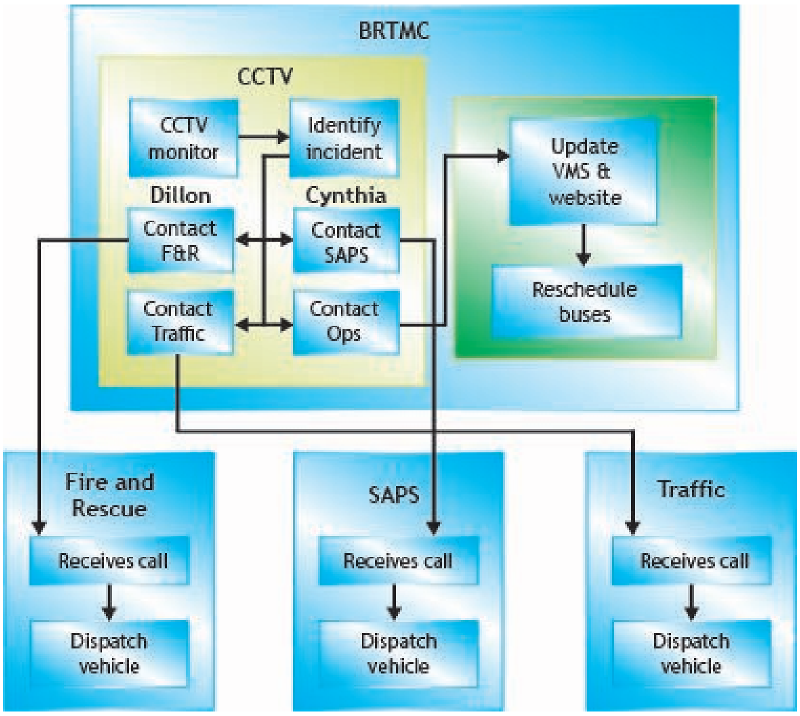

Figure 27.18. Emergency process. *TECHSO.*

VOLUME VII

Integration

Volume 7 goes into the potential for BRT to extend beyond its stations, vehicles, and corridors, and compound its environmental, social, and economic benefits to the greater transport network of non-motorized transit, while encouraging effective transportation demand management and transit-oriented development.

28. Multi-Modal Integration

Introduction

> *"I waited and waited on the platform, but the train never came and it seemed odd that no one else was waiting with me...Finally, I went and asked a porter and he indicated to me that I had to take a bus and, when pressed as to where I might find this bus, motioned vaguely with the back of his hand in the direction of the rest of the world."*
>
> — From "African Diary" by Bill Bryson, Anglo-American writer, 1951 –

The ideal BRT system is fully integrated within the larger circulation network, from airports and intercity rail, to public bikes and neighborhood walkways. Taken as a whole, this is referred to as multi-modal integration, also known as intermodal, implying the actual use of multiple modes as opposed to co-location of those modes. As BRT systems are usually being planned and implemented into existing urban frameworks and transportation systems, the onus is on BRT to integrate with those systems, especially at key nodes. In fast growing cities, where multiple systems are being planned and implemented at the same time, these systems will need to be coordinated in order to reduce redundancies and maximize the synergies between modes. At those key nodes and where those systems intersect and it makes sense to link systems and modes, a multimodal facility may be needed. These facilities, however, typically have a large footprint for the urban context, creating a design challenge.

Integration should be logical from a system-wide perspective. The goal of integration is 1) to improve access and coverage, while avoiding duplication of service, and 2) to make trips as short as possible, in both time and distance, while minimizing the number of transfers. The convenience of the transfer will impact the customer's decision on whether to take a particular mode or trip. This convenience depends on two main things – the wait time for the next service and the physical connection, including level changes, walking distance, and ambiance of the transfer (such as protected from rain, climate controlled, etc.). Customers are willing to transfer if the frequency of the connecting service is high so the customer is guaranteed a short wait time, and if the transfer process is easy. Intermodal facility design is, thus, critical in successfully achieving integration.

Three main forms of integration include:

1. Physical Integration
2. Information Integration
3. Fare Integration

The BRT Standard awards 15 points in total for access and integration, with points for integration with public transport, cycling, walking and universal access, and bike share. Ideally, this leads to operational integration which maximizes transfer possibilities and minimizes idle and wait times.

This chapter provides an overview of these three types of integration, with a focus on facility design. Chapter 25: Station Design provides details on station design that will not be reiterated here. The following chapters (Chapters 29: Pedestrian Access, 30: Universal Access, 31: Bicycle and Pedicab Integration, 32: Transportation Demand Management) provide more detail on those modes and will not be reiterated here.

From a customer point of view, the various types of transport are meaningless. They are primarily interested in ease-of-use, from transfers to payment to destinations. The rise of private automobile use can partially be explained because there are no transfers, there is one payment (gas), and one can drive anywhere at any time. For transport to effectively compete, it must cater to the same demands – be as convenient. Integrating across modes helps achieve this.

28.1 Physical Integration

> *"Art has to move you and design does not, unless it's a good design for a bus."*
>
> — David Hockney, English artist associated with the 'pop art' movement, 1749 – 1827

Physical (or spatial) integration describes efforts to co-locate the various parts of a transport system. This generally occurs at stations, but also happens elsewhere in the network. Examples include taxi stands outside bus terminals, walkways connecting stations directly to adjacent buildings, stations serving various bus and train lines, and bikeways along BRT routes, among others.

The first priorities for physical integration within a BRT network, essentially pre-requisites of good system design, is with the pedestrian and cycling environment surrounding the station, terminal or multimodal facility (see Chapters 29: Pedestrian Access and 31: Bicycle and Pedicab Integration for more information) and with the different lines and services of the BRT system itself by creating an easy transfer between them.

BRT can be complementary with other urban and long-distance public transport options. Cities with existing metros and urban rail services should ideally integrate these options with BRT. Cities with water transport systems should also seek to closely integrate these systems with the BRT network.

BRT can be integrated with long-distance public transport infrastructure such as long-distance bus stations and train stations, and, in some cases, airports. Again, physical planning is key to making this option viable. Customers from such modes often are carrying luggage or goods and need a convenient transfer mechanism.

Figure 28.1. The Airport Station of Cape Town's BRT allows passengers to go into downtown. *ITDP.*

Figure 28.2. The Cape Town BRT service from the airport has buses with space for luggage. *ITDP.*

Figure 28.3. Transcarioca in Rio de Janeiro connects to the airport. *ITDP.*

Aside from BRT buses and feeder buses, which form an integral part of the BRT system, other local bus services may interface with BRT stations. These include municipal buses, private buses, and various coach and bus shuttle services, such as employee buses, hotel coaches, and even school buses. A high-quality walking network is desired for access to buses not integrated into the BRT system or otherwise located in an intermodal terminal shared by both BRT and local buses.

28.1.1 Networks

At the planning level, circulation networks (including transport networks) should be organized to share resources and maximize coverage. The public right-of-way is historically where roads and services are located, including BRT. Not coincidentally, many corridors contain facilities for many modes: streets, bikeways, busways, and utilities. Organizing the BRT network in concert with other networks allows maximum integration. Other modes and networks that BRT can connect with include:

- Airport;
- Bike (bikeway, public bikes);
- Bus (city, school, jitney);
- Coach (long distance, inter-city, charter);
- Ferry (seaport);
- Light Rail (tram, streetcar);
- Metro (skytrain, elevated);
- Train (inter-city, suburban);
- Walking (footpaths, connections to buildings, crosswalks, bridges).

This could include high quality walkways and crosswalks around the BRT corridor, parallel bike lanes along the corridor, BRT intersecting with a rail corridor, or BRT leading directly to and integrated with airports, seaports, and other terminals.

The different opportunity for customers to transfer is influenced by the physical relationship of one mode to another. Examples include BRT platforms adjacent to rail platforms or BRT platforms directly linked to intercity coach departure points. BRT stations can be planned and designed as the primary interface of customers from one mode to another. Public transport planners can, during the planning phase, optimize the location of BRT roadway alignments to interface other existing modes.

Platforms can intersect at predetermined levels linking 'paid' customers and maximizing connectivity. Practical and technically constructible linkages of BRT infrastructure with other modes can help support a 'network effect' within public transport systems. The network effect can be described as multiple points created for the opportunity to transfer between many different services of one mode with the different services of another mode. Customers can plan trips based on their opportunity to transfer between services at key points.

Political realities factor in deciding what to integrate. Generally it is easier and more convenient for BRT to integrate with other modes also managed by the agency or jurisdiction that manages the BRT. For example, if both BRT and bicycles are part of the transportation agency or if BRT, taxis, and Metro are part of the public transport agency, it is much easier to integrate the services and spaces. If the rail service is owned by a completely different agency from the BRT system, integration becomes harder to achieve. When two modes are controlled by different operators, there is little motivation to make the connection as smooth as possible. These realities hone the focus of integration.

Figure 28.4. Map showing relationship of various public transport networks in Zoetermeer, Netherlands. *infrastruct.wordpress.com.*

Figure 28.5. Sketch of interconnected public transport networks (regional rail, tram, BRT) in Al Ain, United Arab Emirates. *Nelson\Nygaard.*

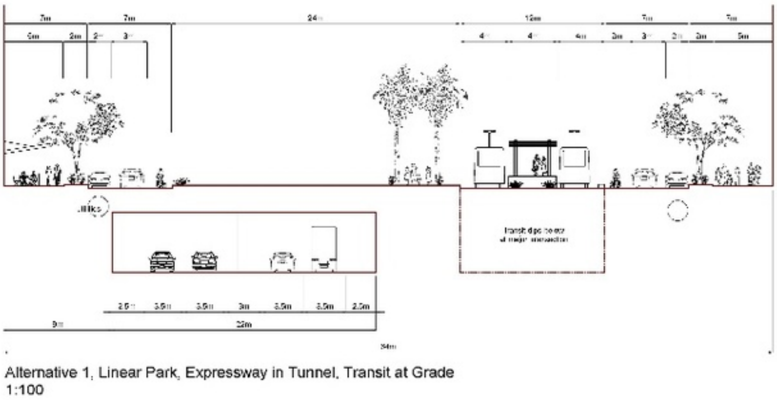

Figure 28.6. Bike route along a LRT corridor in Charlotte, North Carolina, USA. *Michael King.*

Figure 28.7. Cross-section of 64 meter-wide corridor showing BRT/LRT, highway in tunnel, linear park, utilities, local streets, and sidewalk cafes in Doha, Qatar. *Nelson\Nygaard.*

Figure 28.8. The Brisbane Busway is closely integrated with the city's commuter rail service. *Queensland Transport.*

Figure 28.9. A model of integrated train, bus, and canal systems in Changzhou, China. *Michael King.*

Figure 28.10. The Morogoro BRT in Dar es Salaam, Tanzania, has parallel bike lanes and improved sidewalks all along the corridor. *ITDP Africa*

28.1.2 Terminals and Stations

The physical planning of terminals and stations is a crucial part of successful public transportation network integration. Small-scale intermodal transfers often happen in an ad-hoc manner: a person may lock a bicycle to a lamppost and enter a BRT station; hail a taxi on the street after coming out of a BRT station; or walk from a ferry pier to the nearest BRT station. Even such "spontaneous" inter-modality requires some degree of physical facilitation, such as a continuous pedestrian realm, abundant bicycle racks, and easy curbside access to taxis. However, systemic intermodal transfers, which are meant to handle large numbers of customers and accommodate peak commuting patterns, require the careful planning of intermodal transfer facilities in order to ensure they can cope with high flows of people. The challenge of multimodal integration is a physical challenge often trying to connect modes that are offset both horizontally and vertically.

Figure 28.11. In Pimpri-Chinchwad, India, The terminal is open aired and spacious. *ITDP*

Figure 28.12. Pimpri-Chinchwad's terminal has places for people to sit while waiting for the bus. *ITDP*

Figure 28.13. Customers can transfer from the BRT buses to feeder buses at the Pimpri-Chinchwad terminal. *ITDP*

Figure 28.14. BRT buses are at level with the high platform at the Pimpri-Chinchwad terminal. *ITDP*

Figure 28.15. For customers transferring to and from the feeder busses that run in mixed traffic and are not high platform at Pimpri-Chinchwad's terminal, steps are built from the high platform of the station to the ground. *ITDP*

Three concepts undergird the planning of intermodal transport facilities:

1. **Forecasts.** Forecast all expected transport modes, with details on the mode splits and expected intermodal transfer flows. In the absence of reliable forecasts, plan for worst-case yet plausible scenarios.
2. **Flexibility.** Anticipate changes in the market, operators, vehicle types, and modes. Planning assumptions should be reviewed periodically and the terminal design adjusted as much as possible.
3. **Expandability.** Design for long-term forecasts and for the facility to be expanded to accommodate that growth. Concept plans for the expansion should be in place at the time of the initial design.

Forecasting underpins any successful design of transport facilities. In less mature cities, where there is still a lot of growth, forecasting becomes harder. When the data does not exist, the next thing is to maximize what can be done on the site. If possible, plan for greater demand than anticipated as a way to safeguard against poor data. Another way to safeguard is to use a modular design, so that expansion can happen if needed.

In the absence of forecasts, one method to figure out how to size various facilities, such as platforms, ticketing areas and corridors, is to design around capacity and plan for the plausible worst case scenario, which in the case of transit systems is when everyone gets on and off. That scenario usually only happens at a terminals. Walkways, platforms, stairs / escalators all need to be balanced to cater to that maximum capacity.

When designing these facilities, the following principles instruct that process:

1. **People get priority.** As much as possible, the first priority is to design for the people using the facility and the services, and not design around the different transport modes.
2. **To integrate different modes** in order to streamline and optimize the overall transport network functionality. Without transport hubs, there is a tendency to have less coverage and significant route overlaps, all of which makes for a less efficient system.
3. **To provide a seamless transfer.** Given the choice, most people would prefer a non-stop journey, whether from door to door (by foot, bike, or private vehicles) or on a single mass transit mode. High customer level of service (LOS) is therefore key to nudging commuters to use public transport on journeys requiring intermodal transfer. This includes short walking distances, few and assisted level changes, and comfortable transfer environment, including weather protection where appropriate.
4. **To maximize commercial opportunity** within the hub in order to provide additional revenue source to subsidize the hub maintenance and operation. The high traffic flow is attractive to many types of commercial operators and can generate income without compromising operations or LOS.
5. **To integrate within the urban environment** in order to maximize the pedestrian catchment area, encourage transport-oriented development, and maintain the continuity of the surrounding urban fabric.
6. **To separate motorized and non-motorized modes**. It is advisable to locate motorized modes (bus, taxis, car parking, para-transport, coach) to one side of a terminal and non-motorized modes (walking, cycling, pedicabs) to another. It is best for motorized facilities to be located for easy access to highways and the non-motorized modes directly adjacent to built-up areas. This, however, should be done without leading to a "hostile" interface with the urban environment.

As BRT stations are often located at street level in the median, connecting to any other mode will typically require crossing the street or going up or down a level.

Figure 28.16. In Yichang, the BRT system stops at this intercity bus terminal and also has some small shops. *ITDP.*

Figure 28.17. This station in Yichang allows customers provides a large transfer and comfortable transfer area. *ITDP.*

Figure 28.18. This station in Yichang also has places for buses to layover during off-peak hours. *ITDP.*

Figure 28.19. Right-of-way reserved for future BRT in Arlington, Virginia, USA. Photo by Michael King. *ITDP.*

Figure 28.20. The noticeable differnet pannel is removable to provide additional access to a BRT station during high volume events such as New Year's Eve. Brisbane, Australia. *ITDP.*

Figure 28.21. During special events, the removed pannel allows an entrance from the street, which is exclusive for pedestrians during events. *ITPD*

Urban Design and Land Use

The design of the station should include high-density, mixed-use development to maximize the benefits and synergies between the transport accessibility and land use. It should be as organically integrated in the surrounding area as possible, in terms of use, mass, and accessibility. Transport hub "fortresses" surrounded by high-capacity roads create a rupture in the urban fabric.

Building Organization and Layout

The following apply for all types of transport terminals, from bus stops to airport terminals.

- **Provide sufficient LOS**. Every element in a transport facility needs to be designed and sized to meet the target LOS. Areas with insufficient space will be perceived as bottlenecks and excessive space will be seen as a costly overbuild;
- **Size for Peak Conditions**. The forecast peak flow of customers forms the basis for sizing all terminal elements, including platforms, corridors, waiting areas, ticketing, queue space, and escalators. There are different methods of determining the peak conditions for the purpose of design (which is usually not the same as the "worst case" peak), and different parts of the terminal may require different methods. The flow analysis must be detailed enough to provide sizing guidance for each and every terminal element; important to sizing considerations are queueing areas, such as at the top or the base of stairs, turnstiles, etc.
- **Take advantage of non-overlapping peaks**. Most urban transport terminals witness two daily peak travel periods (morning and evening) which typically feature opposite flows. Good design takes advantage of this phenomenon to minimize construction costs by placing elements such as escalators, stairs and turnstiles so that they can serve flows going in either direction. This may require a dynamic assignment of escalator directions, turnstile orientation, railings, signage and other elements by the terminal operational staff;
- **Minimize conflicting flows.**
- **Cross flows** create conflicts, thereby reducing capacity and creating confusion and discomfort. They should be avoided as much as possible;

- **Counter-flows** within the same corridor can also slow traffic unless clearly separated. In larger terminals with significant surges and distinct movement patterns, such as airports and long-distance rail stations, separation of arriving and departing customers may be advisable;
- **Minimize walking distances** from the station entrances to the boarding area and for intermodal transfer. Transfer distance requiring more than a five minute walk is a deterrent for many customers; keep distances short and direct;
- **Minimize level changes.** Level changes are uncomfortable for customers, increase journey time, and vertical circulation elements such as escalators and elevators are costly to install and maintain; as much as possible, make vehicles change levels, not people. However, if level changes are a must, make them as easy as possible by the use of gentle ramps, escalators, and elevators, with mechanized modes strongly recommended for upward movement;
- **Vertical circulation.** Escalators, elevators and inclined travelators should be designed carefully to provide the target LOS with sufficient redundancy. For example, a facility should have two elevators for redundancy considerations, even if demand only requires one. In long-distance terminals special consideration should be given to luggage portage;
- **Avoid road crossing.** This is in particular relevant for bus and taxi bay access, although pedestrian bridges and underpasses should be seen as a solution of last resort as they inconvenience passengers. Terminal planning should attempt to create contiguous pedestrian-only zones on a single level;
- **Easy wayfinding.** No amount of online information makes up for good, intuitive wayfinding in the terminal itself, comprising of signs, station maps, and directories listing the transport services provided. Planning the station with simple intermodal transfer routes and open sightlines greatly helps. This is particularly important in intermodal hubs serving non-regular users, such as tourists and crowds going to event venues.

One way to judge the success of the building design is by the Level of Service (LOS). The classic metric of LOS is related to capacity and defined in terms of space per person for queueing areas, space per person per width per minute in flow areas, and the number and width of stairs and escalators. Other ways to evaluate LOS could be the number of level changes in a journey (the lower the better), minimizing crossflows, no bottlenecks, etc.

One of the key sizing principles in transport facilities is ensuring that the platform can be cleared by the time the next vehicle arrives. In the case of buses, the designer will need to know how many people are disembarking the bus, the frequency of the bus, the number of bus bays and where the customers are going. For example, if a 12-meter bus comes every minute to each of the two bus bays, and 50 passengers disembark from each bus, 100 people will need to clear the platform every minute before the next set of buses come through. What happens if they haven't cleared the platform yet when the next two buses come in, for example because they have to negotiate a narrow stairwell or an exit with only two turnstiles? The balanced sizing of all station elements against such "worst case scenarios", including some redundancy provisions, will ensure such situations are avoided.

Box 28.1. Technical Operating Envelops

A specific study comparing the 'technical operating envelops,' or the design parameters and space needed for different modes and vehicles, of one vehicle to another within the BRT network and between vehicles of different modes is useful to determine the compatibility and consistency of customers accessing vehicles. This is particularly important that platform-boarding heights are consistent along their length for the co-location of vehicles using platforms and so the ease of passenger accessing different vehicles is optimized. Differential boarding heights can be provided along a platform should the vehicles be significantly different from one to the other. The 'tracking' of vehicles for pulling in and out of platforms, the turning circles including sightlines of vehicles and the location of doors that provide a consistent boarding and alighting location on platforms will assist in the assessment of vehicle to vehicle integration. Consistent standards for the protection of customers from vehicles and from the different power sources those vehicles use should also be examined. Invariably the differences in the operating envelops of vehicles will determine the physical proximity of one vehicle to another defining the minimum distance customers have to negotiate between modes.

Building Design and Facilities

Chapter 25 covers the building design of the stations and terminals. Here is a summary of main concerns for multimodal facilities:

- **High quality design** is recognized and respected. Many transport terminals (New York's Grand Central Terminal, Mumbai's Chatrapati Shivaji Terminus - a UNESCO Heritage Site, Moscow Metro Stations, Paris Metro Stations) have become beloved civic structures over the centuries;
- **Cleanliness.** It is important to design terminals so they are easy to clean and maintain. Surveys reveal that customers rank cleanliness at the top of their concerns regarding transport facilities;
- **Weather protection** is one of the most important features of a successful transportation terminal, especially in cities with a harsh climate. The ideal terminal will extend the same weather protection offered on the vehicles themselves, including air conditioning, and avoid any "weak links" such as open-air passages;
- **Air quality** must be high with a high degree of fresh air replacement, especially in bus terminals and deep subway tunnels;
- **Seating and waiting lounges.** Providing seats is important for the elderly even in high-capacity mass transport stations, such as subway platforms and concourses. For longer-distance travel terminals, such as train stations, long-distance buses and airports, sufficient seating must be designed in the waiting lounge to accommodate the majority of waiting customers according to the demand forecast. Seating should be as close as possible to the boarding area;
- **Restrooms.** Restrooms are essential in larger intermodal terminals, especially ones serving long-distance traffic (see related item: Cleanliness)
- **Retail.** Retail is both a welcome amenity to customers and an important source of income to the operator. This may include convenience stores, packaged food stores, dry cleaners, flower shops, and other pick-as-you-go retailers. Larger terminals, especially ones serving long-distance traffic, also require food and beverage outlets;
- **Facilities in Long Distance Terminals.** Patrons at long-distance terminals benefit from children play areas, VIP lounges, business centers, internet kiosks, and culture-specific facilities such as prayer rooms.

Figure 28.22. escalator capacity is designed for the morning rush hour peak, Hong Kong. *Oren Tatcher.*

Figure 28.23. Customers resting against "leaning rail" *Oren Tatcher*

Figure 28.24. Shops within transport station. *Oren Tatcher*

28.1.2.1 Internal Intermodal Connections

The design of terminals, stations, and stops contributes vastly to the intermodal integration. Metro stations and airports are designed for seamless transfers between lines and planes and the same is true between modes. Wayfinding, ease of ticketing, sufficient walkway width, and other aspects are imperative. A classic example is Hong Kong's airport where the different modes (plane, bus, taxi, train, ferry) are stacked vertically. Access is accomplished via gentle ramps and escalators. Berlin's Hauptbanhof (main train station) is similarly stacked vertically. São Paulo's Metro terminals have large ramps connecting the trains and BRT.

Figure 28.25. A map of high speed ferries connections to Hong Kong Airport. From the various seaports one can connect to other transport. *Hong Kong International Airport.*

Figure 28.27. An integrated bus station and shopping mall, Jakarta, Indonesia. *Michael King.*

Figure 28.26. A direct connection between monorail and shopping mall, Seattle, Washington, USA. *Michael King.*

Figure 28.28. A railway station with integrated bike path in Zoetermeer, Netherlands. *"Wandelen in beeld" (http://www.nlwandel.nl/Album/NS-Buytenpark%20%28Zoetermeer%29/slides/01%20Station%20Zoetermeer.html).*

Pedestrian Facilities

Transport hubs need to be integrated within the surrounding pedestrian network. Multiple points of entry should facilitate direct access from surrounding streets and abutting commercial developments. This may occur via bridges or tunnels, covered walkways, or simply high-quality sidewalks and crosswalks. The general idea is to ”extend” the transport station outward. This increases passenger comfort as they ”feel” they are in the station sooner. One caveat is that pedestrian bridges and tunnels tend to distract from the overall surface-level walking experience. They should only be used in high volume situations where physical separation is desired for flow control. See Chapters 29 and 30 for more information.

Figure 28.29. Pedestrian bridges connecting Skytrain to malls in Bangkok, Thailand. *Michael King.*

Figure 28.30. A covered walkway leading to a train station in Vancouver, Canada. It leads to the bus stop, shopping center, and park-and-Ride. *Michael King.*

Figure 28.31. A pedestrian route through a bus depot to a train station, Buenos Aires. *Michael King.*

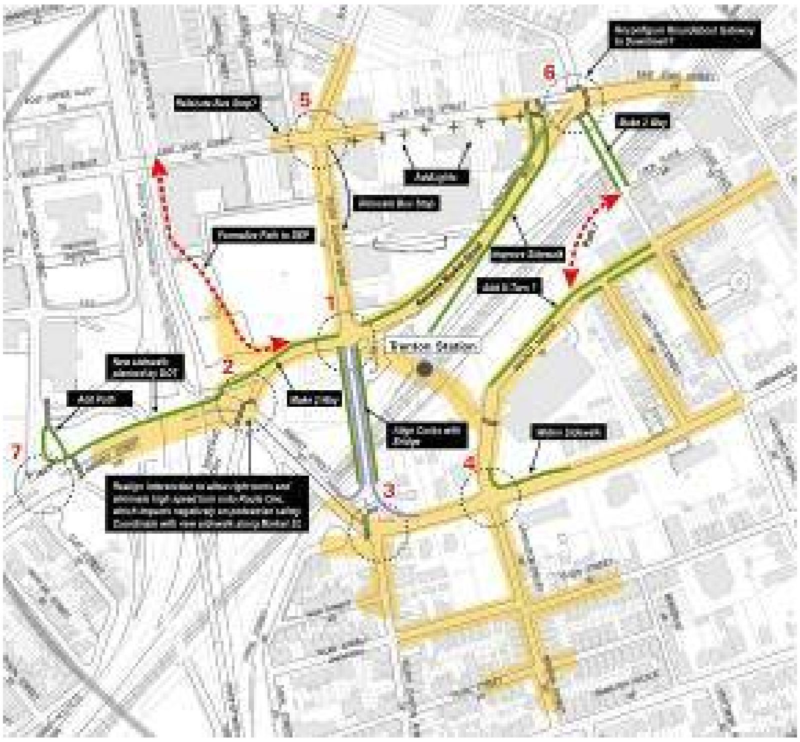

Figure 28.32. An analysis of actual five-minute walking distances around station, Trenton, New Jersey, USA. By identifying actual walking routes the implementing agency could then make upgrades. *Nelson\Nygaard.*

Bicycle Facilities

Bicycles are a viable part of the public transport mix, and progressive transport agencies are integrating facilities for bicycling at a rapid pace. This includes bicycle parking, bike sharing (public bikes), bike taxis, bike routes, and bike stations. Investments range from small, such as bike racks to large, such as bike ramps directly into terminals. In that the physical space needed to accommodate high-quality bicycle transport is so much smaller than that needed for auto transport, the economic benefits are clear. To wit, the bike to car parking ratio is 10:1. See Chapter 31 for more information.

Figure 28.33. A BRT Station and Cycle Center in Brisbane, Australia. *ITDP.*

Figure 28.35. Bike parking at a train stationin Buxtehude,Germany. *Michael King.*

Figure 28.34. The Ozone Station of the Nagoya, Japan public transport system represents a nexus of the elevated BRT system, the suburban rail system, and the subway system, as well as ample provisions for bicycle parking. *Lloyd Wright.*

Figure 28.36. Bike route and parking at a train stationin Berlin, Germany. *Michael King.*

Figure 28.37. Bike parking at Midway Airport in Chicago. *Michael King.*

Figure 28.38. Closed bike parking at a BRT terminal in Bogotá. *Karl Fjellstrom.*

Figure 28.39. Plastic bags protecting the saddles on these parking facilities are located near Transoeste stations in Rio de Janeiro. *Gabriel T. de Oliveira, ITDP.*

Figure 28.40. Bike parking facilities are located closed to the entrance in this stations in Rio de Janeiro's Transoeste. *Gabriel T. de Oliveira, ITDP.*

Figure 28.41. Bike share stations are located along the BRT corridor in Guangzhou, China. Bike lanes were added to run parallel to the corridor as well. *Karl Fjellstrom.*

Figure 28.42. Bike lanes running parallel to the BRT in Belo Horizonte. *ITDP Brazil.*

Non-BRT Bus Facilities

Buses, especially when parked or idling, are an environmental nuisance. When bunched together, they block street-level views and generate significant noise and pollution. As much as possible, bus terminuses should be located so they do not abut major pedestrian routes and in particular public open space.

Four principles of bus facility design:

- **Pedestrians first.** Pedestrian safety and convenience is the highest priority within and around a bus terminal. At-grade crossings are preferred to pedestrian bridges or underpasses. As much as possible make the buses make the level changes, not the people.
- **Parking bay design.** Bus loading/unloading bays are ideally operated independently. The most common solution is a sawtooth arrangement or a stacked arrangement for a single route.
- **Smooth integration in surrounding traffic.** Dedicated ramps, lay-by bays, merging lanes, traffic lights and other transport design features are necessary in order to ensure road traffic to and from the hub moves smoothly and the hub area does not become gridlocked.
- **Staging areas**. Sufficient provisions must be made for the staging of buses. In dense urban areas, staging may need to be provided in a different site, with on-time dispatch to the pick-up area.

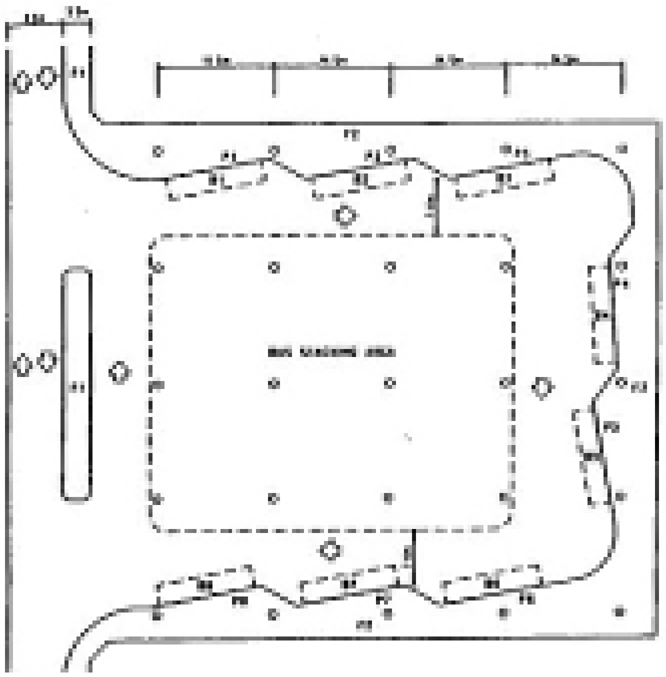

Figure 28.43. Typical layout of bus station. Taxi, Pedicab, and Paratransit Facilities *ITDP*

Taxis

> *"Too bad all the people who know how to run the country are busy driving taxi cabs and cutting hair."*
>
> — George Burns, comedian, 1896 – 1996

Taxis and other semi-private transport, such as auto-rickshaws, are necessary to extend the reach of transit, especially for those who need to travel long distances, have heavy parcels, or are disabled. It is best to locate parking for taxis and paratransit either within the station, or directly adjacent. By developing integrated taxi facilities in conjunction with BRT stations and terminals, multiple benefits can be achieved.

Developing taxi stands at public transport stations reduces the need for taxi drivers to operate without customers. Instead, the customers come to the taxis rather than the other way around. The strategic location of taxi stands in close integration with BRT stations can thus prove to be a win-win for system designers, taxi drivers, city officials, and the public. System designers win by adding another important feeder service to their route structure and taxi owners and drivers win by dramatically reducing their operating costs. The BRT stations provide a concentration of customers for the taxis without the need to circulate the city expending large quantities of gas. City officials win by helping to reduce a major factor in urban traffic congestion. And finally, the public wins by having a more flexible and convenient public transport system that also reduces urban emissions and promotes greater overall efficiency.

Modern vehicle designs, escalating fuel prices, and growing environmental concerns have led to a resurgence in pedicabs in many parts of the world, especially in the Western European cities of Berlin, Copenhagen, and London. Pedicabs can make for an almost ideal feeder service to BRT stations, especially trips of four kilometers or fewer. Pedicabs are low-cost vehicles that provide high levels of employment while producing zero emissions. See Chapter 31 for more information.

Box 28.2. Taxis without passengers may add to congestion

In many cities of the world, and especially in developing-nation cities, taxis represent a large proportion of the vehicles on the road at any given time. However, taxis spend much of their time in search of customers rather than providing actual customer trips. Prior to the introduction of improved taxi ranks and dispatch systems, taxis in Shanghai were estimated to spend eighty percent of their travel time without customers. Thus, these non-customer trips can add greatly to congestion levels without serving any real purpose. This, however, may be changing with taxi-ordering apps such as Uber, EasyTaxi, and others, but it is unclear if this is the case or if these will increase congestion.

Figure 28.44. A taxi stand at a BRT station in Quito, Ecuador. *Lloyd Wright.*

Figure 28.45. A taxi stand at Metro station in Kuala Lumpur, Malaysia. *Lloyd Wright.*

Park+Ride and Kiss+Ride Facilities

Park+Ride and Kiss+Ride are not really recommended for the land adjacent to transit systems. Generally, park and ride presumes low land value around transit while high quality transit generates high land values (Jarrett Walkerr,Basics: The math of park and ride http://humantransit.org/2014/10/basics-the-math-of-park-and-ride.html). Park and rides will ultimately be a constraint in increasing ridership on transit, as once it is built it is hard to remove. The land is more usefully used to house people and have services nearby to transit. It is preferable to devote some space for Kiss and Ride and connections to intermediate modes of transport that can be shared as opposed to private car use. These include bike share, ride shares, shared taxis, three-wheelers. Thus, park and ride is really only recommended for suburban and rural areas, if at all.

Park-and-ride facilities provide secure parking for cars in a garage or lot. Kiss-and-ride facilities provide pick up and drop off for customers immediately adjacent to the station entry.

Park-and-ride and kiss-and-Ride are only recommended for terminal stations in suburban and rural areas where population densities are insufficient to justify feeder services and/or distances are too far to make direct walking and cycling access to the station viable for most people. These conditions will primarily be found in neighborhoods dominated by affluent households that have sufficient disposable income to own a private vehicle. Attracting this income group to the public transport system can deliver several benefits.

- Offsetting private vehicle use pays significant dividends in terms of emission reductions and congestion relief;
- A public transport system that is of sufficient quality to attract even the highest income groups is a worthy objective;
- A healthy mix of all a city's income groups in the system means that all political interests will have an incentive to ensure the system's future;
- Systems, which serve all income groups, also serve an important social function since the public transport system may be the one location where all segments of society come together.

Park-and-ride and kiss-and-ride are not recommended in downtown locations where the parking facility is more likely to be used to drive into the downtown. Private vehicle owners are less likely to use a park-and-ride facility if they are driving a substantial distance into the city and then using the public transport only for a small final portion.

The location of the parking facility should be convenient to the station area. A long walk may discourage usage from discretionary customers. In cities with frequently unseasonable weather (wind, rain, strong sun), covered walkways in the parking area may be a worthwhile investment. In some areas, it will be necessary to include security measures at the parking facilities. Security measures such as an attendant or security cameras can be effective. If security is insufficient, motorists will choose to use their private vehicle for the entire commute.

Whether motorists should be charged for parking at a park-and-ride facility depends on the location of the facility and the set of incentives in place. Subsidizing parking for higher income motorists far from the city center can be justified because it will encourage motorists to make a long public transport trip, reducing significantly the congestion and air pollution that would otherwise have resulted from the trip. The closer the park-and-ride facility is to the city center, the less the social benefit, and hence the weaker the justification for a public subsidy.

Parking facilities can be quite costly to develop and construct. Each at-grade parking bay may cost US$3,000 to US$15,000 when land purchase costs are included. Each parking bay within a multi-level parking facility will likely cost in the range of US$20,000 to US$35,000. Costs can be even greater in areas with significant land costs. Thus it can be necessary to establish a fee for use of parking facilities at public transport stations. The challenge is to develop a fee structure that still provides a strong incentive for using the public transport system.

Box 28.3. Locating a parking garage or lot immediately adjacent to a transport station can be problematic

- The land may be more suitably integrated with other active uses such as civic places or public amenities;
- People arriving to the station by foot or bike have to walk or cycle through the garage or lot, which makes the journey longer;
- Introducing private vehicles into the station area decreases safety;
- Buildings typically produce more rental income than garages or lots;
- Prioritizing drivers is counter to the aims of public transport.

The preferred solution is to build a parking garage and integrate it into the surrounding building context so that it does not call attention to itself.

Figure 28.46. The park-and-ride facility at the Mo Chit station of the Bangkok Skytrain brings customers who would normally drive in private vehicles. *Thirayoot Limanond.*

Figure 28.47. The parking facility at the Eight Mile Plains station of the Brisbane BRT system provides convenient access for drivers. People arriving by foot or bike must walk through the lot. *Queensland Transport*

28.2 Integration Information

> *"Any sign is an admission of architectural failure"*
> — Massimo Vignelli (author of the 1972 NYC Subway Map) as retold by Michael Bierut of Pentagram and quoted in Metropolis Magazine, April 2007.

Intermodal facilities are the result of transport planners purposely linking the operational characteristics of one mode to another. This enables customers to transfer between BRT services and to access services of other modes. It is the compatibility and the 'interwoven' matrix of scheduled services, communicated through integrated information systems, both static (such as timetables and maps), and dynamic (i.e., real-time information about approaching vehicles), and the use of an integrated ticket that helps determine the level of transfer and the success of an intermodal station.

28.2.1 Wayfinding

Four principles of wayfinding for intermodal hubs:

1. **Easy and Intuitive.** Station should be designed so that customers can intuitively find their way and see their destination. Direct lines of movement and sight are key;
2. **Consistent, Clear and Legible.** Signage should be consistent, clear, and easily legible from a distance. Ingress and egress signs should be clearly differentiated;
3. **Extensive.** Information boards providing route information, station layouts, and local destinations should be located all around the station and the surrounding area. This allows people to orient themselves before they exit the station, and to know how to get to the station;
4. **Standardized.** The use of standard station layouts, signage, and information systems within a transport network significantly improves the wayfinding experience.

Internal Circulation

Information germane to the multimodal terminal, station, or stop includes route identification (line number), directions to the various modes contained within the station (Metro, ferry, BRT, bike parking), intermodal possibilities within the station and along the transport route, and arrival and departure information. Much of this will be provided by each service provider; however, the smart systems will organize and coordinate the information.

Figure 28.48. Overhead wayfinding signs which use mostly pictograms and colors for quick comprehension. *Michael King.*

Figure 28.49. Wayfinding signs in Metro station showing surrounding neighborhoods, wheelchair boarding, and bicycle parking, Rio de Janeiro. *Michael King.*

Figure 28.50. A wayfinding map at a Metro terminal station, showing location of bus stops surrounding the station in Philadelphia, USA. *Michael King.*

Figure 28.51. A wayfinding map in a Metro station in Rio de Janeiro showing multimodal connections. *Michael King.*

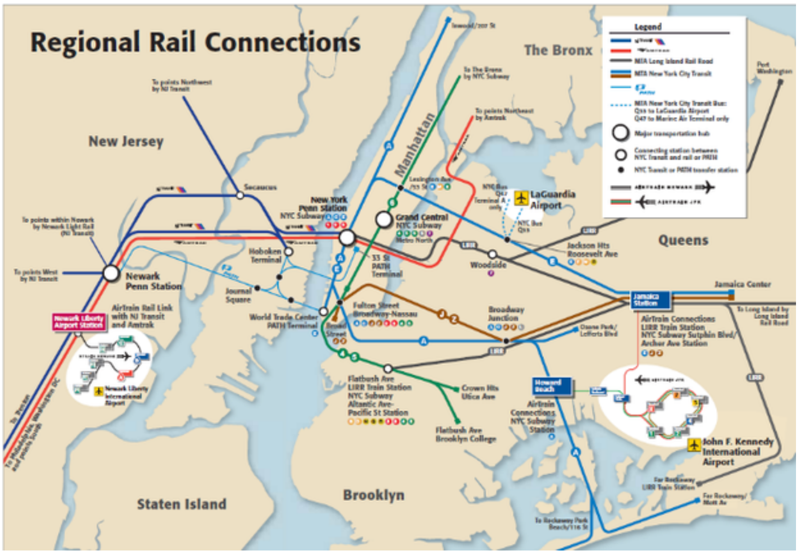

Figure 28.52. A map of public transport connections to New York City airports. Note the current bus connection to LaGuardia Airport is to be upgraded to BRT. *Port Authority of New York and New Jersey.*

Figure 28.53. BRT arrival information at the top of the stairs in the pedestrian mall to access the underground BRT station, Brisbane, Australia. *ITDP.*

External Circulation

Information about access to and from the station and the surrounding neighborhoods is integral to intermodal integration. This "last-leg" of a journey completes the system. Often this is a walking trip, so much of the information at this level is highly detailed. It is important to display this information as time-based (e.g., within a ten-minute walk) as people more intuitively understand time (as opposed to distance). Signage is not limited to the station proper; signs giving directions to stations should also be away from the station.

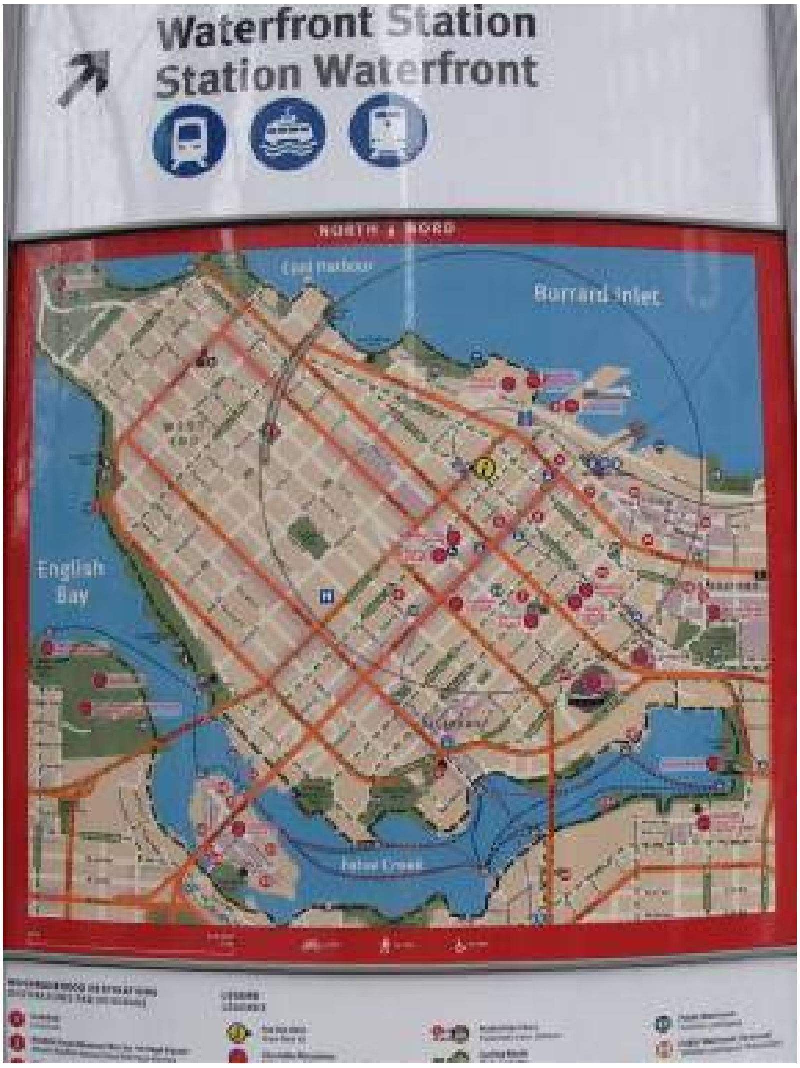

Figure 28.54. A wayfinding map with walking distances and intermodal connections (ferry, bus, train) in Vancouver, Canada. *Michael King.*

Figure 28.55. A wayfinding map with walking distances around a train station in Dubai, United Arab Emirates. *Michael King.*

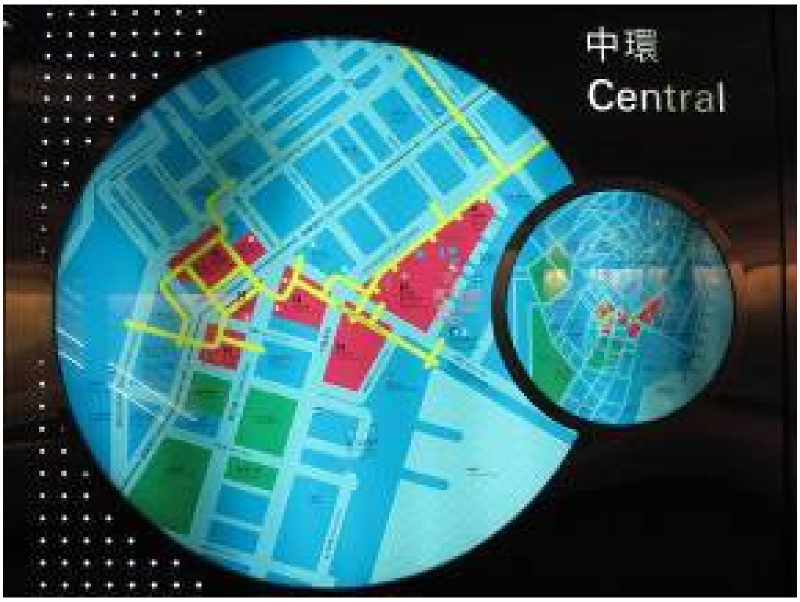

Figure 28.56. A wayfinding map of pedestrian bridges in Hong Kong. *Michael King.*

Figure 28.57. A wayfinding sign to public transport inside a mall in Dubai, United Arab Emirates. *Michael King.*

Figure 28.58. A wayfinding sign found outside the Metro station, Washington, DC. These signs route patrons to the station, thereby extending the station "footprint." *Michael King.*

28.3 Fare integration

> *"Growing up in New York City, my car culture is minimal. I rode on the train, the bus. I walked; I rode my bike, and when I was younger, I rode my skateboard."*
>
> — Ramón Rogdríguez – American actor, 1979 –

Integrating fare payments across various transport systems benefits the patron and system. For the customer, it makes it easier to use the entire transport system by simplifying the way the customer pays to use those services or allows easy switching or transfer between modes. It could help with regional integration, too, as fare integration can help bridge jurisdictional boundaries.

Integration allows both to benefit from economies of scale. See Chapters 15: Fare Policy and Structure and 19: Information Technology Systems for more information.

Examples of fare integration include:

- **Common fare card**. When all services use the same fare media, such as the Oyster Card in London. This allows a customer to use any service without having to buy a new ticket or purchase a different card. Ideally, these can be purchased within any of the participating systems, at independent outlets, or on-line. Computerized fare cards direct payment to each system based on ridership;
- **Common transfers**. Discounted or free transfers between various systems. This is made even easier with technology that recognizes the transfer for the customer;
- **Integrated tickets**. This allows one fare to cover multiple modes for one journey. Purchasing a fare on one system provides a free ride on another. Examples include a free ride on the airport shuttle connect the train to the plane, a free ride on the regional rail from the inter-city rail terminal, use of the campus shuttles with paid parking, etc.

The easiest to start with is using a common fare media, like a smart card. It is harder to tackle the institutional issues behind that though, including coordinating multiple agencies or operators, as well as the accounting and accountability needed behind that (Jorge Rebelo, Nine Suggestions for Designing and Implementing Integrated Fare Systems at http://blogs.worldbank.org/transport/nine-suggestions-designing-and-implementing-integrated-fare-systems).

Figure 28.59. In Buenos Aires, Argentina, a customer can use the SUBE fare for the bus, metro, train, and BRT system pictured above. *ITDP.*

Figure 28.60. In Guangzhou, the 'Yang Cheng Tong' card can be used for the bike share system, the bus, the BRT, and the Metro. *Karl Fjellstrom.*

28.4 Real Time Information

> *"I feel more comfortable in a place like Brighton - a town, with one centre, one bus station, one train station. And there are so many arty, creative people, and things are less rushed, less stressed."*
>
> — Gabrielle Aplin, English utube-singer-songwriter, 1992 –

Advances in technology are helping to make information integration easier and making traveling through the city easier. Having static information about how to connect to other modes at a station helps customers finish their trip. Even just mapping the existing services can be revolutionary in terms of helping customers know how to make and plan for trips. Having digital information available to the customer, where it be through Google maps using data standards like GTFS, or through apps like Where Is My Transport, helps customers plan and make better decisions about how to reach their destinations.

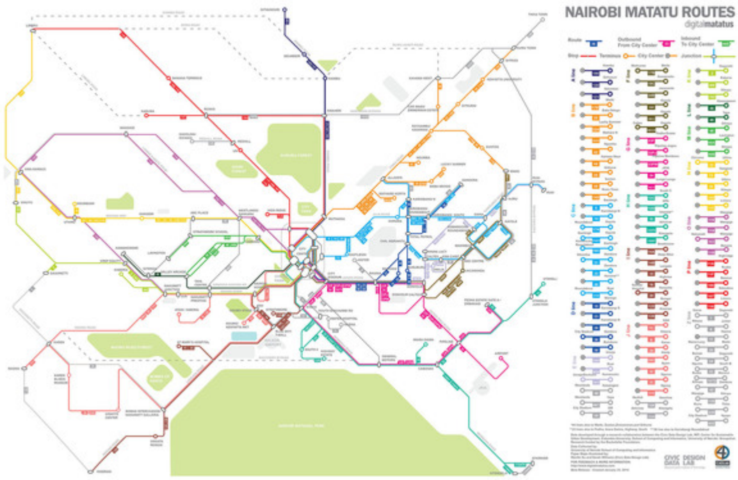

Figure 28.61. Conceived out of collaboration between Kenyan and American universities and the technology sector in Nairobi, the Digital Matatu project captured transit data for Nairobi, developed mobile routing applications and designed a new (and first) transit map for the city. *The Digital Matatu Project (www.digitalmatatus.com)*

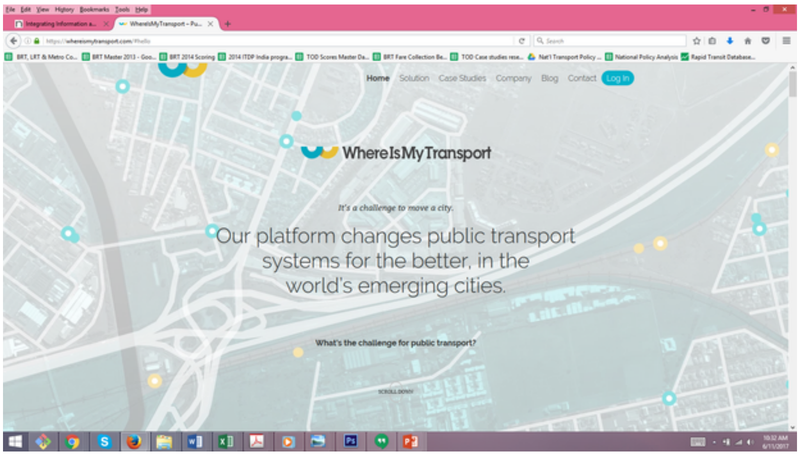

Figure 28.62. New platforms that aggregate transport service information is making it easier for customers to plan and make trips. *Where Is My Transport website.*

29. Pedestrian Access

> *"Whether you live in a city or a small town, and whether you drive a car, take the bus or ride a train, at some point in the day, everyone is a pedestrian."*
>
> — Anthony Foxx, politician, 1971–

A key component of BRT planning and design is the provision of safe, convenient, and secure access for pedestrians. If it is difficult to walk to a BRT station, then customers will be discouraged from using the system altogether.

Pedestrian access includes three critical components: (1) distance from the neighborhood to the corridor; (2) crossing the corridor to access the station; and (3) circulation inside stations. An effective pedestrian-access plan addresses each of these trip segments. Ignoring just one of these stages can render a system unusable for a large segment of the potential customer base. This chapter focuses on the first two components of customer access. For information on circulation inside stations, see Chapter 22: Roadway and Station Configurations and Chapter 25: Stations and Terminals.

A well-designed access system makes walking to a station safe, comfortable, and convenient. The best way to evaluate the quality of the pedestrian environment is to put oneself in the shoes of the user. Are the pedestrian sidewalks leading to the station well maintained and easy to walk on? Are they wide enough to handle existing and projected customer volumes? Are they safe at night? Does clear signage show the way to the station? Are there logical pedestrian connections between the station and major destinations such as shops, schools, and workplaces? Could someone in a wheelchair use them comfortably?

This chapter discusses key principles of the design of pedestrian facilities and station-area streets, and access to stations. It then introduces pedestrian-planning techniques that can be employed to evaluate the quality of existing infrastructure and identify priorities.

Figure 29.1. First component of pedestrian access to a BRT system: access routes through the surrounding neighborhood (Jakarta, Indonesia). *Michael King*

Figure 29.2. Second component of pedestrian access to a BRT system: crossing the corridor to reach the station (León, Mexico). *Michael King*

Figure 29.3. Third component of pedestrian access to a BRT system: circulation inside the station itself (Jakarta, Indonesia). *Chris Kost*

Figure 29.4. Unsafe pedestrian conditions along a roadway near Mexico City's metro system. *Michael King*

Figure 29.5. Pedestrian conditions connecting Mexico City's metro system to nearby municipal offices are not pedestrian-friendly. *Michael King*

Contributors: Chris Kost, *ITDP Africa*; Shreya Gadepalli, *ITDP India*; Michael R. King, *BuroHappold Engineering*

29.1 Principles of Pedestrian Planning

> *"Restore human legs as a means of travel. Pedestrians rely on food for fuel and need no special parking facilities."*
>
> — Lewis Mumford, writer, 1895–1990

This section discusses the six main principles of pedestrian planning:

- Safety;
- Security;
- Directness;
- Legibility;
- Comfort;
- Universal access.

29.1.1 Safety

A safe pedestrian route implies that pedestrians are well protected from road hazards such as moving vehicles. Dangerous conditions can be mitigated by addressing three root causes of pedestrian-vehicle crashes: vehicle speeds, pedestrian-exposure risk, and driver and pedestrian predictability.

Vehicle Speeds Vehicle speed has a direct impact on the severity of a crash. Vehicle volumes tend to correlate with frequency of crashes, but not their severity. Both vehicle volume and vehicle speed are controllable and are ultimately determined by the decisions of road designers and policymakers.

The relationship between vehicle speeds and the risk of death or injury has been well documented in a range of settings. Research suggests that a drop in speed of only 5 kph results in 10 percent fewer pedestrian fatalities and 20 percent fewer severe pedestrian injuries (Anderson 1997). At speeds of less than 32 kph there are almost no pedestrian deaths, while at 80 kph almost all vehicle-pedestrian incidents result in death (Scully et al., 2007). Thus, there is good reason why residential speed limits in countries with good traffic safety records are set at 30 kph or less.

Pedestrian-Exposure Risk Pedestrian "exposure" risk refers to the time that pedestrians are exposed to potentially dangerous traffic conditions. The exposure time is a factor of the distance between secure pedestrian facilities, the way traffic signals are phased, and the type of facility. Exposure has both temporal and spatial components. To reduce exposure risk is to increase safety.

Driver and Pedestrian Predictability Road users are constantly making decisions, and if other street users—walkers, cyclists, and drivers—can better predict those decisions, the street will be safer. Reducing the number of options for drivers at key junctions is the simplest way to improve driver predictability. Similarly, pedestrian facilities that follow intuitive movement patterns are more likely to be used, thereby improving the ability of drivers to predict where pedestrians will be present.

Figure 29.6. A redesigned intersection in Mexico City. The medians were extended into the intersection to reduce turning speeds and provide more pedestrian refuge areas, and crosswalks were brought into line with actual observed pedestrian movement. *ITDP*

29.1.2 Security

"Security" refers to providing an environment where pedestrians are not susceptible to robberies, sexual harassment, or other crimes. The physical design of streets, parks, buildings, and the relationships therein play a role in increasing the number of "eyes on the street," which in turn can increase security.

Figure 29.7. In Beijing, pedestrians are at risk from unsuspecting motorists. *Lloyd Wright*

Figure 29.8. Vendors and active storefronts in Chennai, India help keep this street environment safe at night *ITDP*

Figure 29.9. A continuous wall on this road in Kuala Lumpur means that there is no street surveillance offered by residents, passersby, and shopkeepers *Karl Fjellstrom, Far East BRT*

29.1.3 Directness

"Directness" involves a pedestrian path that minimizes the distance travelled to access the public transport station. Normally, locating stations near popular trip origins and destinations like shopping malls, large office complexes, or popular intersections will minimize pedestrian walking times. Small block sizes (e.g., one-half hectare) can ensure that direct walking routes are available from any location to the BRT station.

The level of directness is also influenced by pedestrian crossings and other design details at the micro level. For example, crossing facilities placed near pedestrian desire lines contribute to the directness of walking routes. Desire lines are the paths worn in unpaved areas, medians, and elsewhere that indicate where people travel. It is advisable to observe existing pedestrian behavior and then plan infrastructure interventions to ensure that these trips are made safely, rather than designing pedestrian facilities that attempt to force pedestrians to behave in ways that are highly inconvenient. Providing direct connections increases the likelihood that pedestrian behavior will be organized and predictable.

Figure 29.10. Pedestrian-access lanes that increase the permeability of city blocks can reduce walking times, and thereby improve access to public transport as is the case here in Guangzhou, China. *Karl Fjellstrom, Far East BRT*

Figure 29.11. Pedestrian alleyway in Nantes, France *Karl Fjellstrom, Far East BRT*

29.1.4 Legibility

The "legibility" of an area refers to the ease in understanding the street environment. The selective use of signage and maps contributes to a system's legibility. Likewise, design options such as infrastructure coloring determine how quickly customers understand system information. Good legibility can play a role in directing customers to a BRT system. Local-route signs along the pedestrian path both help customers find the BRT station and help pedestrians emerging from the station reach their destinations.

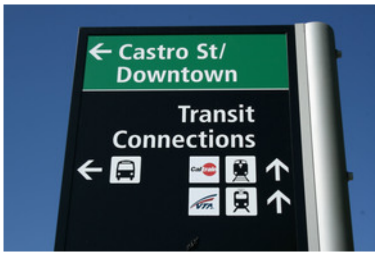

Figure 29.12. Pedestrian wayfinding in San Francisco separates attractions from transportation destinations through simple color-coding. *Nelson\Nygaard*

29.1.5 Comfort

The steepness of inclines, presence of weather protection, condition of the walking surface, and protection from noise and air pollution all affect the level of comfort enjoyed by pedestrians. In cities with extreme heat, shade can reduce temperatures by five to eight degrees Celsius, and thus make reaching a BRT station more comfortable. Additionally, the aesthetic value of the walking environment will play a role in the potential customer's disposition toward the walk. If the walk is pleasant and intriguing, then more customers will be attracted to the BRT system. System developers should assess the quality of pedestrian corridors connecting the BRT stations with major origins and destinations.

Figure 29.13. Arlington, Virginia, USA, incorporates simple directions with a map oriented toward the pedestrian's location. *Nelson\Nygaard*

29.1.6 Universal Access

"Universal access" refers to designs that allow customers with mobility limitations to access the system. The main considerations in accessible design are removing physical barriers, avoiding excessive customer volumes that impede timely access, providing a safe route, and minimizing conflicts and detours. Designing from the perspective of a parent with a stroller, a child, an older adult, or a physically disabled person can result in good design for everyone.

Accessible design does not end at the station door. There is little value in making station platforms and vehicles friendly to those with mobility limitations if it is impossible for these customers to reach the stations in the first place. Universal access is described in greater detail in Chapter 30: Universal Access.

Figure 29.15. Designing for the physically disabled also helps families with strollers and others carrying bicycles or large packages as shown at the Avenida Jimenez station in Bogotá. *Carlosfelipe Pardo*

Figure 29.14. Shade cover dramatically reduces pavement temperatures and makes walking more comfortable, as demonstrated by this walkway in Panama City, Panama. *Lloyd Wright*

29.2 Pedestrian Infrastructure in Station Precincts

"I am a slow walker, but I never walk backwards."

— Abraham Lincoln, 16th United States President, 1809–1865

For a potential BRT customer, the quality of the pedestrian infrastructure between the home or workplace and the BRT station can make the difference between using the system versus travelling by another mode. A new BRT system offers the opportunity to reevaluate pedestrian conditions and to develop a vastly improved pedestrian environment. The principles introduced in the previous section can help guide the design of the new facilities.

A few meters of quality infrastructure around the public transport station do little to attract customers from their homes and offices. High-quality pedestrian walkways should extend from BRT stations well into surrounding neighborhoods. Most pedestrians approach BRT stations from within a radius of approximately 1 kilometer. Surveys from TransJakarta indicated that 58 percent of customers walked fewer than 500 meters to the station, and an additional 31 percent came from locations within 500 meters to 1 kilometer (see Table 29.1). Therefore, pedestrian facilities should be upgraded at least within a 1-kilometer radius around each station. In order to do this, it may be necessary to evaluate how to integrate BRT implementation plans with the city's overall urban development plans. (BRT designs normally do not include areas larger than those directly near the station.)

Table 29.1. Walking distance at 1.5 meter per second

Time	Distance
5 minutes	450 meters
10 minutes	900 meters
15 minutes	1.35 kilometers
20 minutes	1.8 kilometers

Pedestrian facilities can take different forms, depending on the size of the street, the traffic volume, the character of street usage, and adjacent land uses.

29.2.1 Walkways

As stated above, reducing pedestrian exposure to fast-moving vehicles is critical to a safe walking environment. On arterial streets where vehicle speeds are likely to exceed 50 kph, it is essential to create a separate slow zone where there is adequate space for walking. If the slow zone takes the form of a sidewalk, it should meet the following design standards:

- A continuous unobstructed effective width of two meters (see box 29.1);
- No breaks or obstructions at property entrances and side streets;
- Continuous shade through tree cover or awnings;
- Separation from the roadway via a vertical curb (100 to 200 millimeters), physical barrier such as a series of bollards, or a setback;
- Adequate cross slope for stormwater runoff;
- Surmountable gratings over tree pits to increase the effective width of the sidewalk.

One way of characterizing pedestrian space on sidewalks is the "zone system," in which sidewalks are divided into three zones that serve separate purposes:

1. Pedestrian zone. This zone provides continuous space for walking and should be clear of any obstructions. It should be at least 2 meters wide;
2. Frontage zone. Provides a buffer between street-side activities and the pedestrian zone. Next to a compound wall, the frontage zone can become a strip of landscaping;
3. Furniture zone. This is a space for landscaping, furniture, lights, bus stops, signs, and curb cuts.

Well-functioning sidewalks incorporate each of these areas to reduce conflicts among uses.

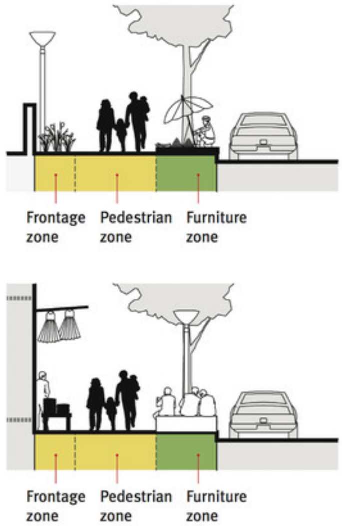

Figure 29.16. Sidewalks should include a frontage zone to buffer adjacent land uses and a furniture zone to accommodate underground utilities, trees, and furniture in order to ensure that the pedestrian zone remains free of encroachments or obstacles. *Diagram courtesy of ITDP's Better Streets, Better Cities (2011)*

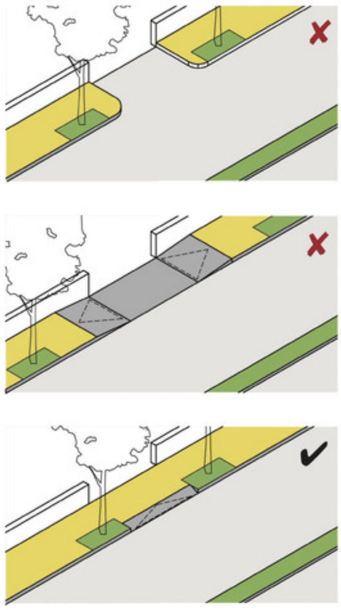

Figure 29.17. Where required to enable access to private properties, curb cuts should be provided in the landscaping strip, but not in the area of pedestrian through-movement. Ending the footpath with abrupt curbs, or lowering the entire footpath to the level of the roadway is unacceptable as property entrances may become waterlogged. *ITDP's Better Streets, Better Cities (2011)*

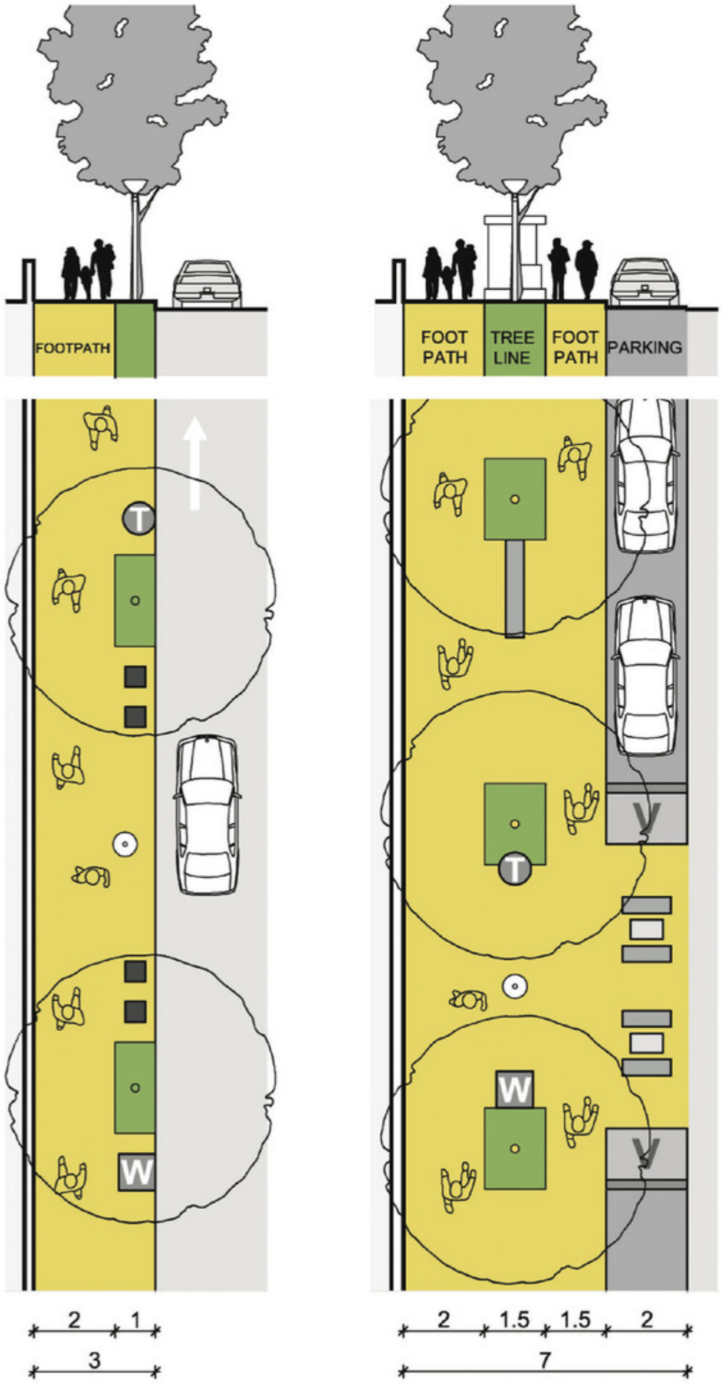

Figure 29.18. The smallest well-functioning footpath/tree package has a width of 3 meters, including a 2-meter clear space and 1-meter tree pits. Street furniture is positioned in line with the tree pits to maintain 2 meters of clear space. Wider footpaths can accommodate street vending and larger seating areas, and are recommended in areas with large pedestrian volumes. *Diagram courtesy of ITDP's Better Streets, Better Cities (2011)*

Box 29.1. Defining Effective Width

The notion of "effective width" of a sidewalk is central to sidewalk usability. The effective width refers to the amount of space that is actually available for pedes-trian through movement, and effective width determines the sidewalk's capacity and the level of pedestrian comfort.

Figure 29.19. Sidewalk along a BRT corridor in Ahmedabad, India. While the gross width of the footpath is around two meters, obstructions reduce the usable clear width to zero meters. *ITDP*

Figure 29.20. Another location along a BRT corridor in Ahmedabad, India where there is sufficient effective width for moderate pedestrian volumes. *ITDP*

29.2.2 Pedestrian Crossings

Formal pedestrian crossings should be provided at regular intervals along all major streets, including the BRT corridor itself. On arterials with great distances between intersections, it is common for pedestrians to cross at random points along the corridor. Providing safe, formal crossings encourages pedestrians to cross in designated locations. This increases predictability and allows pedestrians to benefit from safety in numbers when they cross the street.

Camera enforcement of speeding vehicles and police campaigns can be effective, but the most reliable method is to employ physical designs that compel motorists to slow down. While slowing vehicle speeds can compromise mixed traffic throughput, recent Dutch research has shown that it can frequently increase mixed-traffic

Figure 29.21. The lack of formal pedestrian crossings in Dhaka, Bangladesh, creates significant risks. *Karl Fjellstrom, Far East BRT*

capacity through a process known as "traffic smoothening," which ends the accordion action that can lead to traffic bottlenecks. Thus, pedestrian crossings should meet the following design standards:

- Except on expressways, pedestrian overpasses and subways are to be avoided;
- Raised crosswalks should be located at all intersections (both signalized and uncontrolled), and at frequent intervals (e.g., every 50 meters). Crosswalks should be as wide as the adjacent sidewalk, and never narrower than 2 meters;
- Raised crosswalks should be elevated to the level of the adjacent sidewalk with ramps for motor vehicles. The ramp should be designed as per the target speed of the street (e.g., a slope of 1:10 yields about a 20 to 25 kph vehicle speed whereas 1:12 yields 40 to 45 kph);
- Guardrails and high curbs are discouraged because they hinder pedestrian and cycle movements. They should be provided only on roadways with a curb-to-curb width of 18 meters or larger. Where fences are present, informal crossings in the form of breaks in the fencing should be provided at regular intervals (e.g., every 50 meters). The opening in the fence should be at least 2 meters in length in order to create a refuge island so that pedestrians do not spill over into the main roadway. Adjacent to BRT lanes, longer stretches of guardrail can be provided, with breaks only at formal crossings;
- At formal and informal crossings, parking lanes should be converted to bulb-outs to reduce the crossing distance and to lower vehicle speeds;
- On an artery where the curb-to-curb roadway width is 12 meters or wider, a continuous median surmountable by pedestrians (maximum elevation 150 millimeters) is advised. In order for the median to function as a safe pedestrian refuge, a minimum width of 2 meters should be provided;
- If pedestrian crossings are signalized, the waiting time should be minimized. The likelihood of compliance with pedestrian signalization falls greatly if wait times exceed 30 seconds (in a similar fashion, elevators are generally designed so that people do not have to wait more than 30 seconds);
- In an additional effort to enhance pedestrian safety, designers should consider including a median strip that will double as a pedestrian island, facilitating safer crossings for all pedestrians. As a result, the median will minimize the number of lanes that a pedestrian has to cross.

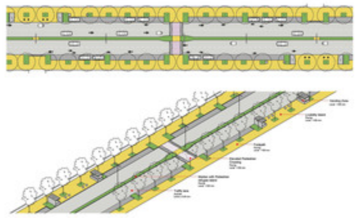

Figure 29.22. Formal pedestrian crossings, in which pedestrians remain at the same level as the footpath (e.g., +150 millimeters), and vehicles pass over ramps are required on major streets. Between formal crossings, hardscaped pedestrian refuge islands should be provided at intervals of approximately 50 meters. At both formal and informal crossings, curb extensions into the parking lane reduce the total crossing distance. *ITDP's Better Streets, Better Cities (2011)*

Figure 29.23. At this junction in Pune, India, a raised pedestrian crossing compels drivers to slow down and allows pedestrians to remain at the same level while crossing to the other side. *Chris Kost*

29.2.3 Intersections

Pedestrian-vehicle conflicts at intersections can be mitigated by reducing turning radii, simplifying the turning movements to two or three phases, restricting free right or left turns where possible, avoiding slip lanes where possible, and using the physical measures described above.

Separating the use of the intersection in time through turning restrictions and signal phasing can reduce pedestrian exposure. Free right and left turns improve vehicular travel times, but they are very dangerous for pedestrians. To optimize the intersection, the vehicular turning volumes should be weighed against the pedestrian volumes and the frequency of crashes. If turning volumes are relatively low, and pedestrian volumes and crashes are high, free right and left turns should be restricted. Reducing the number of phases can also help simplify turning movements and reduce the number of potential conflicts during the green phase of the signal cycle.

Figure 29.24. Raised intersection in Quito. *Lloyd Wright*

Figure 29.25. A median in the center of the road keeps drivers from swinging wide during a turn in Shenzhen, China. *Karl Fjellstrom, Far East BRT*

Where slip lanes must be maintained, building a pedestrian island and tightening the turning radius can slow turning vehicles, while reducing the distance pedestrians must cross to reach the other side of the road safely. In such cases, a "pork chop" slip-lane design will force vehicles to slow down where they enter the oncoming traffic, just at the point where pedestrians need to cross. A "pork chop" is a triangular island with a "tail" that faces oncoming traffic and controls speed and movements. Pork chops may serve as pedestrian refuges. Coupled with an elevated crosswalk, this slip lane can significantly improve an intersection's pedestrian safety.

Where separate pedestrian signals are available, a novel technique to reduce pedestrian exposure at intersections is the "leading pedestrian interval." Under such an arrangement, a pedestrian-only phase begins a few seconds before the vehicle phase. This permits a pedestrian to get halfway across the street and establish their presence in the crosswalk before vehicles start turning, thus increasing the chance that drivers will yield as required.

29.2.4 Shared Space

Small local streets where vehicle speeds are low may not require separate pedestrian footpaths. Where a BRT system goes through a city center or on smaller access roads, there may be opportunities to implement "shared space," in which all physical differentiation between vehicle and pedestrian space is removed.

Figure 29.30. Many streets in Mumbai, India, and other Indian cities function as safe shared spaces. *ITDP*

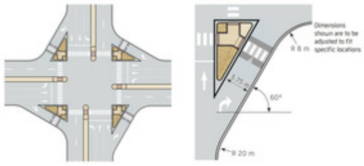

Figure 29.26. A pedestrian island, in conjunction with a tightened turning radius (right), can do much to benefit pedestrian safety (left). *Emirate of Abu Dhabi*

Figure 29.27. A raised crosswalk on the Delhi, India, busway helps reduce the speed of left-turning vehicles. *Chris Kost*

Figure 29.28. Pedestrian phase of a leading pedestrian interval in New York City. Pedestrians are permitted to begin crossing the intersection before vehicles get a green light. *Michael King*

Figure 29.29. Vehicle phase of a leading pedestrian interval in New York City in which vehicles are given a green light only after pedestrians are allowed to begin crossing *Michael King*

Figure 29.31. However, on arterial streets where motor vehicle speeds are high, and there are no designs aimed at speed reduction; these ad hoc "shared space" arrangements are unsafe and inconvenient for pedestrians. *ITDP*

In shared space, the roadway is designed to look like a public plaza where motor vehicles do not belong, sending a visual signal to motorists that they should slow down. Often, simply redesigning a street to look like a pedestrian zone alone, with no restrictions on motorist access, will fundamentally change driver behavior in this environment. There are no traffic signals or explicit signage to dictate who has priority. People must resort to eye contact and other forms of subtle communication to navigate the roadway safely.

Shared space along a BRT corridor is closely related to the transit mall concept introduced in Chapter 23: Roadway Configuration. BRT vehicles intermingle with pedestrians and other non-motorized users. The sharing of space will likely affect public transport vehicle speeds. However, this concept is successfully utilized along corridors such as Avenida Jimenez in Bogotá, and Line 4 in Mexico City.

Figure 29.32. Avenida Jimenez in Bogotá only allows BRT and non-motorized access. *Diego Velazquez*

Shared space is also relevant to BRT in the context of safe routes to accessing stations. Pedestrian corridors connecting to the station can benefit from an application of shared space, which will reduce speeds of private motorized vehicles and thus encourage more persons to utilize the public transport system. Pedestrianizing pathways leading to the public transport system can be part of a mutually beneficial strategy for both public transport and public space. A pedestrian zone, especially in city center locations, can help concentrate large numbers of customers around the BRT system. The public transport system likewise supports pedestrian areas by reducing the demand for city-center parking. Without high-quality public transport, it is much more difficult to allocate the space needed for full pedestrianization while providing easy access for personal vehicles.

Figure 29.33. Public transport, pedestrians, and cyclists amicably share space in Biel, Switzerland. *Lloyd Wright*

Figure 29.34. In Curitiba, a pedestrian mall leads directly to BRT stations. *Cara Seiderman*

Figure 29.35. A shared space environment such as this street in Amsterdam can make for a safe corridor for accessing public transport. *Cara Seiderman*

Figure 29.36. Due to the ease of use and directness of at-grade crossing, customers almost always prefer them (Quito). *Lloyd Wright*

Figure 29.37. A steep, narrow stairway in Beijing makes for poor accessibility to the busway. *Lloyd Wright*

Figure 29.38. This overpass in Mexico City is virtually ignored as most pedestrians choose to cross directly. *Michael King*

29.3 Station Access

"Pedestrians are hardly pedestrian, because we all have to cross the road."

— Robert D. Dangoor, author

One of the most common questions in the design of a new, center-running BRT system is: "How will the customers get to the BRT station if it is in the center of the roadway?" Safe pedestrian access is required for both standard and BRT systems. Even with normal curbside bus stops, customers need to cross streets for their return trip.

The most significant BRT-access decision is typically whether to utilize at-grade crossings (street-level crosswalks) or grade-separated infrastructure (overpasses or tunnels). As a general rule, at-grade pedestrian crossings are the most convenient way for pedestrians—and people with disabilities—to access a BRT station. As described in the previous section, at-grade crossings can generally be made safe through various traffic-calming measures.

Grade separation reduces the exposure risk to pedestrians, but significantly increases their inconvenience. Pedestrian overpasses or underpasses are usually designed with the primary aim of getting pedestrians out of the way of vehicle traffic—not to enhance the safety and convenience of pedestrians. In cities around the world, pedestrians avoid such infrastructure because it is poorly located, overly steep, badly maintained, or inherently crime-ridden. The narrow confines and infrequent usage of these spaces mean that criminals have greater opportunities for theft and assault. If the overpass or underpass requires walking up and down stairs, many individuals will simply not be able to make use of the infrastructure. The physically disabled, elderly, and parents with strollers will essentially lose access to the public transport system. Studies indicate that 70 percent of pedestrians would use an overpass if the travel time equaled the at-grade crossing travel time, and very few would use an overpass if the travel time were 50 percent longer than at-grade crossing (ITE 1998). Therefore, BRT station access should generally be provided at grade.

Figure 29.39. With traffic stopped at a signal crossing in Jakarta, Indonesia, pedestrians prefer to cross without the use of the overpass. *Walter Hook*

There are some conditions where topography, vehicle speeds, and traffic levels may make grade separation a reasonable option. If a median station is flanked by high-volume, high-speed, multiple-lane expressways far from any intersections, the constant flow of high-speed vehicles will be almost impossible to cross. The conditions that may imply the need for grade-separated access to a median BRT station include:

- Four lanes or more of traffic to cross per direction along a high-volume, high-speed arterial or expressway;
- Connecting an underground subway station to a median BRT station (a tunnel will be most effective in this situation);
- Overpass or underpass leads directly to a high-demand destination, such as a sports facility, school, or shopping complex.

Even in these situations, there are design solutions that can frequently make at-grade crossing reasonably safe and feasible. However, if pedestrian overpasses in these conditions are a reasonable option, they may even be preferred if they reduce overall crossing time and improve the walking environment.

29.3.1 Designing Effective At-Grade BRT Access

When the BRT station is at or near an intersection, pedestrians can cross with the rest of the traffic during the green signal phase. Measures suggested above for safe intersection design are generally applicable: elevating crosswalks across slip lanes; creating additional pedestrian-refuge space; reducing vehicle-turning radii; and extending medians. Signal phases should be planned to prevent conflicts between turning vehicles and pedestrians.

Figure 29.40. For stations at intersections, customers can reach the station during the green phase as shown here in Guadalajara, Mexico. *Michael King*

Figure 29.41. Pedestrian island allows for safe crossing to and from the BRT station in São Paulo, Brazil. *Michael King*

BRT stations are often placed away from intersections to increase queuing space for public transport and private vehicles at intersections. When the BRT station is mid-block, a few additional design considerations apply. The crossing should include elements that signal to the driver that he or she is approaching a pedestrian crossing, such as signs, lighting, vertical markers, and overhead indicators. As described in the previous section, an elevated crosswalk or a speed bump placed before the crosswalk helps force motorists to slow down. Pedestrian-refuge islands between lanes and narrower lane widths also reduce pedestrian-exposure time. Using different surface colors and textures will draw further attention of motorists. Lighting at the crosswalk at night is important.

Several different types of signaling options may be employed at mid-block crossings. If pedestrians only have to cross two lanes, and where speeds and vehicle volumes are not that high, signals may not be necessary at all. As traffic speeds, volumes, and lanes increase, the need for standard red-yellow-green signals mid-block also tends to increase.

Figure 29.42. Example in Berlin of a pedestrian crosswalk with vertical elements indicating to drivers the location of the crosswalk. *Michael King*

Figure 29.43. Example in Toronto of a pedestrian crosswalk with vertical elements indicating to drivers the location of the crosswalk. *Michael King*

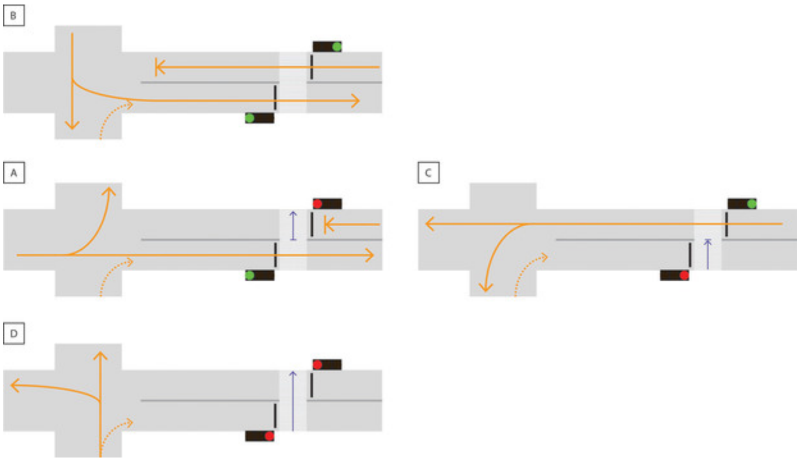

Figure 29.44. Signals can be timed to correspond to the red-and-green time at the nearest intersection to reduce the delay for mixed traffic. *ITDP*

Street Family	Vehicle ADT < 9,000			Vehicle ADT > 9,000 to 12,000			Vehicle ADT >12,000 to 15,000			Vehicle ADT > 15,000		
	Speed Limit											
	≤ 30 km/h	40 km/h	60 km/h	≤ 30 km/h	40 km/h	60 km/h	≤ 30 km/h	40 km/h	60 km/h	≤ 30 km/h	40 km/h	60 km/h
Street	●	●	N/A	●	●	N/A	●	●	N/A	●	○	N/A
Avenue	●	●	○	●	○	■	○	○	■	■	■	■
Boulevard	■	■	■	■	■	■	■	■	■	■	■	■

● Acceptable to use marked uncontrolled ○ crossing

■ Consider traffic calming, signal, or other Do not use marked crosswalk without a signal, and consider additional traffic calming measures

Figure 29.45. Recommendations for installing pedestrian crossings at mid-block locations based on vehicle speed, vehicle volume, and street type. On a two-lane street with low volumes and speeds, a marked crosswalk will suffice. As speeds, volumes, and/or widths increase, additional measures and/or signals are needed. *Nelson\Nygaard*

Figure 29.46. This pedestrian crossing in León, Mexico, is 100 meters away from the BRT station, and thus will tend to encourage people to cross closer to the station, away from the zebra crossing. *Michael King*

Figure 29.47. In São Paulo, this mid-block station is served by a pedestrian overpass, but does not have physical separation to keep customers from crossing travel lanes to access buses. *Michael King*

Figure 29.49. These "Blue Hearts" in Quito mark the spot where two pedestrians lost their lives while taking the most direct route to the BRT station. *Lloyd Wright*

It is generally possible to signalize the crossing for the mixed-traffic lanes while allowing bus vehicles to continue without a light. Pedestrians then cross the busway whenever a gap appears. At higher vehicle volumes, the public transport vehicles should also be controlled by a traffic signal. Especially in BRT systems with very high

Figure 29.48. This BRT-identification post in Quito is placed in a pedestrian island, and acts to block the pedestrian's view of both oncoming mixed traffic as well as oncoming BRT vehicles. *Lloyd Wright*

demand (i.e., over 10,000 customers per hour per direction), an additional pedestrian-refuge island should be provided between the BRT lanes and the general traffic. This island can be dimensioned to a convenient size for the projected customer demand.

Station areas are prone to unpredictable pedestrian behavior, as customers have a tendency to run to catch an approaching bus or train without paying attention to signals. Motorists may not be expecting this type of pedestrian movement, particularly in mid-block locations. Therefore, at-grade crossings should be placed as close to the station entrance as possible. Otherwise, customers may simply cross at an uncontrolled point closer to their intended destination. Planners should strive to fully account for likely human behavior whenever designing a pedestrian crossing.

The areas to the side of the roadway should allow for clear visibility, so that the sight lines of both pedestrians and vehicle users are unimpeded by signage or vegetation. Signage for the BRT system, trees and shrubs, and other potential obstructions should be carefully placed to avoid blocking pedestrian sight lines.

29.3.2 Designing Effective Grade-Separated BRT Access

When designing grade-separated pedestrian access, the following design considerations come into play:

- Illumination. Overpasses and tunnels should be well lit to increase security;
- Visibility. There should be clear lines of sight between the bridge or tunnel, station, and street to increase security;
- Width. Overpasses and tunnels should be wide enough to accommodate peak-hour demand;
- Ramps, escalators, or elevators. The overpass or tunnel should be accessible to a person in a wheelchair, a parent pushing a stroller, someone with a bicycle or packages, or one who has trouble climbing stairs. If elevators are used, stairs must also be provided for circumstances when the lifts are not functioning;
- Flood protection. Tunnels must be supported by an effective drainage system;
- Cleanliness. If the bridge or tunnel is perceived as unsafe or unclean, it will not be used, regardless of the design.

The design of overpasses in Bogotá demonstrates how an effective grade-separated solution can be achieved. Bogotá provides a ramped entry to the overpass, with a gradual slope to ease the climb. Customers typically also have the option of a stairway if they wish to access the overpass more quickly. Utilizing a 2.5-meter-wide pedestrian space and an open design, Bogotá's pedestrian bridges alleviate many of the security concerns normally associated with overpasses. The long ramp may be an inconvenience for some; it is possible to have shorter, steeper stairs for the able-bodied, such as in Beijing.

Figure 29.50. Direct connection from an overpass to the BRT station in São Paulo. *Michael King*

Figure 29.51. A well-lit pedestrian tunnel in Bogotá. *Carlosfelipe Pardo*

Figure 29.52. Cyclists using ramps along stairs in Guangzhou, China. *Michael King*

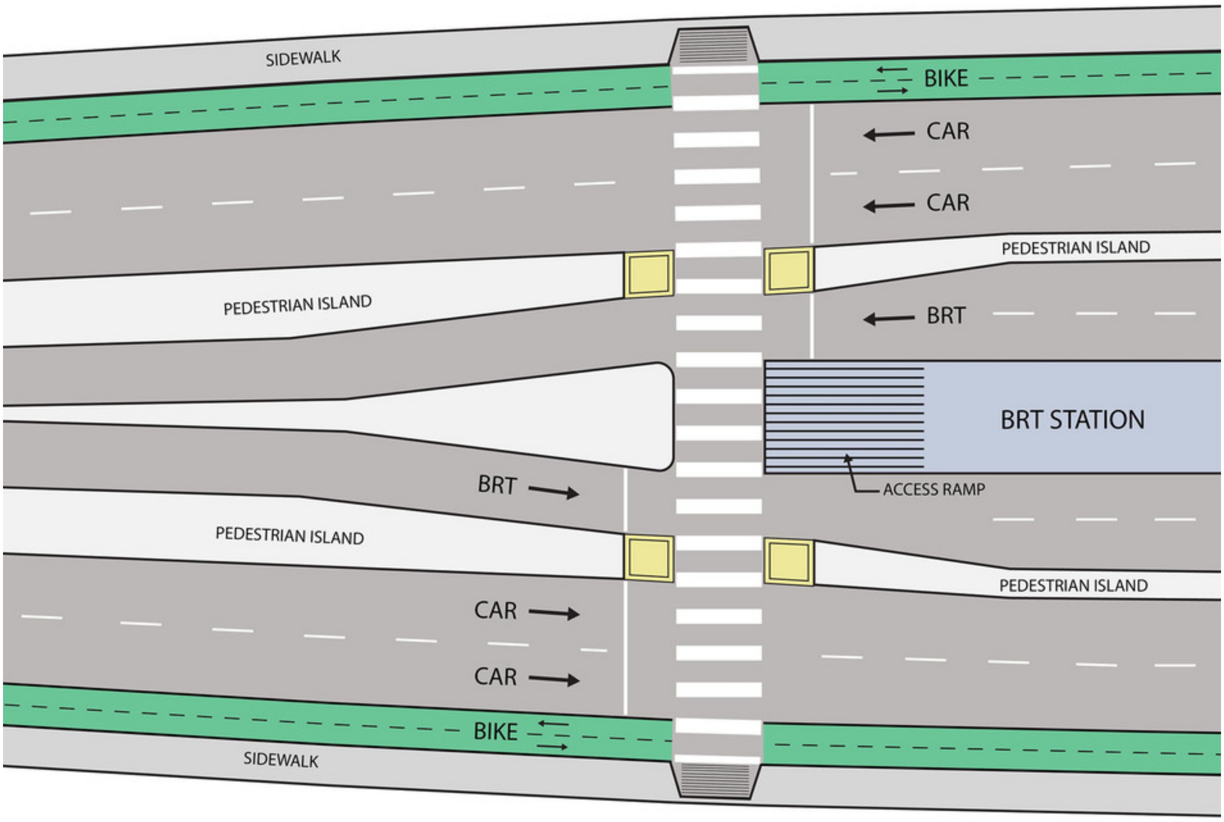

Figure 29.53. Pedestrian islands should be constructed between the busway and mixed traffic lanes. *ITDP*

29.4 Planning Process

> *"Planning is bringing the future into the present so that you can do something about it now."*
>
> — Alan Lakein, author, 1938-

After the general routing and station locations of the BRT are determined, efforts are needed to tie the stations into the existing or proposed pedestrian network. An audit to evaluate the quality of the existing pedestrian infrastructure along these corridors can locate potential problem areas. Other types of surveys can document pedestrian movement patterns. With this information in hand, priority areas for improving pedestrian conditions can be identified and included in the BRT budget.

29.4.1 Station Adjustment

Once the station locations have been preliminarily identified, a closer look at the micro-network can take place. This includes existing (or planned) crossing opportunities, desire lines, minor intersections, ideal crosswalk locations, and so forth. The idea is to adjust the station location so that it may enhance pedestrian activity.

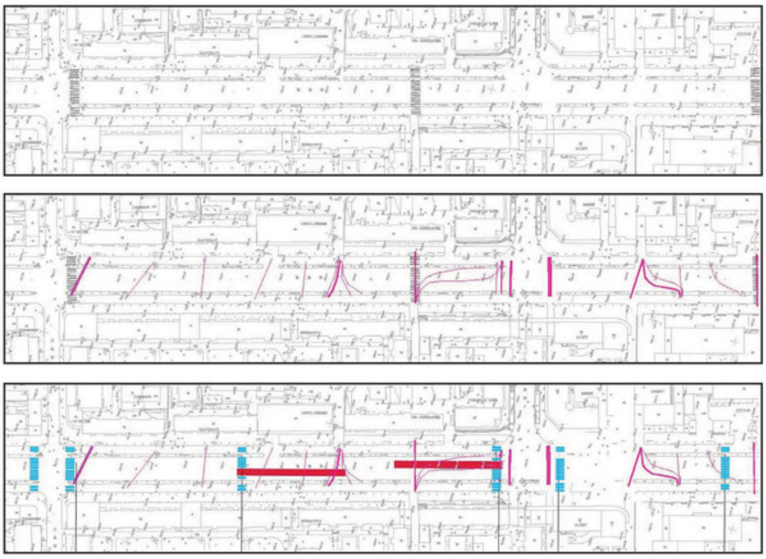

Figure 29.54. This series of images from Lanzhou, China, demonstrates how a tracking survey is used to inform the location of a BRT station. The top image shows the existing roadway. The middle image overlays a tracking survey (the smallest line represents 10 people, while the largest is 500). As shown, some people cross at the designated crosswalks, while many cross elsewhere, such as at intersections and where small streets intersect the larger road. The last image shows the BRT station and proposed crosswalks, which try to accommodate as many of the crossing patterns as possible. *ITDP*

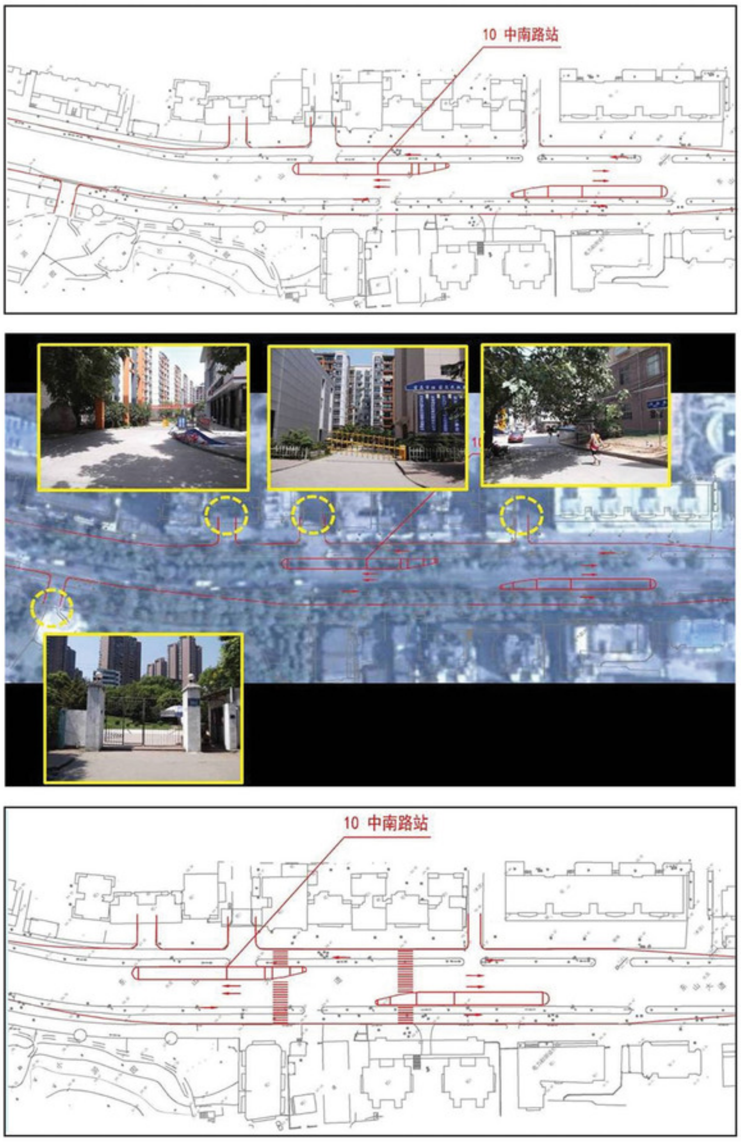

Figure 29.55. This series of images from Yichang, China, shows how a BRT station location is slightly adjusted to better serve the surrounding pedestrian network. The top image shows the initial layout. The second image locates adjacent streets and crossing opportunities. In the last image, the station has been moved to the left and crosswalks added. *ITDP*

Figure 29.56. Survey teams assessing the walking conditions in Rajkot, India *Michael King*

Figure 29.57. Survey team assessing the walking conditions in Pune, India *Michael King*

29.4.2 Pedestrian Infrastructure Audits

Evaluating the quality of the pedestrian infrastructure in a station area is not complicated. A quick visual scan of the area around the station can usually determine whether good-quality sidewalks exist, whether good-quality crossing facilities have been provided, whether proper lighting exists, and whether pedestrian facilities are free of encroachments.

The principal tools for conducting a pedestrian infrastructure audit are a map, a camera, and a device for measuring distances. As the audit team walks along the corridor, the following features are observed:

- Width of the clear space available for walking, noted at periodic intervals;
- Number of obstructions on the sidewalk, both permanent (e.g., building encroachment) and temporary (e.g., a parked car, vending stand, or construction debris);

- Number of pedestrian facilities/elements, such as trees, street vendors, seating, garbage bins, and public toilets;
- Number of pedestrians on walkway, in street, and in plazas.

The last indicator is an overall measure of the success of the surveyed facility at attracting users. If most pedestrians are not using the walkway, this is a clear sign that a design or management issue needs to be resolved. Once this information is collected, street environments can be ranked based on their positive and negative attributes.

The evaluation of the pedestrian environment should be standardized to allow performance measures to be tracked. The United Kingdom's Transport Research Library developed a standardized review process called the Pedestrian Environment Review System (PERS) that includes the criteria seen in Table 29.2. Tied to software that maps the indicators, it is possible to evaluate walking environments near station areas.

Table 29.2. Pedestrian Environment Review System (PERS) criteria

Pedestrian Route Review	Pedestrian Link Review	Pedestrian Crossing Review
Directness	Effective width	Crossing provision
Permeability	Dropped curbs	Deviation from desire line
Road safety	Gradient	Performance
Personal security	Obstructions	Capacity
Legibility	Permeability	Delay
Rest points	Legibility	Legibility
Quality of environment	Lighting	Legibility for the sensory impaired
Contributing link reviews	Tactile information	Dropped curbs
Contributing crossing re-views	Color contrast	Gradient
	Personal security	Obstructions
	Surface quality	Surface quality
	User conflict	Maintenance
	Quality of environment	
	Maintenance	

Source: Reproduced from Reid, Stuart (2003), "Pedestrian Environments: A Systematic Review Process."

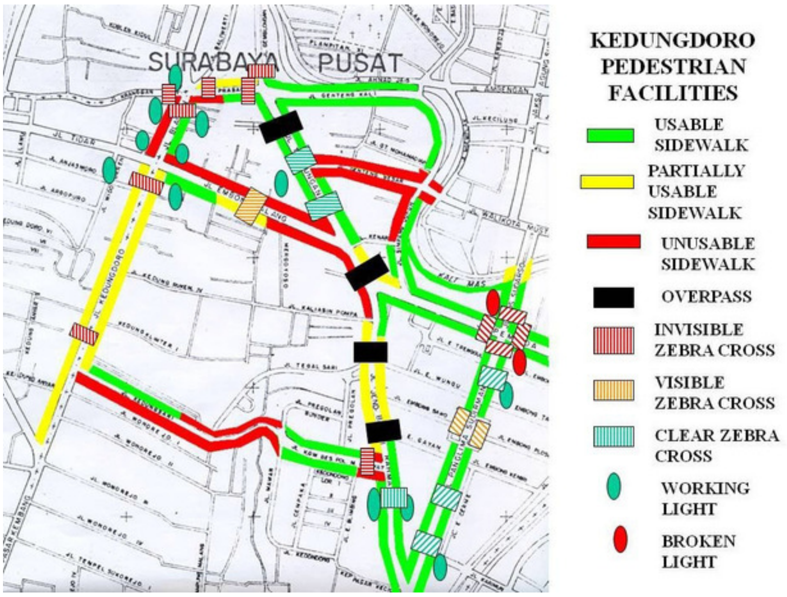

Figure 29.58. Results of street audit for Surabaya, Indonesia, with the quality of the pedestrian environment color-coded according to usability: green, usable; yellow, partially usable; and red, unusable. *GIZ and ITDP*

29.4.3 Tracking Surveys

Pedestrian-tracking surveys are a useful way to document how people use a street, intersection, or plaza. Tracking surveys are usually conducted at complex intersections and public transport facilities, particularly if these facilities or intersections have been identified as having a high number of pedestrian injuries and fatalities. Insights from the survey can inform the design of pedestrian improvements. Just as traffic counts are an important input element in the BRT modeling and operational planning process, pedestrian counts and pedestrian movements are needed to understand issues around station access.

The basic technique for tracking pedestrians is to position several surveyors throughout the location. As someone walks past, the surveyor records on a map exactly where he or she walked, crossed the street, turned around, and so on. The surveyors do not actually follow anyone, but observe all movements from a single location. The survey can last 20 to 60 minutes, depending on how long it takes to establish the walking patterns. The survey should be conducted across different periods since usage patterns vary by the time of day. For example, morning and evening flows may be reversed, and an optimum design should accommodate the peak flows in both directions. Rather than rely upon a team of surveyors to catch pedestrian movements as they occur, an alternative methodology is to record a video of an area and review the footage at a later time. Aerial photos also indicate where most pedestrians want to go by capturing the tracks they leave in landscaped areas.

Once the pedestrian flows have been displayed on a composite diagram, the movement patterns can be used to design curb extensions, new sidewalks, and other facilities. The survey should be conducted once again after the public transport station is opened to see if the design worked.

Just as a public transport corridor is designed to handle a particular customer volume, a pedestrian corridor also possesses an inherent capacity. If a walkway is too closely packed, then the desirability of walking is compromised. Crowded conditions cause delay and create the opportunity for crimes such as pickpocketing and sexual harassment. In general, the effective width of a walkway should be 1.5 to 2 meters in low-volume areas, and 3 to 4 meters in commercial areas. In areas that routinely have more foot traffic, a wider walkway is necessary. The formula for calculating such a width is provided below as per Herbie Huff and Robin Liggett's 2014 The Highway

Figure 29.59. Despite efforts to force pedestrians to take alternative routes at Jakarta, Indonesia's Blok M, most customers still prefer to enter by the direct, at-grade approach. *Lloyd Wright*

Figure 29.60. Aerial image recording pedestrian tracks in Brasília, Brazil. Formal pedestrian facilities can be constructed in these locations. *Michael King*

Figure 29.61. Aerial image recording pedestrian tracks in Cape Town, South Africa. Formal pedestrian facilities can be constructed in these locations. *Michael King*

Capacity Manual's Method for Calculating Bicycle and Pedestrian Levels of Service: The Ultimate White Paper, which pulls the equation from the 2010 Highway Capacity Manual:

$$F_w = 1.2276 \ln(W_v + 0.5W_1 + 50p_{pk} + f_b W_{buf} + f_{sw} W_{aA})$$

Where:

- F_w = width of the crossing;
- W_v = effective width of the outside through lane, bike lane, and shoulder width;
- W_1 = effective width of the combined bike lane and shoulder width;
- p_{pk} = proportion of on-street parking occupied;
- f_b = buffer area coefficient;
- W_{buf} = buffer width between roadway and sidewalk;
- f_{sw} = sidewalk coefficient;
- W_{aA} = adjusted available sidewalk width.

It is important not to oversize a walkway, lest it be barren.

Figure 29.62. The limited capacity of this walkway at a public transport interchange in Hong Kong reduces the pedestrian level of service. *ITDP*

29.4.4 Crash Mapping

Determining where vehicles hit pedestrians and other vulnerable road users is a fundamental step in safety analysis in general, and for planning a BRT station in particular. Planners should first collect traffic-crash data for incidents involving non-motorized road users from the police and map the locations as precisely as possible. A division between intersection and non-intersection crashes is required. Even though the numbers are likely to be significantly underreported, this simple mapping exercise should make it possible to identify particularly dangerous locations.

Once an especially dangerous location or a future station area has been identified, more detailed analysis should be conducted. Researchers at Lund University in Sweden have developed a "conflict-analysis" technique where a location is observed, and conflicts between various roadway users are recorded. These "conflicts" can include near misses, evasive maneuvers, or simply a reduction in speed. This information complements the crash statistics to help paint a complete picture of safety issues at the location.

Careful analysis of these locations showed that by far the largest number of serious pedestrian crashes and fatalities occurred in the slow lane of the higher-speed section of the BRT corridor, and determined that the primary cause was competition for customers among BRT drivers and other commercial vehicles in the curb lane. The next most dangerous location was high-speed access and egress ramps onto highways. The next most-dangerous location was at poorly lit underpasses where many people were crossing to catch buses and motorcycle taxis going in the opposite direction. Next were crashes in the fast lane, caused by pedestrians crossing the roadway due to the inconvenience of walking to the nearest pedestrian overpass. As is consistent with research from India, but inconsistent from research of higher-income economies, very few crashes were taking place at intersections or roundabouts.

This comparison showed that higher pedestrian volumes are not necessarily accompanied by more deaths and severe injuries. In fact, vehicle speed was the most representative indicator of injury severity. Pedestrian volumes usually mean numerically more people getting hit, but generally with less severe outcomes. This "safety in numbers" argument is borne out by the research.

Table 29.3 shows crash costs as calculated by the United States government in 2010 dollars. The median external cost of a crash is about US$45,000. This includes costs typically absorbed by local governments (police departments, EMS services, property damage). The external and internal cost is about US$160,000. This includes market productivity and household costs. The median quality of life years cost is about US$320,000.

Table 29.3. Crash Costs

CRASH COSTS	Property Damage Only	Minor Injury	Serious Injury	Critical Injury	Fatal Injury
Medical	US$0	US$2,999	US$58,584	US$418,896	US$27,840
Emergency Services	US$39	US$122	US$464	US$1,074	US$1,050
Legal Costs	US$0	US$189	US$19,918	US$100,619	US$128,694
Property Damage	US$1,870	US$4,843	US$8,567	US$11,902	US$12,944
Market Productivity	US$0	US$2,204	US$90,032	US$552,768	US$750,151
Household Productivity	US$59	US$721	US$26,555	US$188,128	US$241,342
Insurance Administration	US$146	US$934	US$23,805	US$85,928	US$46,771
Workplace	US$64	US$318	US$5,375	US$10,321	US$10,965
Travel Delay	US$1,012	US$97	US$1,184	US$11,526	US$11,526
Market Cost	US$3,190	US$13,308	US$234,482	US$1,381,163	US$1,231,282

Source: L. Blinco, A. Seay, E. Zaloshnja, T. Miller, E. Romano, S. Luchter, R. Spicer. May 2002. The Economic Impact of Motor Vehicle Crashes 2000 (costs in US dollars). National Highway Traffic Safety Administration.

Table 29.3 lists weight factors that can be used to determine the relative safety of a location or area. This list includes direct costs (property damage, emergency medical services, medical treatment, lost productivity, insurance payouts) and indirect costs (insurance premiums, automobile safety features). These multipliers can be applied to existing crash data to show the approximate annual cost of the existing roadway configuration. This list can also be used to estimate potential cost savings of a proposal relative to the cost of construction.

Table 29.4. Factors to Determine the Relative Safety of a Location

Factor	Severity
1,300	Fatality
90	Incapacitating injury
18	Evident injury

10	Possible injury
1	Property damage only

Source: Homburger, W.S., Hall, J.W., Loutzenheiser, R.C. and Reilly, W.R., 1996. Fundamentals of Traffic Engineering. University of California, Berkeley.

Box 29.2. The Limits of Crash Statistics

Vehicle-vehicle incidents and incidents involving fatalities are typically reported with reasonable accuracy, and need not be adjusted. However, research indicates that only 35 to 85 percent of vehicle-bicycle and vehicle-pedestrian incidents involving injury are included in typical crash statistics. A study of California children estimated that police reports only cover 80 percent of hospital admissions (Agran et al., 1990). A British study found that only 67 percent of slight injuries to pedestrians were reported, while 85 percent of serious injuries were (James, 1991). In Germany, the figures are 50 percent for major injuries and 35 percent for minor ones. Based on this research, it is appropriate to adjust vehicle-bicycle and vehicle-pedestrian injury statistics upwards by at least 50 percent (Hautzinger, 1993).

29.4.5 Origin-Destination (OD) Studies

By identifying the likely origins and destinations of pedestrians and the most travelled walking routes, planners and designers can prioritize infrastructure improvements in the most effective locations. If the most common walking routes are not inherently clear, it is sometimes helpful to do a localized Origin and Destination (OD) survey of customers disembarking at a BRT station to determine their final destinations. The survey should record all trips, regardless of the mode currently being utilized. If certain OD pairs show a very high proportion of short motorized trips, it may be because the pedestrian facilities are of very poor quality. Often, popular short OD pairs currently dominated by motorized modes can indicate locations where pedestrian improvements might be prioritized. When new pedestrian facilities along the TransJakarta system were opened, taxi drivers in the corridors complained of losing a considerable number of short fares.

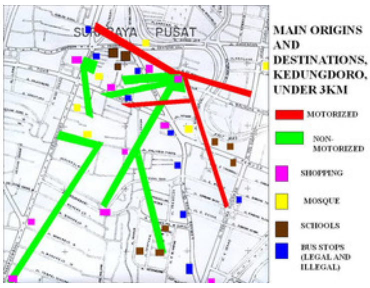

Figure 29.63. Origin-destination map from Surabaya, Indonesia, showing non-motorized trips in green and motorized trips in red. The short trips taken by motorized modes indicate that there may be a severance problem, and that these trips could otherwise take place by walking. *ITDP*

Another type of mapping that can provide useful insights into severance problems is to record travel times from the station. Maps showing areas covered in such intervals as 1 minute, 5 minutes, 10 minutes, 20 minutes, and 30 minutes not only indicate the potential catchment area for the station, but may also highlight potential barriers to pedestrian access. For example, a busy roadway near the station may create severance issues for approaching pedestrians. Other impediments, such as blocked or nonexistent pavements, will become evident in a time-based mapping. Also, long signal cycles for pedestrian crossings will increase walking travel times. This type of analysis can often show areas where distances are relatively short but pedestrian travel times are lengthy.

29.4.6 Detour Factors

Detour factors are the distance that the average pedestrian, cyclist, or pedicab operator needs to travel out of their way in order to reach their destination, relative to the straight-line distance. In a typical European or American traffic grid with no restrictions on non-motorized vehicle travel, the detour factors are generally very low. A detour factor of 1.2, as observed in Delft in the Netherlands, is extremely low. This level means that the average cyclist only needs to travel 20 percent farther than a straight-line distance in order to reach the destination. Unsafe, high-speed roads can create severance problems by restrictions on non-motorized vehicles on specific streets, by barriers to crossing streets, by a one-way street system, a lack of a secondary and tertiary road network, and by large canals, railroad tracks, and other impassable infrastructure.

It is fairly typical in lower-income countries for distances between intersections to be 1 kilometer or greater. Normally pedestrians are able to cross reasonably safely at grade at intersections, but sometimes traffic planners even discourage at-grade crossings at intersections in order to allow free left- or right-hand turns without any pedestrian conflicts. Traffic planners also like to erect barricades that try to force pedestrians to cross major roads only at designated pedestrian overpasses, and frequently, these overpasses are as much as a kilometer apart. In these typical conditions, if a pedestrian simply wants to cross a 50-meter wide street, and the nearest overpass is 225 meters away, the pedestrian will have to walk 500 meters to go a straight-line distance of 50 meters. This distance represents a detour factor of 1:10. At a moderate walking speed of 1 meter per second, this represents a 7.5-minute detour. This situation is a reason why pedestrians frequently refuse to use pedestrian overpasses.

Pedestrian connectivity to a BRT station is also a function of the layout of area roads and paths, with and without pedestrian infrastructure. It is fairly typical in lower-income economies for the secondary street system to be extremely weak. Residential areas often connect to major arterials only at a very limited number of access points, and these local streets rarely connect to other residential areas except via the major arterials. Street networks that rely on a high number of minor roads that do not connect with each other severely limit the pedestrian's ability to reach the BRT station. This pattern reduces the functionality of the BRT station, since it requires longer trips to reach destinations. Conversely, networks developed on an interconnected grid system provide greater accessibility, because streets are more connected, which allows pedestrians to travel directly to BRT stations. A grid street system also tends to be more resilient, because the system will not fail if one link is blocked. It is sometimes possible to find locations for small pedestrian shortcuts to reduce high detour factors caused by the lack of a secondary street system.

29.5 Bibliography

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30. Universal Access

> *"Mind the gap"*
>
> — London Underground

The rapid spread of Bus Rapid Transit (BRT) presents a historic opportunity to create models of accessible public transport for customers with disabilities. These benefits also extend to a wide range of typically underserved patrons, including the elderly, women, and children. Accessible BRT systems can move the more than 130 countries that have ratified the United Nations Convention on the Rights of Persons with Disabilities closer to their goals.

This chapter begins with a discussion of how universal design benefits all users and how to include the disabled community in the planning and design process. The main portion covers accessibility within stations and terminals, station-vehicle interface, and vehicle access. It discusses accessibility of the infrastructure surrounding the station, although this is covered in more detail in Chapter 29: Pedestrian Integration. This chapter also describes driver and staff training, as well as customer communication. Finally, there is a BRT accessibility checklist and references.

Contributors: Tom Rickert, *Access Exchange International*; Michael King, *Buro-Happold Engineering*

30.1 Introduction

> *"Some do not walk at all; others walk in the highways; a few walk across lots."*
>
> — Henry David Thoreau, author and naturalist, 1817–1862

Most customers benefit from inclusive features on and around BRT systems. For example, everyone benefits from good sidewalks leading to BRT stations, a narrow platform-to-vehicle gap, nonskid floors, plentiful handholds on BRT vehicles, audio and text signage in stations and on vehicles, and drivers trained to avoid sudden starts and stops. However, for customers with special needs, inclusive design often makes the difference between being able to use the system or not. Such customers include:

- Customers with permanent or temporary physical disabilities, including those who use canes, crutches, or wheelchairs, and those with hidden disabilities such as arthritis or a heart condition. Most frail elderly persons will fit into this category;
- Customers with sensory disabilities, such as blind persons, those with reduced vision, and persons who are deaf or hard-of-hearing;
- Customers with temporary or permanent cognitive challenges, such as first-time BRT users, people who do not speak the language, the illiterate, and tourists;
- Children and young customers, who may need more orientation than other customers, or benefit from design features for short persons;
- Customers with children, or pregnant women;
- Customers travelling with packages and luggage.

The number of people who benefit from universal design is growing. According to United Nations data, existing BRT systems must incorporate an average of over 40 percent more older persons into their service areas during the next twenty years.

Figure 30.1. Accessibility measures help families with strollers. *Carlosfelipe Pardo.*

30.1.1 Not Just Wheelchairs

Because wheelchair users are especially identifiable, they have become surrogates for other categories of beneficiaries of universal design. This contributes to the general practice of saying a vehicle "is accessible" or "is not accessible" solely based on the ability of customers using wheelchairs to get on the vehicle. Yet, for every wheelchair user, there are up to four persons using canes, crutches, or other mobility aids, and the percentage of persons with disabilities with sensory and cognitive disabilities is greater than the percentage with mobility impairments.

Figure 30.2. Travelling with a stroller presents some of the same accessibility issues as for those in wheelchairs. *Carlosfelipe Pardo.*

30.1.2 Where are the Special Needs Customers?

Trips by the disabled tend to parallel travel patterns of all other customers. The assumption that they are concentrated in select areas is seldom correct in regions with accessible public transport systems and a culture of independent living. The maps below illustrate the experience of San Francisco, California, USA.

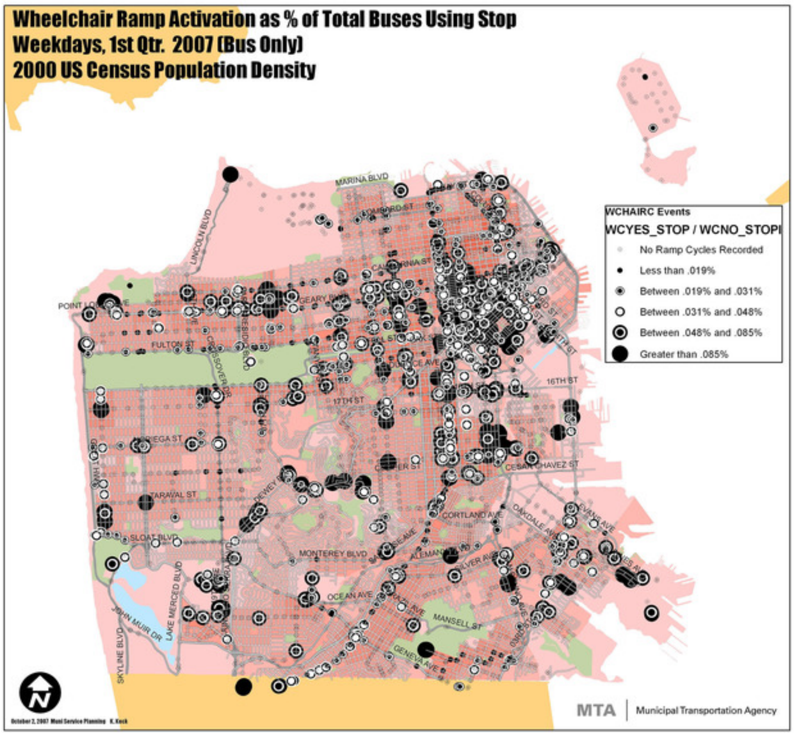


Figure 30.3. The map on the left shows public transport use by people in wheelchairs. These maps show that people in wheelchairs have similar travel patterns to the general public. *San Francisco Municipal Transportation Agency.*

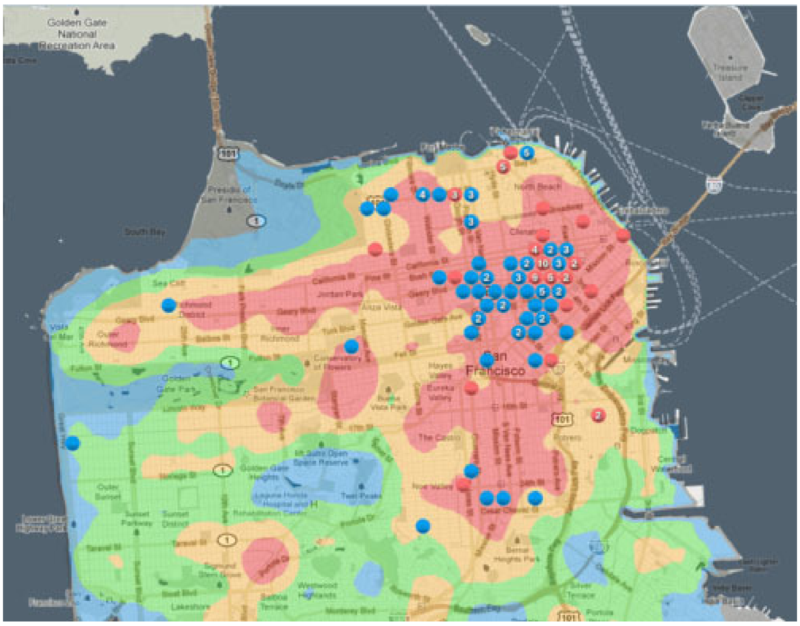


Figure 30.4. Locates hotels (dots) and restaurants (heat map). These maps show that people in wheelchairs have similar travel patterns to the general public. *Hipmunk, Inc.*

30.1.3 Can Public Transport Accommodate the Disabled?

Public transport systems, including BRT, can and do play a role in accommodating the disabled.

- Curitiba provides 21,000 daily trips for registered disabled persons (slightly under 1 percent of all trips). Of this number, about 1,000 individual wheelchair users ride the system daily, implying in excess of 500,000 one-way trips per year, forming part of 8 million annual trips by all registered disabled persons and their attendants. This number does not include unregistered users.
- San Francisco, California, provides 180,000 to 200,000 trips by wheelchair users per year system-wide, or approximately 200 trips per year per vehicle in peak hour service.

Crafting a BRT system accessible to all, from those with hidden disabilities to those in wheelchairs, benefits everyone and remains the goal of a just and equitable society.

30.1.4 Islands of Accessibility

A full-featured BRT corridor may begin its life as an island of accessibility in a sea of inaccessibility. Streets with no sidewalks, sidewalks with no ramps, sidewalks in disrepair, noncontiguous sidewalks, vehicles parked in the road and on the sidewalk, sidewalks jammed with vendors, shops, and garbage, and drivers who do not yield to pedestrians all limit access to public transport. Accessible BRT counters this. It can stimulate a growing network of accessible streets and sidewalks reaching far beyond the actual BRT.

Figure 30.5. Level surface at a bus terminal in the Bronx, New York City. Lack of curbs increases accessibility for all. *Michael King.*

Figure 30.6. The South African Department of Transport brought together a group of disability NGO leaders and accessible public transport experts from around the country for a one-day workshop to learn more about public transport access. *South African DOT.*

Figure 30.7. Mexico City's Metrobús invites disabled advisers to inspect stations during construction, in this case an access ramp. *Secretaría de Obras y Servicios de México, DF,*

Figure 30.8. Workshop participants on a "wheelchair tour" of walkway conditions in San Antonio, Texas, USA. *Michael Ronkin.*

30.2 Consultation with Customers with Special Needs

> *"The ability to focus on BRT characteristics unique to communities or system users during the design phase of the project allows early solutions and reduces the potential for expensive fixes during the construction phases of the project . . . By taking into consideration user-safety, comfort, and accessibility right from the start, public transport agencies can move forward more quickly and avoid the pitfalls and expensive cost of retrofitting."*
>
> — Project ACTION (2009, p. 11)

It is imperative to consult customers with special needs during the planning and design stages of a BRT system. They can field-test certain aspects such as level boarding and station orientation before the crush of opening day. Too often, the opening day of a BRT system has been accompanied by media coverage of persons with disabilities stating that various access features are either inferior or lacking altogether. Including them in the planning and design process can mitigate this outcome.

Recommended consultations include:

1. Contact established disability NGOs:
    - Share the positive features of BRT design;
    - Seek input on ways to enhance universal access features.
2. Convene short-term focus groups to enhance universal access features. during the planning and design stages o
    - Composed of six to twelve people with different types of physical, sensory, and cognitive impairments, including frail seniors;
    - Identify travel barriers;
    - Prioritize access features;
    - Field-test access features, or mock-ups thereof;
    - Focus on trunk-line *and* feeder-line issues.
3. Schedule construction tours:
    - Identify overlooked elements.
4. Tour other BRT systems:
    - Identify transferable elements.
5. Establish ongoing advisory committee:
    - Approximately fifteen to thirty people with different types of physical, sensory, and cognitive impairments, including frail seniors;
    - Include representatives from throughout the BRT service area;
    - Meet monthly during planning and design, and periodically thereafter;
    - Review planning for inclusive design and operation;
    - Work directly with the system operator;
    - Monitor system accessibility, compliments, and complaints.
6. Participate in interagency working groups:
    - Typically includes representatives of government ministries and external stakeholders;
    - Encourage multi-jurisdictional planning and cooperation;
    - Focus on long-term accessibility issues.

A model flyer, "BRT and You" prepared by the World Bank in 2010 for use by persons with disabilities, discusses some of the characteristics of BRT, and how planners and customers with disabilities can work together.

30.3 Station Access

> *"Be an opener of doors."*
>
> — Ralph Waldo Emerson, essayist and poet, 1803-1882

Chapter 29: Pedestrian Integration covers pedestrian access to stations and terminals. This chapter highlights specific accessibility issues.

The image below summarizes some of the main features detailed in this and the following section.

1. Universal accessibility symbol;
2. Traffic lights with acoustic signals;
3. Access ramps;
4. Well-marked pedestrian crossings;
5. Curb ramps with color and texture differentiation;
6. Accessible pedestrian walkways;
7. Wide fare gates.

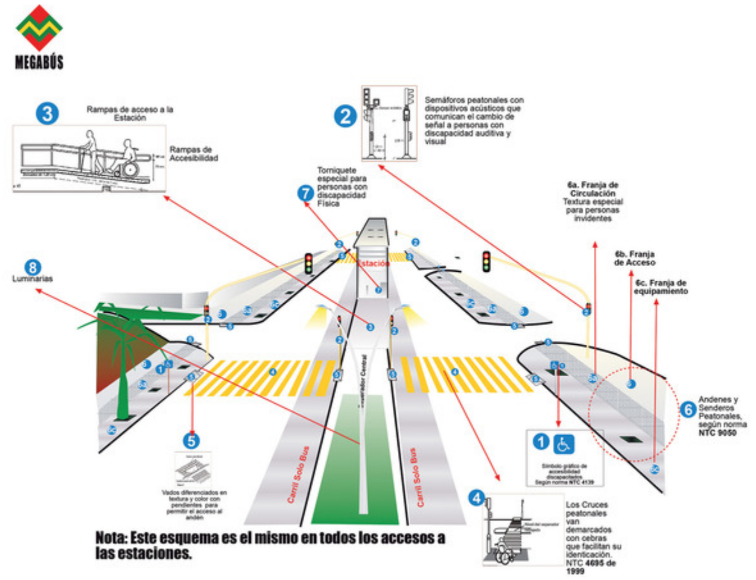


Figure 30.9. Pedestrian-access features are depicted in this diagram of approaches to a typical BRT station on Avenue Simón Bolívar in Pereira, Colombia. *Pereira Megabús.*

30.3.1 Walkways

Walkways refer to any facility used by pedestrians, including sidewalks, pavements, shared streets, footpaths, and paths. As a general rule, accessible and well-lit walkways should exist along the main approaches to all BRT stations. They should extend for at least 400 meters in all directions. Ideally, they should exist along the entire length of any BRT trunk line. The following are critical accessibility elements and dimensions for walkways:

- Straight and unobstructed;
- Smooth, even, well-paved, nonskid surfaces;
- Contrasting color for street furniture and other obstacles;
- Minimum passing width for a wheelchair at an obstruction—0.9 meters;
- Minimum overhead clearance (at signs)—2.0 meters;
- Maximum cross-slope (for drainage)—2 percent;
- No gratings or other items that would catch the small front wheels of wheelchairs;
- Maximum opening or gap in a grating—13 millimeters.

30.3.2 Tactile Guideways

Tactile guideways are characterized by a series of raised parallel bars pointing in the direction of travel. The bars are typically molded into a 300-millimeter-square tile, installed one or two tiles wide. They benefit blind persons and those with reduced vision and help others to find their way:

- Across large unmarked areas;
- Along complex paths to a specific destination (information booth, BRT station);
- On walkways without a well-defined boundary with the road.

Figure 30.10. Constructing a BRT system provides the opportunity to address accessibility issues on routes to stations (Boston). *Michael King.*

Figure 30.11. Tactile guideway. *Lloyd Wright.*

Figure 30.12. Tactile guideway leading to a BRT station in Ahmedabad, India. *Michael King.*

Guideways should be used in a consistent manner within a country and should be in a color contrasting with their surroundings. Research has shown that grooved concrete is not detectable underfoot. Therefore, texture differences should be detectable under foot and by a long cane.

In BRT environments, a tactile guideway is useful to mark a travel path from a sidewalk to a pedestrian crossing to a BRT station. It can continue on the other side of the crossing, turning up the ramp into the station and proceeding to the ticket vending and information booth. The guideway can then proceed down the center line of the station, with guideways branching off at right angles to station doors.

30.3.3 Tactile Warnings

Tactile warnings, also called attention patterns and detectable warning strips, are characterized by a series of raised truncated domes, typically molded into a 300-millimeter-square tile. They mark *edge* or *stop* locations, such as platform edges or curb ramps. They are typically two tiles wide to assure that pedestrians do not step over them. They are of a contrasting color with the surrounding surface. In some countries, tactile warnings are placed immediately adjacent to the edge or curb, while in other countries they are placed 600 to 1,000 millimeters away. Tiles are recommended as they can be detected by canes as well as underfoot. Maintenance is key so that broken tiles do not become trip hazards (Bentzen and Barlow 2011).

Figure 30.13. Warning strips mark platform edges of BRT and rail stations. *Tom Rickert/AEI.*

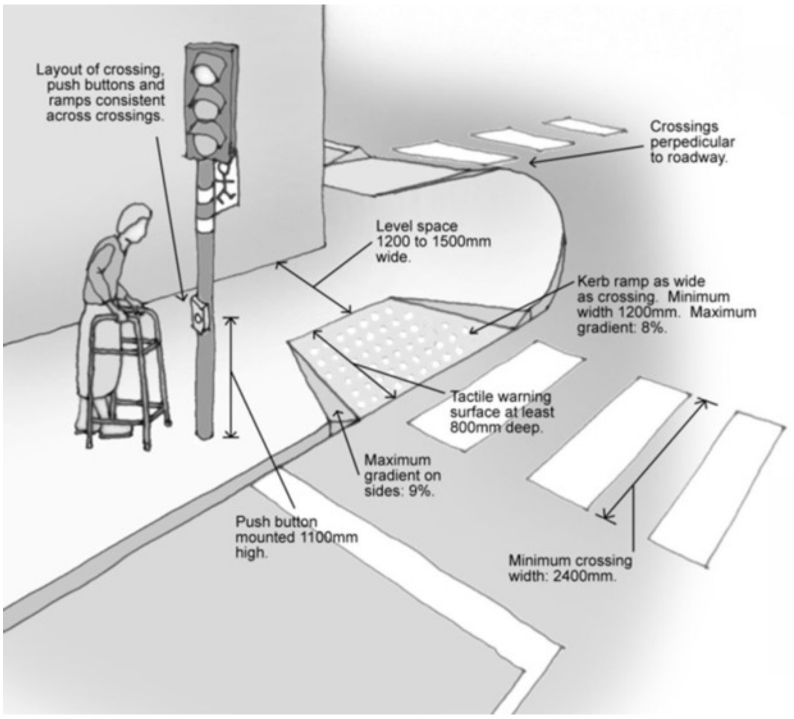


Figure 30.14. Good practice at street crossings. *TRL, sponsored by the United Kingdom's Department for International Development.*

Figure 30.15. A curb ramp the full width of the crosswalk in Shenzhen, China. *Michael King.*

30.3.4 Curb Ramps

Curb ramps (also known as pedestrian ramps, wheelchair ramps, and curb cuts) are ramps that allow a person in a wheelchair to roll up or down at a curb, instead of stepping. They benefit people with walkers, strollers, bicycles, carts, and anyone else who has trouble with steps. The slope of a curb ramp is critical, lest a person in a wheelchair fall backward. Also critical is placing a curb ramp at the opposite side of the street.

General curb ramp requirements, based on TRL guidelines:

Figure 30.16. Curb ramps are required on both sides of the street, and at any median in between. The median opposite the curb ramp shown here in Mexico City lacks a curb ramp. *Michael King.*

- Placement: within crosswalk markings;
- Orientation: perpendicular to curb (creates a flush public transportation);
- Width: ideally equal to crosswalk width, minimum 1.2 meters;
- Slope: maximum 1:12 (8 percent);
- Side flange slope: 1:10 (9 percent);
- Level landing and turning area: 1.5-meter square at top and bottom of ramp;
- Tactile warning strip at base of the ramp.

Curb ramps should be required in all new construction, and there should be a program to retrofit existing streets. As a priority, curb ramps should be installed on routes between BRT stations and important trip generators.

30.3.5 Raised Crossings

Figure 30.17. Raised crosswalk at bus stop in Mérida, Mexico. *Michael King.*

An alternative to curb ramps is a raised crosswalk (raised crossing, raised intersection, continuous sidewalk). Here the street is raised to sidewalk level, and pedestrians cross without having to step down to street level. It is recommended for all streets with speeds of 50 kilometers per hour or less and may be used elsewhere.

Figure 30.18. A vibro-tactile pushbutton for requesting a crossing phase. *Janet Barlow.*

30.3.6 Traffic Signals

Figure 30.19. Audible signal at a crossing leading to a BRT station in León, Mexico. *Michael King.*

Figure 30.20. A "walking man" countdown signal in Mexico City. The green man speeds up as the clock ticks to zero. *Michael King.*

Where traffic signals are employed, they must be timed so that slower pedestrians have sufficient time to cross the street (0.75 meters per second). Countdown, tactile, and audible indicators are preferred.

Figure 30.21. A well-lit pedestrian tunnel in Cali, Colombia, El MIO. *Tom Rickert/AEI.*

Figure 30.22. Pedestrian bridge with a smooth, gradual slope in Utrecht, Netherlands. *Michael King.*

30.3.7 Pedestrian Bridges and Tunnels

As discussed in Chapter 29: Pedestrian Access, at-grade crossings are preferred to access BRT stations. Should a pedestrian bridge or tunnel be considered, a tunnel with ramps is preferred. The second choice would be a bridge with ramps. Elevators are a last choice for reasons other than accessibility.

Tunnels are preferred because they require less vertical clearance (than a bridge over a roadway), thus the ramp slope and/or distance is less. While bridges with ramps may be technically "accessible" to a wheelchair user, the sheer length of ramps to pedestrian bridges is so daunting that most wheelchair users are unlikely to use the ramp without the help of a friend to push the chair. Customers with less visible disabilities, such as arthritis or a heart condition, may also find long ramps difficult to access. Elevator procurement is costly, and elevator maintenance can become an issue for the operator. For this reason, Bogotá's TransMilenio will avoid elevators in the future.

Figure 30.23. Signalized crossing leading directly to a BRT station in Guangzhou, China. *Michael King.*

Figure 30.24. The man on crutches is able to cross due to the help of security personnel. This approach requires a long-term commitment that is not likely to endure for the life of the system. *Gerhard Menckhoff.*

30.3.8 “Special” Crossings

Figure 30.25. A “special” crosswalk and gate for people with disabilities in Guangzhou, China. There are many who would benefit from elevators and shallow ramps who instead are deterred by the approach. *Michael King.*

Persons with disabilities should cross the street and access BRT stations along with everyone else. “Special” crossing and access points are to be discouraged. This practice relies on the presence of security or traffic personnel, which may or may not be available, and it has been viewed as preventing access by persons with mobility impairments in Latin American and Asian countries.

30.3.9 Ramps to BRT Stations

Ramps are the preferred method of access to BRT stations, as opposed to elevators or stairs. Station assistants may be assigned to assist wheelchair users and others who need help up the ramp.

General ramp criteria (TRL 2004, pp. 145–146):

- Width: equal to station width;
- Slope—1:20 (5 percent), maximum 1:12 (8 percent);
- Run (length)—maximum 9 meters with no resting area;
- Rise (height)—maximum 0.75 meters with no resting area;
- Level resting area dimensions—equal to width of ramp by 1.5 meters;
- Handrails on both sides;
- Level landing and turning area—1.5 meters square at top and bottom of ramp.

The norms in some countries specify a level resting area after a maximum run of 6 meters (e.g., Argentina’s Ley Nacional 24314), others specify 9 meters, and others specify other lengths. Section 4.8 of the United States’ ADA Accessibility Guidelines (ADAAG) states, “The shortest possible grade for a ramp shall be used. The maximum angle for a ramp in new construction should be 1:12. The maximum rise should be 30 inches (760 mm)” before a horizontal resting area.

Figure 30.26. Ramp to BRT station, equal to the width of the station. *TransMilenio.*

Figure 30.27. BRT station access is the full width of this station in Guadalajara, Mexico. *Michael King.*

Figure 30.28. A pedestrian ramp leading to a BRT station in Bogotá. *Michael King.*

Figure 30.29. A ramp from a BRT station to a pedestrian tunnel in Cali, Colombia. *Tom Rickert/AEI.*

30.4 Stations and Terminals

> *"I think about non-visual design, which comes from my experience, but also from a general critique of architecture. It's so much about how things look. I'm interested in how a building is experienced when you touch it with your hand, when you grab a railing or lean into an atrium."*
>
> — Chris Downey, architect, planner, and consultant

This section presents universal access features of BRT stations and terminals.

30.4.1 Station Personnel

It is important to train BRT staff to be respectful and courteous to patrons with disabilities. While many will need no assistance, some will need help with fare payment, route information, navigation (e.g., to elevators and wide fare gates), and passage through turnstiles. The presence of uniformed staff and security personnel makes BRT more appealing to persons with disabilities. This is especially true at night, when such customers may be hesitant to travel.

Figure 30.30. A station attendant in a TransMilenio station. Image *TransMilenio.*

30.4.2 Fare Payment

30.4.2.1 Fare Cards

Prepaid proximity cards (contactless cards) require less hand dexterity and benefit persons with limited mobility. The option of purchasing multiple trips may also reduce stress for persons with disabilities. However, disability correlates with poverty, and the problem of poor persons who cannot afford to prepay for multiple trips needs to be recognized.

30.4.2.2 Fare-Card Vending Sites

A low counter, to serve wheelchair users and short persons, should ideally be included at neighborhood fare card vending locations and should be a feature of formal BRT facilities. An accessible counter or ticket vending window should be:

- 800 millimeters high, ideally with knee space for a wheelchair user;
- At least 500 millimeters deep;
- At least 900 millimeters wide;
- With at least 1,200 millimeters of clear space in front.

Electronic ticket vending machines should have buttons and slots for cash and for dispensing fare cards, located not more than 1,200 millimeters above the ground. Assistance should be provided as needed to blind customers, deaf customers, and others who may have difficulty with card-purchase procedures.

Consideration should be given to hiring disabled persons to work at fare vending sites where appropriate space needs are met.

30.4.2.3 Fare Gates

There should be one or more wide fare gates in each station (clear width of at least 900 millimeters) for customers using wheelchairs, walkers, or crutches.

30.4.3 Mobility Features

30.4.3.1 Uniform Design

A uniform design throughout the system assists all customers with navigation, especially those with sensory and cognitive disabilities.

30.4.3.2 Entrances and Exits

Longer stations—especially those over 50 meters—should have entrances at each end when possible to assist those who are unable to walk long distances, as well as all other customers. An exit should be considered at the "far end" of such stations, even if an entrance is not possible. Exit doors require a minimum of 900 millimeters of clear space. Manually operated doors should open easily, requiring no more than 15 newtons of operating force.

Figure 30.31. Perches increase comfort for all customers (photo of Macrobus BRT station in Guadalajara, Mexico). *Michael King*

30.4.3.3 Seats and Supports

Figure 30.32. Elders also benefit from access features (TransOeste BRT station in Rio de Janeiro, Brazil). *EMBARQ Brazil.*

Provide seating (benches, folding seats) in stations, especially where wait times exceed five minutes. Back and hip supports (horizontal "perches" or "leaning rails"), about 700 millimeters high, assist customers with hidden disabilities such as arthritis. Seats and supports should be painted a high contrast color.

Locate seats and supports where people are most likely to wait for the BRT vehicle (not in an out-of-the-way location). Overcrowded stations present challenges to customers with special needs; locating seating near the vehicle door addresses this. Coordinate seat location with doors reserved for those with disabilities.

Figure 30.33. Sliding doors are a feature of many BRT systems. *ITDP*

30.4.3.4 Station Gates to Vehicles

Figure 30.34. Sliding doors are a feature of many BRT systems. *TransMilenio*

Since the smallest platform-to-vehicle gap is usually found at the front entrance of the vehicle, this entrance is typically designated for use by disabled persons, who also benefit from being closer to the driver. Transparent sliding doors, activated when vehicles dock opposite the doors, enhance safety at platform edges, especially for customers who have reduced vision. Transparent doors also facilitate visibility—that is, to see route signs on approaching vehicles. Doors should have audible signals to assist all customers, and especially blind persons, to know when they are opening and closing. A tactile warning strip is required if sliding doors are not provided and platform edges are not protected.

30.4.3.5 Elevators and Lifts

Ramps are preferred at regular stations because they require little maintenance and have few security risks. At terminals, bridges, and other locations where customers must ascend multiple levels, elevators may augment ramps. They also assist customers with reduced mobility and people carrying children or heavy packages. Nevertheless, elevators should never be the primary mode due to maintenance issues. Escalators are not recommended, as they have a poor maintenance history.

Figure 30.35. If grade-separated transfers across an intersection are necessary, then infrastructure must be available to make such transfers possible. *Lloyd Wright.*

30.4.4 Visual Elements

30.4.4.1 Lighting

Adequate lighting is essential for those with reduced vision. It also provides more safety and security for all customers.

30.4.4.2 Signage

Signs and the text on them need to be of a minimum size (Table 30.1). Many countries use icons and specific colors to supplement text for route and station names, thus assisting persons with cognitive impairments, visitors, tourists, and others who may not be able to read text. Variable signage indicating the arrival time of the next vehicle helps those with hearing impairments.

Table 30.1. Recommended letter sizes and applications. Source: TRL

Application	Minimum letter height
Long-distance reading (e.g., signs on station entrances); Signs in corridors and stations; Information on vehicle-stop flags and shelters; Close reading, e.g., wall-mounted timetables; Minimum for any text displayed;	150 mm; 50–100 mm; 50 mm; 25 mm; 22 mm;

30.4.4.3 Color Contrast

Figure 30.36. Signage in Lima, Peru, Metropolitano station. Image *Tom Rickert/AEI.*

Color contrast is useful for signage (see chart below) and for station features such as railings, turnstiles, wide fare gates, tactile warnings at vehicle-entry gates, folding seats, and ischiatic supports. A number of countries use “safety yellow” as the color of choice for such uses. The International Organization for Standardization (ISO) standard 3864 specifies “safety yellow.” The standard in the United States is “Yellow-Federal Standard #33538.”

Table 30.2. Color contrast for station signage. Source: Merseyside Code of Practice (UK) in Oxley (2002) and TRL, p. 162.

Background	Sign board color	Letter or symbol color
Red brick or dark stone	White	Black, dark green, or dark blue
Light brick or light stone or white walls	Black or dark blue or dark green	White or yellow
Green vegetation	White	Black, dark green, or dark blue
Backlit sign	Black	White or yellow

30.4.5 Audible Elements

Audible signage assists customers with reduced vision, particularly at the opening and closing of sliding doors. Depending on the system, announcements can be activated by GPS technology, or simply provided by station staff.

30.4.6 Tactile Elements (Braille)

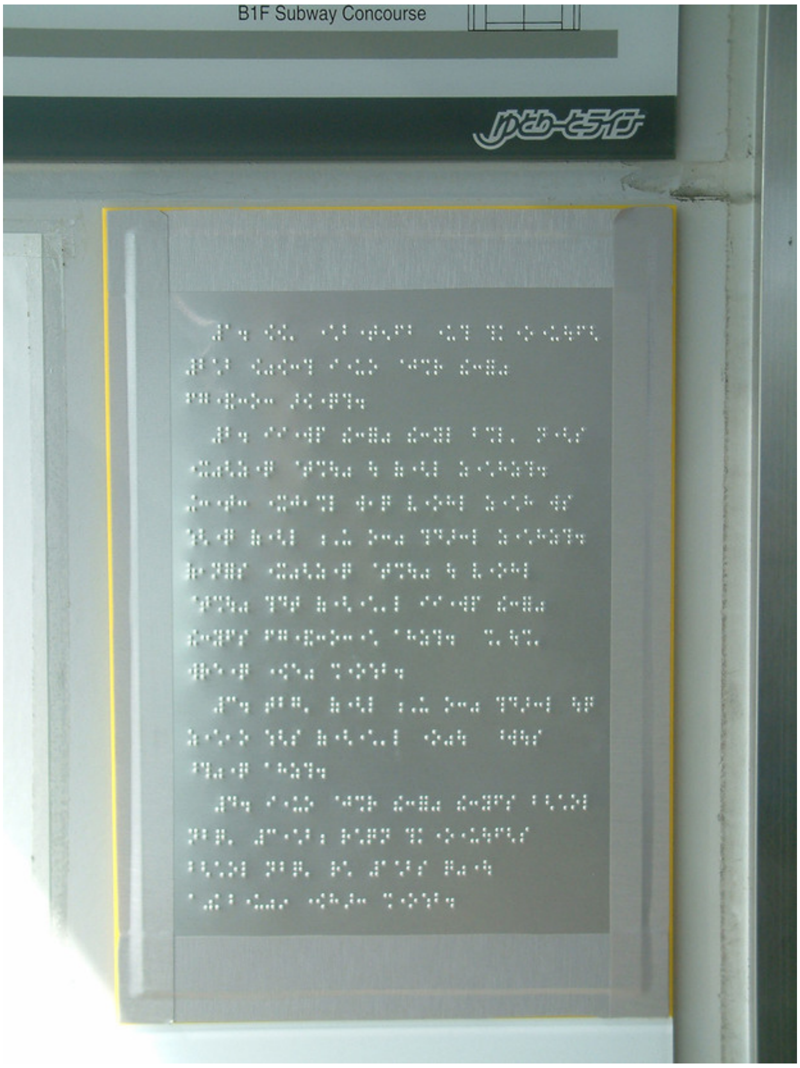


Figure 30.37. Travel information in Braille helps the sight-impaired plan and undertake their journeys in Nagoya, Japan. *Lloyd Wright.*

Some blind persons may benefit from raised tactile route numbers at stations. Letters are generally 20 millimeters high and raised 1 to 2 millimeters. Others may prefer Braille signage. Consult with focus groups and advisory committees to decide.

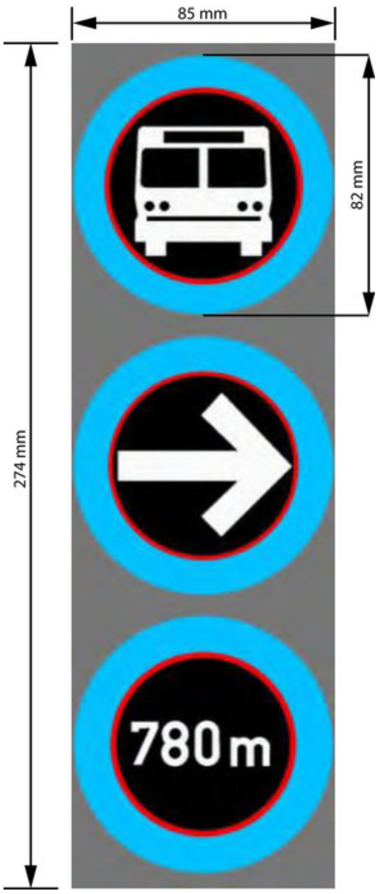


Figure 30.38. Adhesive tactile wayfinding that utilizes a printing technique to create tactile differentiation in the pictograms and simple symbols to help users overcome visual impairments or language barriers (Cape Town, South Africa).) *HHO Africa*

30.4.6.1 Adhesive Tactile Wayfinding

Figure 30.39. Adhesive tactile wayfinding that utilizes a printing technique to create tactile differentiation in the pictograms and simple symbols to help users overcome visual impairments or language barriers (Cape Town, South Africa). *HHO Africa*

Adhesive Tactile Wayfinding is a new development in signage made possible by three-dimensional printing technology. The development of this signage was applied to the MyCiti Integrated Rapid Public Transport (IRT) in Cape Town, South Africa.

MyCiti IRT signage and designs are supposed to encompass identification, confirmation, and directional information that are inclusive of all IRT users. The MyCiti IRT system utilized international best practices and standards to construct an exemplary IRT system with wayfinding and fair accessibility standards.

Illiteracy and site impairment can hinder an individual's ability to recognize and utilize signage. While Braille is internationally recognized, it is not widely used in South Africa. Therefore, tactile pictograms, or raised images, include a wider group of users. These three-dimensional signs featuring universally understandable figures can be attached to poles surrounding IRT stations using the adhesive backs.

The wayfinding directional signs consist of the name of the MyCITI station, the distance to that specific station, and an arrow pointing in the direction of the station. The signs are made more recognizable by the MyCITI red branding on them. In some sections of Cape Town, tactile wayfinding systems have been introduced, as seen in Figures 30.38 and 30.39.

- The original adhesive panels were designed to a width of 85 millimeters and a height of 274 millimeters to accommodate three circular images with a diameter of 82 millimeters each. The image above on the left consists of a pictogram of a bus, a directional arrow, and a distance indicating the nearest BRT station, all printed in contrasting colors using MyCiti branding;
- After participants from a study viewed the design, the team decided to increase tactile distinction, leading to more pronounced visibility, depth, and legibility;
- The designs for tactile wayfinding were well received by the cohort participating in the study, especially for the benefits it would have for the sight impaired;
- Directional wayfinding signs are located within 500 meters around MyCiti stations;
- The adhesive panels allow for wayfinding arrows to be placed facing four directions for maximum visibility;
- The wayfinding information is displayed in 40-millimeter white lettering or 120-millimeter symbols on a 150-by-950-millimeter background in the contrasting blue color of MyCITI branding;
- Up to fourteen directional wayfinding signs are placed within the area around each MyCITI station.

Because tactile wayfinding is relatively new, the design team in Cape Town is constantly looking for feedback to improve its services. The team hopes that the design can be applied to civic amenities and other places of public interest in the future.

30.4.6.2 Terminals and Transfer Centers

Terminals and transfer centers can be confusing for many customers and especially those new to the system. Customers must understand different public transport modes and different schedules. Customers also need direction to a range of public services and commerce.

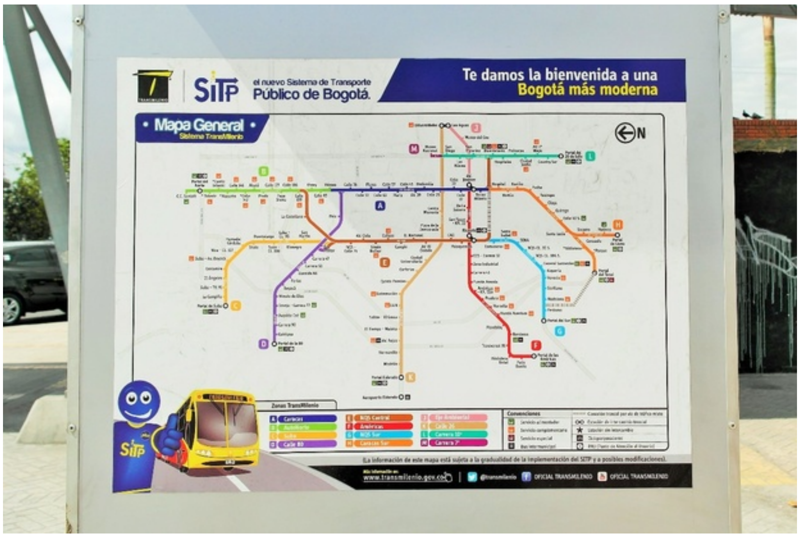


Figure 30.42. TransMilenio system map in Bogota. *Karl Fjellstrom/Far East BRT.*

Figure 30.40. Map of feeder buses that connect to the TransMilenio Portal del Norte station in Bogota. *Karl Fjellstrom/Far East BRT.*

Figure 30.41. Cutaway model of underground terminal of Metropolitano BRT in the center of Lima, Peru. *Tom Rickert/AEI.*

Figure 30.43. TransMilenio system map in Bogota. *Karl Fjellstrom/Far East BRT.*

30.5 Platform-Vehicle Interface

> *"So be sure when you step. Step with care and great tact and remember that life's a great balancing act. Just never forget to be dexterous and deft. And never mix up your right foot with your left."*
>
> — Dr. Seuss, writer and cartoonist, 1904–1991

The platform-vehicle interface can significantly affect accessibility for a variety of users. Levelness and gap issues can be serious barriers to access. This section describes techniques to ensure that the interface between the station platform and vehicle is accessible for all users.

There are many means to alleviating platform-vehicle interface issues. In Chapter 25: Stations, a variety of mechanisms that can be applied are evaluated and explained. Those mechanisms include:

- Level Boarding;
- Platform-Vehicle Gap;
- Boarding Bridges;

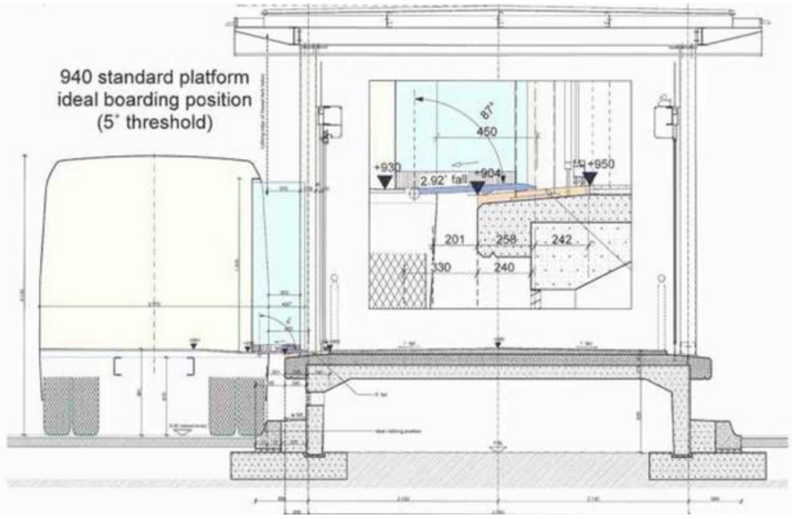


Figure 30.45. Diagram providing detail of the alignment of the boarding bridge with the platform. *City of Cape Town.*

- Alignment Markers;
- Guide Wheels;

Figure 30.44. A boarding bridge deployed in the BRT system in Cape Town, South Africa *City of Cape Town.*

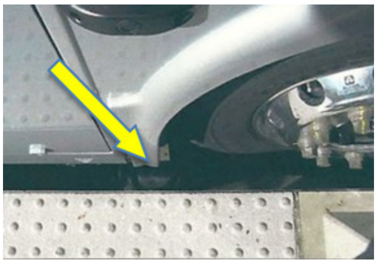


Figure 30.46. Front tire of the vehicle *Cleveland RTA*

Figure 30.47. guide wheel in greater detail *Cleveland RTA*

- Optical Guidance and Magnet Alignment;
- Automatic Enforcement;
- Beveled Curbs;
- Platform Edge Treatment;
- Dedicated Accessible Boarding Area;
- Station-Side Driver.

Figure 30.48. A flat floor of a high-floor articulated bus in San Francisco. *Tom Rickert/AEI.*

30.6 Vehicles

> *"The higher we are placed, the more humbly we should walk."*
>
> — Marcus Tullius Cicero, philosopher and politician, 107 BC–43 BC

This section discusses accessibility features of BRT trunk-line vehicles and feeder buses.

Figure 30.49. The wheelchair securement area is reached quickly on most high-floor vehicles. *City of Cape Town.*

Feeder bus lines that are carefully integrated into larger BRT trunk lines are more likely to be operated in an accessible manner. Sometimes called "complementary buses," they are found in several cities, such as Cali, Colombia, and Johannesburg, South Africa. Typically, a single vehicle design is chosen that can exhibit accessibility features such as audio and visual on-board signage and, to different degrees, access for those who cannot climb steps. They have high doors on one side for use at trunk-line stations and low doors with steps, supplemented by ramps or lifts, for use at curbside stops, where the buses operate in mixed traffic.

A different challenge presents itself if feeder bus lines are cannot climb steps. They have high doors on one side for use at trunk more difficult for such a system to consistently exhibit the driver training, audio and visual signage, minimal vehicle-to-curb and vehicle-to-platform distances, and so forth.

Figure 30.50. Irregular floor plans reduce internal accessibility. *Tom Rickert/AEI.*

30.6.1 Low -Versus High- Floor Vehicles

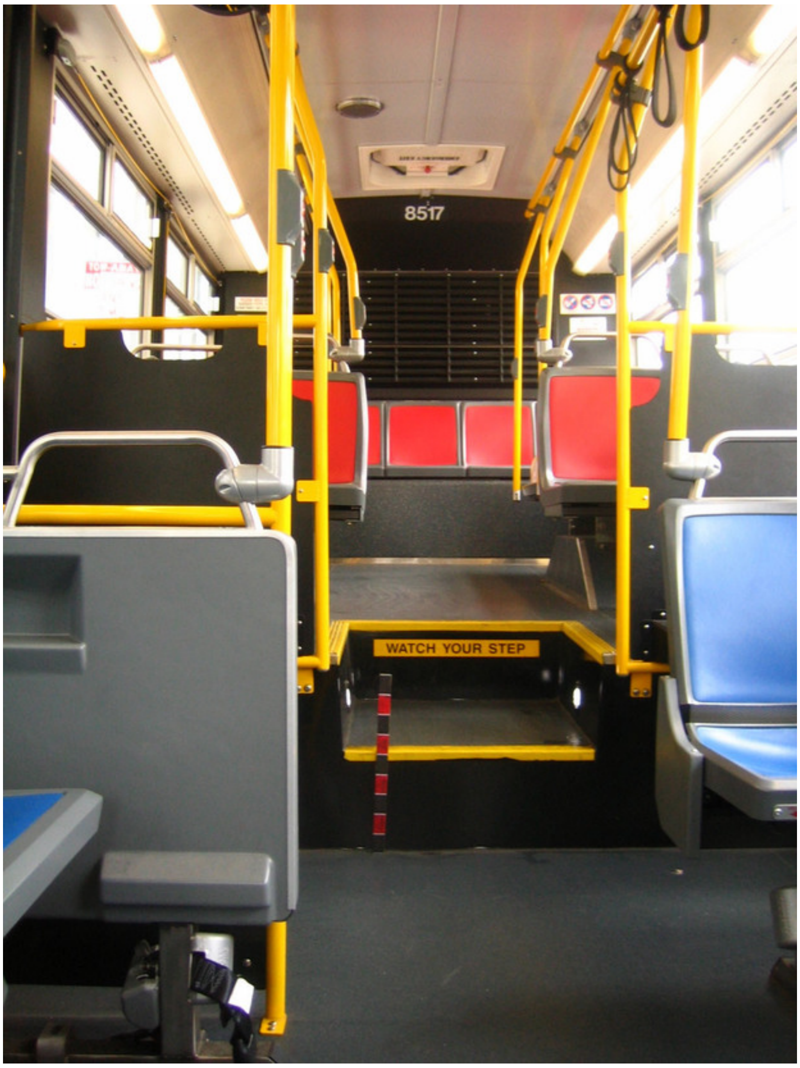


Figure 30.52. Irregular stairs to the rear of the vehicle reduce internal accessibility. *Tom Rickert/AEI.*

Figure 30.51. Irregular seating plans reduce internal accessibility. *Tom Rickert/AEI.*

Figure 30.53. The presence of stairs between vehicle floor levels can limit the maneuvering room to get into a securement position. *Eduardo Alvarez.*

From an internal accessibility standpoint, a standard layout is preferred: one level floor, straight aisle, simple seating plan, seats of a uniform height. This regularity makes the vehicle more accessible for customers in wheelchairs and with disabilities. High-floor vehicles, because the wheels lie beneath the seats, generally use this standard layout.

Low-floor vehicles, while easier to board from the street, generally have an interior design that is less accessible. There are usually multiple levels with steps or ramps between; the aisles tend not to be straight; the seats are at irregular heights;

and a person in a wheelchair is typically constrained to a single location. This irregularity degrades accessibility, especially when the vehicle is crowded.

While any vehicle can be made minimally accessible, the goal should be to ease use for all. Similarly, vehicles with unusual seating plans may create interest, but if the design detracts and dissuades use, then it loses credibility.

Table 30.3. Summary of Internal Accessibility Issues with High- and Low-Floor Vehicles

	High Floor	Low Floor
Floor Level	Generally one level	Multiple levels, steps, and ramps problematic
Aisle	Typically straight	Varies in width, creates obstacles
Seating Plan	Simpler, more intuitive	Irregular, leads to the "better" seats taken first, which may force people with disabilities into seats that are harder to access
Doors	Possible to have additional doors	Typically constrained by seating layout
Wheelchair securement position	Can be directly across from a door, permitting straight entry with minimal turning movements	Typically constrained by seating layout, which may cause additional turning movements, which retards boarding and alighting
Seat height	Generally one height	Irregular heights require more maneuvering

Recent advances in low-floor vehicle design in western and northern Europe may improve accessibility, as vehicle wheel wells and engines have been modified to create less intrusion into the passenger cabin. Several cities in France, including Rouen, Lille, and Paris, now have low-floor BRT systems that appear to perform well for customers with disabilities. A special case is Nantes, France, which is using higher-capacity low-floor articulated vehicles that permit boarding through four doors, thus enhancing customer flows.

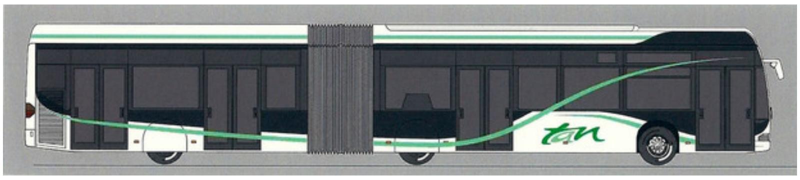


Figure 30.54. Low-floor articulated bus with four doors in Nantes, France. *François Rambaud of CERTU.*

30.6.2 Internal Elements

30.6.2.1 Hand Grasps

Accessible BRT vehicles have vertical stanchions and horizontal grab bars within reach of all customers. They should be placed so that a person may navigate from one stanchion to another over the length of the vehicle. Ideally this is one per seat, or every 1,050 millimeters, whichever is less. The distance between stanchions should not exceed 1,200 millimeters. Stanchions and handholds should be painted in a contrasting color, typically a bright yellow. Straps hanging from horizontal elements near the ceiling can provide handholds to help customers reach a seat, while vertical stanchions also help shorter persons who cannot reach other handholds.

Figure 30.55. Vertical stanchions and grab bars are provided on TransMilenio to assist customers; however, better color contrast is needed. *TransMilenio.*

30.6.2.2 Seat Design

It is important for persons with disabilities that seats are surfaced with materials with a coefficient of friction sufficient to prevent customers from sliding back and forth while the vehicle is in motion. Seat surfaces should be ergonomically contoured. Ideal dimensions are noted in DPTAC and COST 349 (MacDonald 2005, pp. 17–18).

Figure 30.56. The blue seats on this TransMilenio vehicle are reserved for pregnant women and customers with disabilities in Bogotá's BRT system *Lloyd Wright*

30.6.2.3 Prioritized Seats

Figure 30.57. Dedicated seats (in blue) are interspersed with other customer seats *Tom Rickert/AEI*

Prioritized seats should be available for persons with disabilities, seniors, and pregnant women. These seats should face the front or rear of the vehicle, not toward the side, to provide more stability when the vehicle starts, stops, and turns. Priority seats require clear signage, adequate space, and should be located near the driver. The area around the seat should provide room to store a mobility aid, such as a folded wheelchair, a walker, crutches, or a "seeing eye" dog guide.

Contrasting colors help identify priority seats. The color should be consistent across the system and should be determined by local preference or mandate.

30.6.2.4 Wheelchair Travel Path

Ideally, securement areas are located opposite doorways to minimize travel within the vehicle. Where there is only one per vehicle, it should be located near the driver. When not in use, it may be occupied by standing customers, folding seats, bicycles, prams, carriages, and so forth.

Figure 30.58. Wheelchair securement opposite entrance. *TransMilenio.*

Standard dimensions (MacDonald 2005):

- Doorway: 850 millimeters wide;
- Clear route from door to securement location: 750 millimeters;
- Turning area: 1500-millimeter circle;
- Securement area: 750 millimeters wide and 1300 millimeters long;
- Unoccupied wheelchair: 700 millimeters x 1200 millimeters.

It is recommended that vehicle vendors be made responsible for wheelchair accommodation. Typically, this is via detailed design drawings illustrating minimum dimensions and travel paths. Ideally, wheelchair users would test a full-size mock-up (including seats, stanchions, fare box, securement areas, doorways, etc.). Wheelchair users vary in their ability to maneuver; a mock-up is useful in understanding how they react to a particular design.

30.6.2.5 Wheelchair Securement

Some type of securement system is required. In North America, this is accomplished via a three-point safety belt. The customer is seated facing forward or backward. Typically, a wheel clamp is provided. Additional methods may be needed when the route includes severe inclines. Not only do "tie-downs" secure wheelchair customers, but they also protect others from wayward wheelchairs. In every case, all governing norms and standards for safety should be followed.

On BRT routes with large vehicles, few hills, and minimal curves, the "tie-down-less" system used in Europe may be preferred (Figure 30.55). It requires that wheelchair riders face the rear of the vehicle, and assumes that drivers are well trained and monitored to avoid sudden stops and starts.

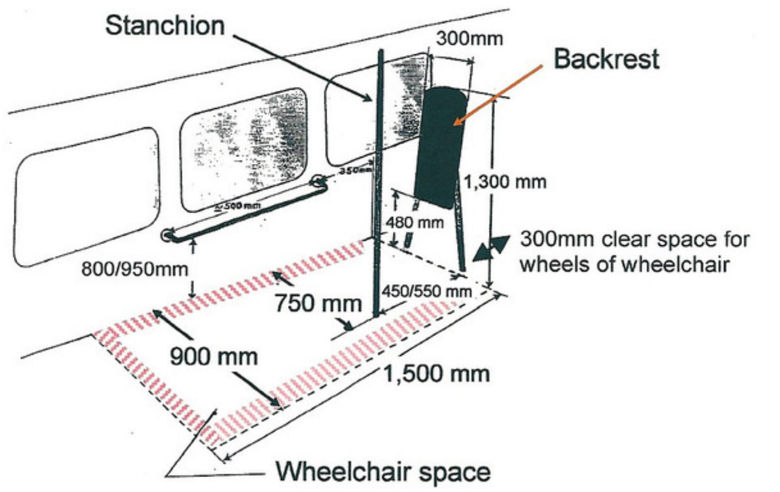


Figure 30.59. Diagram illustrating Swedish securement system. In order to go between the handles of a wheelchair, the backrest is only 300 to 320 millimeters wide and is 480 millimeters high to leave space for power chair motors. Behind the backrest, 300 millimeters of clear space is provided to allow the customer to maneuver the wheelchair so that his/her back actually rests against the backrest (not shown). For more information see COST 349: The Accessibility of Coaches and Long Distance Buses for People with Reduced Mobility (MacDonald 2005). *CGB Mitchell.*

30.6.2.6 Turnstiles

Turnstiles in buses are a barrier to many seniors, persons with disabilities, pregnant women, parents with children, and persons with packages. They should be eliminated.

Figure 30.60. This turnstile slows down boarding for all customers. *World Bank.*

30.6.2.7 Stop-Request Signals

Stop-request signals (buttons or cords) are needed on all vehicles that stop on demand (not on the fixed BRT corridor). They especially help customers with sensory disabilities.

Stop cords or buttons should be located near seats. Buttons are generally preferred because they are more easily used by persons with less strength in their hands. A lower cord or button is required within reach of a customer in a wheelchair securement position. The button or cord should activate a sign in front of the vehicle, providing feedback to customers that their request has been received.

30.6.3 Signage

30.6.3.1 Exterior

All customers benefit from large-print vehicle route and destination signs:

- On the upper front of the vehicle;
- High on the side near the entrance door;
- At the rear.

Signs should be clearly visible with contrasting backgrounds (white or yellow letters against a black background). Increasingly, GPS technology permits automatic stop announcements thereby allowing waiting customers to hear route information as the vehicle approaches a stop or station.

Table 30.4. Recommended letter sizes and applications for signage. Adapted from TRL, page 161

Application	Preferred letter height	Minimum letter height
Route number on vehicles	300 mm	200 mm
Route name/destination on vehicles	200 mm	125 mm

30.6.3.2 Interior

- Tactile route maps with Braille text should be available for blind customers from the public transport operator;
- Electronic visual displays and audible announcements of the next stop are helpful, including audible warnings when doors open or close at trunk line stations. Signs in raised letters assist blind persons to identify priority seating for customers with disabilities;
- Taking advantage of advances in smartphones and other electronic location systems will make the BRT more accessible.

30.6.4 Vehicle Access

30.6.4.1 First Step and Handrails

There is no combination of features that increases accessibility more than:

- Reducing both the vertical and horizontal distance between the station and the first step on the vehicle;
- Providing handrails parallel to the steps on *both* sides of the entrance and exit doors.

Research suggests that the combined horizontal and vertical distance to the first step of a vehicle should preferably not exceed 200 millimeters and definitely not exceed 300 millimeters (Department for Transport 2004). Handrails mitigate the problem of a high first step, even on older vehicles, by enabling frail or semi-ambulatory customers to better use their upper body strength.

Figure 30.61. A low first step makes boarding easier. The man is stepping into the vehicle without lifting his body or bending his knee. Once within the stairwell, he is then better able to use his upper body strength to mount the remaining stairs. *TRL Ltd.*

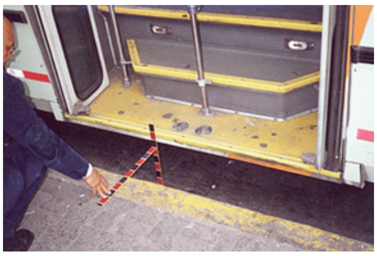


Figure 30.62. An ideal combination of raised vehicle stop, low first step, and proper vehicle alignment. (Each mark on the rulers equals 50 millimeters.) *Tom Rickert/AEI.*

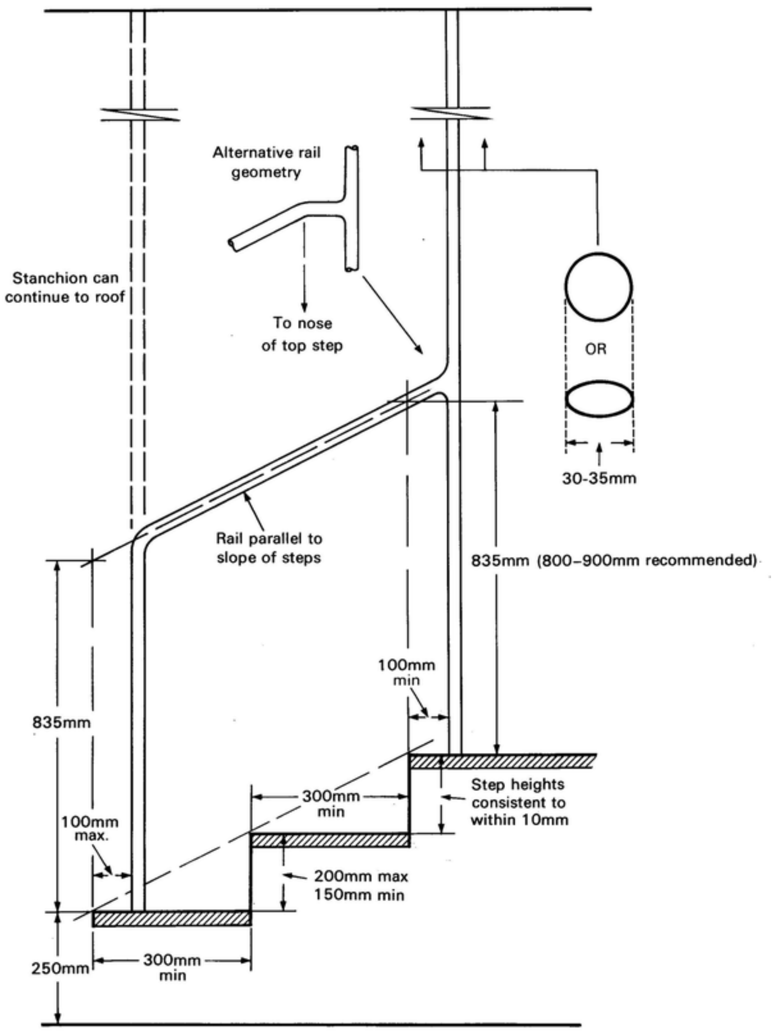


Figure 30.63. The handrail shown is for the center of a two-stream entrance. Handrails at the sides of entrances should have the sloping rail and the vertical rail near the outside of the vehicle. The vertical rail should extend to within 200 millimeters of the first step. Handrail centerlines should be 50 millimeters from bulkheads or doors. On a low-floor vehicle, there should be a vertical rail near the outside of the vehicle, plus a horizontal rail 800 to 900 millimeters above floor level. *DPTAC.*

Figure 30.64. In Nagoya, Japan, a feeder vehicle, equipped with a flip-out lower step. *Lloyd Wright.*

Figure 30.65. A manually operated ramp extended from the vehicle provides access for wheelchair users. *City of Seoul.*

Figure 30.66. A special lift allows access for a wheelchair patron to a high-floor feeder vehicle in Bogotá. *TransMilenio SA.*

30.6.4.2 Kneeler and Flip-Out Step

Techniques to decrease the distance of the first step include "kneelers" and flip-out steps. A kneeler feature lowers the vehicle height of the vehicle by approximately 10 centimeters. A flip-out step effectively adds another step to the vehicle stairwell. Both facilitate more rapid boarding by all customers by lessening the height of the first step. They are especially useful when the vehicle cannot pull all the way to the curb, and customers must board from the street. They do *not* make the vehicle accessible to people in wheelchairs.

30.6.4.3 On-board Ramps and Lifts

Ramps and lifts make a vehicle fully accessible to wheelchair users and others who require a level-change device. There are two typical types: flip-out and telescoping. Both require fairly consistent distances between the vehicle and stop or station. While they may have a reputation of slowing boarding and alighting, adhering to the following mitigates this.

- Locate at or under the front entrance of the vehicle, under direct supervision of the vehicle driver, without requiring the driver to leave his/her seat;
- Locate near the securement area;
- Designate boarding locations at the station or stop;
- Utilize safety features, such as hand grasps and edges or railings, to prevent wheelchairs from sliding off ramps or to keep them safely positioned on lifts while being raised to the vehicle floor, or lowered to the station. Such features should meet or exceed local requirements.

Table 30.5. Various Ramp Dimensions (MacDonald 2006, p. 14)

Element	Minimum	Preferred	Maximum
Ramp width	750 mm	800 mm	–
Typical horizontal extension	–	–	1200 mm
Vertical rise	–	–	300 mm
Vertical rise between telescoping sections	–	0 mm	6 mm
Lip at bottom of ramp	–	0 mm	15 mm

Table 30.6. Various combinations of ramp slopes and vehicle floor heights. Table modified from ADAAG.

Slope	Maximum Height to Vehicle Floor above 150 millimeter Curb
1:4	75 mm
1:6	150 mm
1:8	225 mm

30.6.4.4 Stations

Access by most seniors and customers with disabilities to complementary and feeder buses (even when inclusive design features are not yet phased in) can be greatly enhanced by systematically upgrading stations, beginning with those stations that are most used by all customers. Good station design can enable customers to more easily board vehicles, even when entrances are poorly designed. Good station design also enables the stations to become accessible to wheelchair users when lift- or ramp-equipped vehicles begin service.

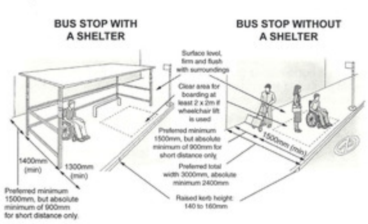


Figure 30.67. Universal design features of bus stops. *Adapted by TRL from Oxley, 2002.*

Shelters and waiting areas benefit all customers, and especially assist seniors and those with disabilities. They provide protection from sun, rain, wind, and wind-blown particles. Illuminated shelters provide additional security at night, especially for women.

Stations can extend across a parking lane to the edge of the traffic lane. These "bus bulbs" or "boarders" can extend across a parking lane to the edge of the 2-meter curb extension, for example, allows the vehicle driver to get the vehicle close to and parallel to the curb so that the vehicle does not need to overhang the sidewalk. This in turn permits the station to be raised still further (e.g., 200 to 250 millimeters) to give better access to the first step of the vehicle.

Box 30.1. Key Features

Figure 30.63 below illustrates key features, including a flat hard surface, minimum dimensions, a clear area for boarding, and a curb height, which reduce the distance to the first step of a vehicle if bus drivers are trained and monitored to properly station the bus adjacent to the stop and steps are taken to ensure that other vehicles do not park in the stop. An ischiatic support is shown, which substitutes for seats in low-cost installations. If adequate space for a shelter is lacking, the shelter can be placed at the rear of the sidewalk, for example, against the side of a building. The use of a beveled curb at bus stops may enable drivers to position their vehicles closer to the curb, as discussed in Section 30.5.

30.6.5 Deployment

BRT systems are often faced with the questions of how to prioritize accessibility—that is, where to use accessible vehicles first.

Option 1: Deploy a few lift- or ramp-equipped vehicles on many or all lines.

In theory, a well-managed and reliable vehicle service with strict schedule adherence could serve a significant portion of travel demand by wheelchair users. It may also be more equitable, as opposed to initially concentrating accessible vehicles on one or two lines. The reality, however, is often less than ideal. Because this type of system must maintain a certain operational rigor, there are many opportunities for it to be unreliable. At best, this system should be reserved for temporary use.

Option 2: Phase in lift- or ramp-equipped vehicles on one line at a time, with all equipment accessible.

Focus on one line at a time during a transition to a fully accessible fleet. This increases the confidence of wheelchair users that they will not be subject to long delays, thus helping to market accessibility features. Public transport agencies may then focus on the line's stops, stations, and surrounding infrastructure as well. Ideally, the most heavily travelled lines, or lines serving major trip generators such as universities, shopping, and residential centers, would be converted first.

30.7 Driver and Staff Training

> *"The one thing that unites all human beings, regardless of age, gender, religion, economic status, or ethnic background, is that, deep down inside, we all believe that we are above-average drivers."*
>
> — Dave Barry, author and columnist, 1947–

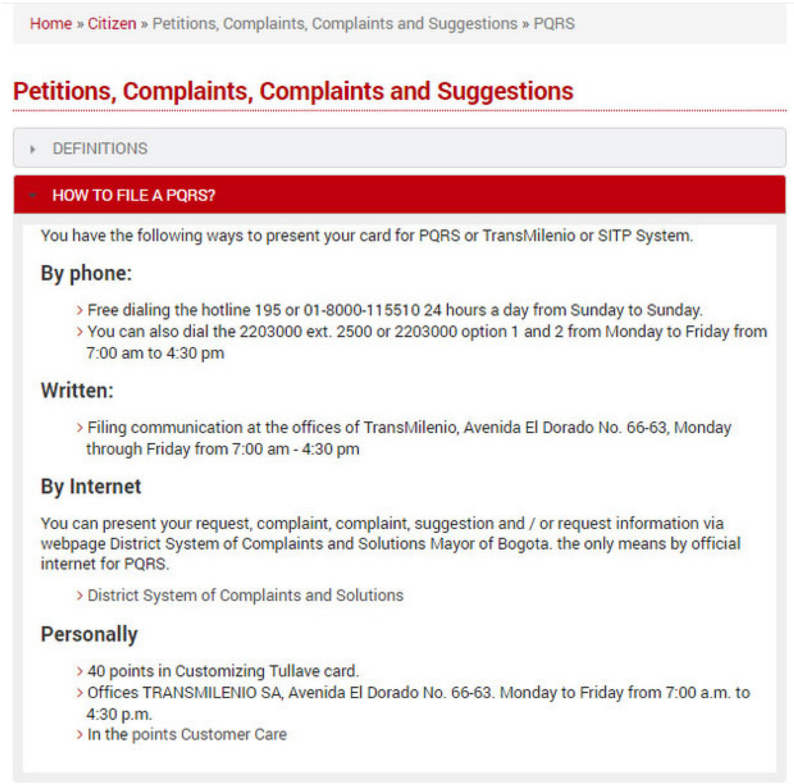
Accessible design must be supplemented by accessible operation in order to enhance universal access to the system. Drivers and public transport staff need to be aware of any laws and regulations concerning customers with special needs, and should be trained to appropriate competency, depending on their varying tasks, concerning the main categories of physical, sensory, and cognitive disabilities, including hidden disabilities. They should understand the appropriate vocabulary to use concerning customers with disabilities. Staff in contact with the public should learn basic skills for communicating with wheelchair users, customers who are deaf or hard-of-hearing, blind customers or those with low vision, and cognitively impaired customers.

30.7.1 Trunk-Line Driver Training

Trunk-line drivers need training:

- To be alert to the needs of customers who are boarding or alighting;
- To pay special attention to ensure that wheelchair users, blind persons, and others with special needs are safely on board and properly secured, seated, or braced prior to moving the vehicle;
- To avoid sudden starts and stops;
- To slow down before going around curves;
- To drive courteously.

A regular monitoring (by uniformed supervisors or by undercover officers) and evaluation process helps to ensure continued accessibility. There should be a system for anonymous customer compliments and complaints (see Figure 30.68).



Home » Citizen » Petitions, Complaints, Complaints and Suggestions » PQRS

Petitions, Complaints, Complaints and Suggestions

DEFINITIONS

HOW TO FILE A PQRS?

You have the following ways to present your card for PQRS or TransMilenio or SITP System.

By phone:

› Free dialing the hotline 195 or 01-8000-115510 24 hours a day from Sunday to Sunday.
› You can also dial the 2203000 ext. 2500 or 2203000 option 1 and 2 from Monday to Friday from 7:00 am to 4:30 pm

Written:

› Filing communication at the offices of TransMilenio, Avenida El Dorado No. 66-63, Monday through Friday from 7:00 am - 4:30 pm

By Internet

You can present your request, complaint, complaint, suggestion and / or request information via webpage District System of Complaints and Solutions Mayor of Bogota. the only means by official internet for PQRS.

› District System of Complaints and Solutions

Personally

› 40 points in Customizing Tullave card.
› Offices TRANSMILENIO SA, Avenida El Dorado No. 66-63. Monday to Friday from 7:00 a.m. to 4:30 p.m.
› In the points Customer Care

Figure 30.68. The feedback instructions on the TransMilenio website. *TransMilenio*

30.7.1.1 Vehicle Docking at Stations

Trunk-line drivers require special training to dock their vehicles within a prescribed distance from the station platform. Periodic retraining is beneficial.

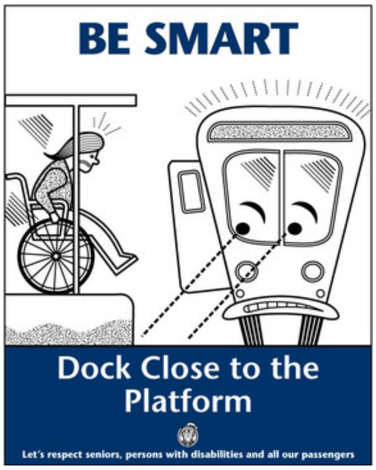


Figure 30.69. Training poster highlighting the importance of docking close to the platform. *World Bank.*

30.7.2 Non-Trunk-Line Driver Training

Drivers on non-trunk-line routes should receive the same training as trunk-line drivers and station personnel. Because these drivers have even more contact with their customers, their training should also include:

- Operating lifts, ramps, and wheelchair securements;
- Pulling up to stations so that the first step of the vehicle entrance can be easily accessed by customers;
- Monitoring movements by wheelchair users to see if help is needed in securing customers;
- Calling out key stops (and requested stops) to assist blind persons and other customers not familiar with the system. Stops should be announced in time for customers to prepare to alight.

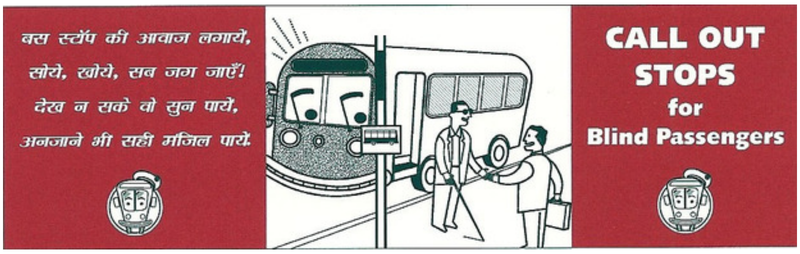


Figure 30.70. Delhi Public Transport Corporation poster in Hindi and English alerts vehicle drivers to call out stations. *Svayam, New Delhi, and the World Bank.*

30.7.3 Staff Training

Station attendants, fare personnel, and security personnel have special responsibilities in a BRT system and should be cross-trained concerning their treatment of customers with disabilities. Orientation to the needs of disabled customers should be part of such training. Ideally, such training would include boarding a vehicle in a wheelchair and navigating a station with a blindfold. Top management should set an example for others by also participating in such training.

Station personnel should be trained to:

- Avoid the extremes of “protecting” or “ignoring” disabled persons;
- Ask if help is needed before offering assistance;
- Be alert for wheelchair users and older persons who may have difficulty crossing the station-to-vehicle gap.

Just as it is beneficial to employ staff with a wide range of language skills, having personnel who know sign language in terminals and at major transfer points would be a boon to those deaf customers who use sign language.

Figure 30.71. Public transport agencies around the world include disability awareness in their training modules. *San Francisco Municipal Transportation Agency.*

30.7.4 Emergencies

Transport providers need emergency plans in place to deal with earthquakes, floods, storms, fires, and other emergencies. The evacuation of customers, including persons with disabilities, *from* a vehicle in an emergency, or *by* a vehicle from a disaster area, should be a part of such planning.

30.8 Orientation, Information, and Evaluation

> *“Knowledge is power. Information is liberating. Education is the premise of progress, in every society, in every family.”*
>
> — Kofi Annan, former secretary-general of the United Nations, 1938–

For information on customer communications, see Chapter 10: Public Participation; this section details elements specific to accessibility to information.

30.8.1 Orientation

Opening day on an accessible BRT system may be the first time some customers with special needs have been on a public transport vehicle. Orientation may be needed for such persons (*Public Transport Access Training Toolkit*, World Bank, 2009). During the orientation there are a couple of methods to consider that wheelchair users might use to cross the platform-to-vehicle gap:

- Some wheelchair users will back over the gap so that the typically larger back wheels cross first, making it easier for the smaller front wheels to cross.
- Others may find it convenient to have a station assistant or friend assist by pushing their chair across the gap while pressing down on the back of the chair to reduce pressure on the smaller front wheels while they cross the gap.

Blind persons also benefit from the opportunity to familiarize themselves with vehicles and public transport stations before using them for the first time in revenue service. See the *Public Transport Access Training Toolkit* (World Bank, 2009) for methods to familiarize the general public, public transport staff, and persons with disabilities in the use of public transport systems by persons with limited mobility. Additionally, travel orientation opportunities provide a chance to generate favorable media attention prior to initiating service.

30.8.2 Information

Marketing and public information requirements for those with special needs should be available in alternative formats. Focus groups or advisory committees can advise.

- Large-print brochures;
- Timetables and maps in Braille;
- Tactile maps of routes and stations;
- Accessible website;
- Text phones;
- E-mail and social media;
- Accessible smartphone apps.

30.8.2.1 Telephone Center

Any large public transport system needs a contact telephone number for complaints and compliments. Phone numbers should be displayed on vehicles and in stations, as well as included in brochures or other public information. Persons who are deaf or hard of hearing need to be able to text the public transport agency. Complaint and compliment data should be directed to the different stakeholders in the system, including persons with disabilities serving on advisory committees. Such transparency can increase confidence and improve the working relationship between the public transport operator and agencies representing customers with special needs.

30.8.2.2 Service Center

A centrally located office may be provided for customer service, accessible to wheelchair users.

30.8.2.3 Website, Social Media

An accessible website should be provided, with large, high-contrast text and software that can be used by persons with different types of disabilities. Photos and animations that interfere with navigating the site should be replaced by text explanations (World Wide Web Consortium 2016). Increasingly, public transport operators are able to communicate service announcements in real time using social media.

30.8.2.4 Public Education

A public education program is often helpful to orient the public to the principles of independent living. The public needs to learn that disabled persons are usually not accompanied by attendants. The public also needs to be educated to yield priority seats and wheelchair-securement areas. Public education can include messages included in the electronic signage in stations and vehicles; TV and radio announcements; and flyers distributed to customers, supplemented by well-publicized events involving persons with disabilities and local officials. Sample public service announcements are found in Section 4 of the *Public Transport Access Training Toolkit*.

30.9 BRT Accessibility Check List

1. Pre-design consultation
    - (a) Advisory committee of disabled persons and seniors
    - (b) Focus groups of disabled persons and seniors
    - (c) Tours during construction
2. Public space elements (within 400 meters of station)
    - (a) Sidewalks and walkways along main pedestrian network at least 2.5 meters wide
    - (b) Sidewalks and walkways along secondary pedestrian network at least 2 meters wide
    - (c) All other sidewalks and walkways at least 1.5 meters wide
    - (d) Clearance at obstructions at least 0.9 meters
    - (e) Overhead clearance at all walkways and sidewalks 2 meters high
    - (f) Walkways paved, level, nonskid, and drained
    - (g) Side slope not greater than 1 to 2 percent, lighting OK
    - (h) Tactile guideway design and use OK (guideways may not be required)
    - (i) Tactile warnings where required (e.g., at curb ramps, unguarded platform edges)
    - (j) Full-width curb ramps at all pedestrian crossings with gradient from horizontal not more than 1:12 (8 percent) and with smooth public transportation to street and/or continuous sidewalks (raised crossings) planned
    - (k) Other ramps with gradients appropriate to length
    - (l) Traffic signals pedestrian-friendly
    - (m) Audible signals where appropriate at crossings
    - (n) Pedestrian bridges or tunnels include access features to assist disabled persons
    - (o) Long-term planning process in place for phasing in accessible footways to BRT stations and to complementary service and feeder bus stops
3. Fare collection
    - (a) Have the needs of disabled customers been taken into consideration in weighing the relative merits of different fare structures?

   (b) Fare cards user-friendly
   (c) Fare card vending sites accessible to disabled persons
4. Access at trunk-line stations
   (a) All stations served by trained station assistants and/or security personnel
   (b) Stations display uniform design understandable by new users
   (c) Ramps to stations not greater than 1:12 (8 percent) gradient
   (d) Long stations have exits at both ends where possible
   (e) One fare gate at least 900 mm wide
   (f) Folding seats or benches, and ischiatic supports, if waiting times exceed five minutes
   (g) Stations have sliding doors that automatically open with vehicle doors
   (h) Adequate lighting
   (i) Adequate color contrast
   (j) Uniform signage, with icons and color coding to assist disabled or new users
   (k) Audible warning at sliding doors
   (l) Public transport information in audible and visual formats, tactile format if desired by blind advisers
   (m) Elevators planned where needed
   (n) Transfer terminals have clear information
   (o) Accessible routes planned to connect stations and terminals with other transport modes (pedestrian paths, bicycle paths, intercity vehicles, etc.)
5. Platform-to-vehicle floor gap
   (a) Gap eliminated by boarding bridges lowered from all doors of vehicle for all customers
   (b) Stations and busways designed so that a horizontal gap of 10 centimeters at the front door of the vehicle is achievable in regular service (preferred gap is 7.5 centimeters)
   (c) Stations and busways designed so that station platform is not more than 1 to 2 centimeters below the vehicle floor
   (d) Station door designated for disabled users at front entrance of vehicle
   (e) Station assistants trained to assist wheelchair users, others with disabilities
   (f) Drivers trained to approach platforms with vehicle parallel to platform edge
   (g) Vehicle design and platform design coordinated to eliminate vertical gaps and minimize horizontal gaps
   (h) Gap mitigated by use of alignment markers on vehicles and stations, beveled curbs, precision docking, and/or gap fillers
6. Access at complementary service and feeder-line stops
   (a) High-use bus stops prioritized for accessibility features
   (b) Enforcement planned to keep stations free of other vehicles
   (c) Shelters and waiting areas meet accessibility criteria
   (d) All-weather concrete pads where no pavement exists
7. Specifying access for trunk-line vehicles and complementary service and feeder line buses
   (a) Seamless integration of accessible station and vehicle design and operational features
   (b) Full spectrum of access features included in specifications for trunk-line and complementary service vehicles, and feeder ve-

hicles where applicable

8. Signage and announcements
    (a) Exterior signage meets or exceeds size and color specifications
    (b) Interior signage and announcements meet needs of visually impaired and hearing impaired customers
9. Vehicle entrances and interior design
    (a) Accessible travel paths checked on any vehicles with doors on both sides
    (b) If low-floor vehicles used, meet access standards
    (c) First step of new complementary service vehicles not more than 25 centimeters above ground level
    (d) Hand grasps on both sides of entrances and exits and meet specifications
    (e) All turnstiles removed from complementary service and feeder vehicles
    (f) Consideration given to including a kneeler feature on feeder-line buses where appropriate
    (g) Flooring is nonskid
    (h) Adequate (plentiful) use of vertical stanchions and handholds painted in bright yellow or other contrasting color
    (i) Seating meets standards to keep customers from sliding
    (j) Prioritized seats for seniors, persons with disabilities
    (k) Visual and audible stop-request signals if vehicles used outside trunk lines
    (l) Wheelchair securements meet stated norms
    (m) Have special circumstances (e.g., steep hills) been taken into consideration in specifying wheelchair securement methods and equipment?
10. Feeder-line vehicle deployment and wheelchair access
    (a) Deployment of accessible vehicles on prioritized lines with integrated phase-in of pedestrian access to prioritized stations
    (b) Wheelchair user access provided or to be phased in by combination of raised stations, low-floor vehicles, and wheelchair ramps
11. Public information
    (a) Public information will be available in alternative formats
    (b) Phone and text numbers for complaints and commendations
    (c) Accessible service center
    (d) Messages on electronic announcements in stations and on vehicles
    (e) Accessible website and social media
    (f) Public education campaign
12. Training
    (a) Driver training to include courteous and appropriate treatment of seniors and disabled customers, as well as smooth operation (avoiding abrupt starts and stops, slowing down before turns, and minimizing vehicle-to-platform gap at BRT stations)
    (b) Consideration given to provision of orientation to new disabled users
    (c) Training for emergencies includes policies regarding disabled customers

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31. Bicycle and Pedicab Integration

> *"When man invented the bicycle, he reached the peak of his attainments. Here was a machine of precision and balance for the convenience of man. And (unlike subsequent inventions for man's convenience) the more he used it, the fitter his body became. Here, for once, was a product of man's brain that was entirely beneficial to those who used it, and of no harm or irritation to others. Progress should have stopped when man invented the bicycle."*
>
> — Elizabeth West, author, 1969–

This chapter covers the integration of bicycles and pedicabs into a BRT system. Bicycles and pedicabs are useful vehicles for expanding the reach of BRT. Whether privately or publicly owned, they serve an important link in the trip chain. Every traveller makes a series of mental calculations based on time, available modes, costs, and familiarity with different modes. There are certain distances where it is more time- and cost-effective for cyclists to continue to their destinations without using public transport. A complete system of bicycle infrastructure and parking allows for the individual to make the best decision.

Contributors: Carlos Pardo, *Despacio*; Chris Kost, *ITDP Africa*; Michael King, *BuroHappold Engineering*; Bradley Schroeder, *Catapult Design*

31.1 Bicycle Network

> *"Every time I see an adult on a bicycle, I no longer despair for the future of the human race."*
>
> — H. G. Wells, novelist, 1866–1946

This section discusses the general planning elements for a bicycle network, and how it fits within the overall public transport network.

31.1.1 Trip Chains

Virtually all trips can be analyzed as a "chain of trips." The simplest chain has three links: a walking trip to a vehicle, a vehicle ride, and a walking trip to one's final destination. For those lucky enough to be able to store their bikes in their homes and offices, the journey may consist entirely of one mode: the bike.

The trip-chain concept is of utmost importance when thinking about public transport. All public transport users have to travel from their origin to the public transport stop, and at the end of the trip from the public transport stop to their destination. This means that "access" and "egress" trips are an integral part of public transport travel. These "feed" the transport system, and are referred to as feeder trips. Given its complementary characteristics, cycling is an excellent feeder mode.

An integrated public transport system allows users to ride their bicycles from their home to the nearest public transport station, and then take public transport to their final destination (by leaving their bicycle at the station or taking it with them on the public transport vehicle). When multi-modal connections are well implemented, travel times become similar to or better than those of a private car, especially in big cities with congestion and less provision for parked cars. Above all, travel times improve when public transport enjoys segregated express routes (e.g., in BRT or rail systems), and can travel congestion free. A transport policy that includes as wide a range of multimodal (or intermodal) trip opportunities as possible can increase public transport ridership, while increasing access for all transport users.

Table 31.1. Possible Trip-Chain Combinations

	Walk	Bike	Public transport	Drive	Transfer
Entire distance	X	X		X	
Partial distance	X		X	X	
To the stop/station/parking	X	X	X	X	
At the stop/station/parking	X				X
From the stop/station/parking	X	X	X	X	
Finding parking		X		X	

31.1.1.1 Integrating Bicycles into the Trip Chain

The following lists precise points in the trip chain that benefit most from bicycle integration:

- To/from the public transport station: Bicycles should be available to serve people whose point of origin or final destination is too far from the public transport station for them to complete their trip on foot. In some cities, users keep a second bicycle parked at the egress station, but this is not normally the case, particularly in developing cities. Three services to meet this need include:
- Rental bicycles: Bicycles that are managed by a specific company and are rented and returned to the same location, mostly for tourist purposes;
- Shared bicycles: An important form of public transport, shared bicycles allow for trips linked to public transport and increased public transport range and are similar to rental bicycles, but organized on a larger scale. Kiosks or stations are located throughout the city to allow users to circulate shared bicycles. Often rented for short periods of time through a membership system, bike-share serves both tourists and commuters;
- Bicycle taxis (pedicabs): Three-wheeled human-powered vehicles that operate as feeders to public transport;
- At the public transport station:
- Bike parking: The provision of ample, secure bicycle parking facilities near or in public transport stations;
- Bike stations: Enhanced bicycle facilities in key locations with various services, used as a multimodal transfer station. Services may include key card access bike parking, locker rooms, showers, rental, and retail facilities;
- During the public transport ride:
- Bikes on buses: Provision of bicycle racks on the front of or within buses, where public transport relies mostly on bus-based systems;
- Bikes on rail systems: Provision of space and permission to enter rail vehicles in specific times and locations, for large cities with rail-based systems.

31.1.1.2 Minimizing Delay and Transfers

When deciding whether and how to make a trip, people make a number of calculations based on time, ease, price, and familiarity. Delays and transfers increase trip time. Predicting and calculating these points of delay is an important part of structuring an overall journey, whether by the consumer or public transport operator. The critical element usually is the amount of delay at each transfer. If the public transport service is very frequent, wait time will be minimized. If finding bike parking is time-consuming, then the transfer can be longer. As shown in the graphic below, the time to ride a bike from origin to destination might be equal to the same journey involving transfers, especially for short trips.

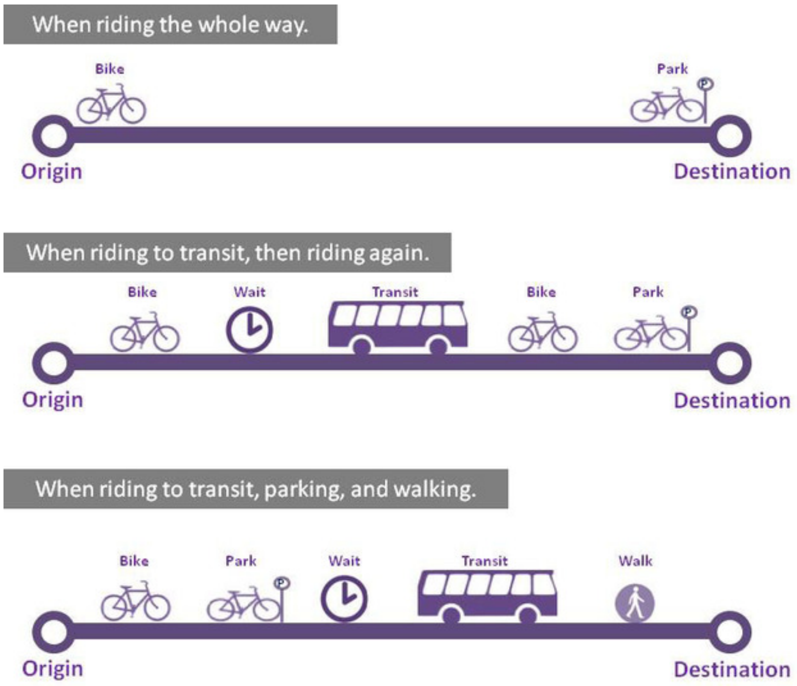

Figure 31.1. Comparison of various trip chains involving the bicycle, public transport, and walking. *TransLink*

31.1.1.3 The Bicycle's Part in Modal Integration

The success of any public transport system depends on modal integration. A driving network extends from one's origin (garage) to one's destination (parking) with an entire complement of integrated roadways: driveways, access lanes, highways, and so on. Likewise, a public transport network should extend from origin to destination. The bicycle can be an integral part in this network as it extends and augments the public transport network; the ability to use a bicycle can be the deciding factor in whether one takes public transport or chooses to drive alone.

31.1.2 Catchment Area

Cycling exponentially increases the catchment area of a BRT station. As shown in Figure 31.4, one can walk about 800 meters in 10 minutes, assuming a 4.8-kph pace. Ten minutes is generally used as the amount of time that one will travel to access high-quality public transport (BRT, metro, ferry). Cycling at 15 kilometers per hour (kph) yields a range of 2.5 kilometers in the same amount of time. Fifteen kph is known as a "no sweat" pace—a speed that will allow you to arrive dry. While the cycling distance is just over three times that of walking, the catchment area is twenty-five times greater. Figure 31.2 applies these catchment areas to the Insurgentes BRT line in Mexico City.

The bicycle-catchment area expands the longer patrons are willing to ride to the BRT station. This is important in lower-density areas, or in areas constrained by geography. A catchment area based on a 60-minute ride is 15 kilometers in radius. This could cover a large part of an urban area. Thirty minutes (7.5-kilometer radius) is the general limit for a normal catchment area.

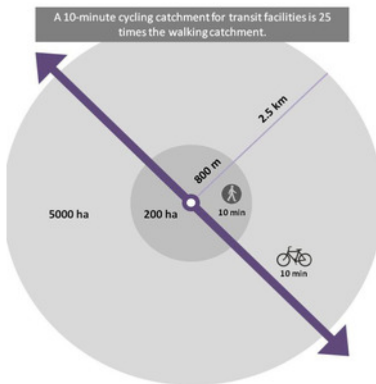

Figure 31.2. Cycling catchment area compared to walking catchment area. *TransLink*

Figure 31.3. Bicycle (larger circle) and pedestrian (smaller circle) catchment areas overlaid on stations along the Insurgentes BRT line in Mexico City. *Google Earth.*

31.1.2.1 Integrating Bicycles with BRT

The benefits of integrating bicycles into the BRT system include:

- Door-to-door service, competitive with private vehicles;
- Larger station-catchment areas (see Section 31.1.2), which increase ridership potential;
- Low-cost system expansion (bicycles used instead of feeder buses);
- Reduced pressure on congested roads and auto parking (trips shift to bicycle);
- Less delay, because patrons do not need to wait for feeder buses.

Key initiatives to improve cycling-BRT integration include:

- Seamless bicycle-route connections to BRT stations;
- Smooth transfers between bicycles and the BRT system;
- Secure parking facilities for bicycles at BRT stations;
- Bike rentals or public bicycle services;
- Pedicabs (bicycle taxis).

31.1.3 Using Bikes to Augment BRT

Typically, bicycles have been used to expand the reach of BRT; however, bicycles can also be used to augment service. For example, if BRT station spacing is based on a cycling catchment area (2.5 kilometers) instead of a walking catchment area (800 meters), fewer stations or skip-stop service are required. With fewer stops, travel time on the vehicle is reduced. Those fewer stations can be more highly developed, with bike parking and so forth. This scenario has been proposed in the Netherlands, where the highly developed bicycle infrastructure makes it feasible.

Bicycles can augment BRT via recreational trips on the weekends and during off-peak hours. Often the system will have excess capacity during these times, which can be used to travel to the outskirts of the city and ride a bike in the country, for example.

Bicycles can help distribute journeys more evenly throughout the system. For instance, patrons arriving by foot typically walk to the nearest station, even though it may be small, crowded, or not an express stop. By bike, one has a greater choice of stations. Thus, one can choose an express stop, a station on a different line (thereby avoiding a transfer), or a station that is less crowded. This may relieve pressure on overloaded segments and add customers on underused stretches.

Figure 31.4. A protected bike lane—which provides physical separation from the roadway—along the BRT in Delhi, India, located between the roadway and trees. *Michael King.*

31.1.4 Complementary BRT and Bicycle Networks

Traditionally, public transport and bicycle networks have been developed and operated separately. In many cases, they were seen as competitors; public transport operators feared that cycling would steal patrons, and vice versa. This is parallel to the animosity between public transport and driving systems.

Some of the more recently successful BRT systems have taken a different approach. They see cycling as complementary and have sought to develop complementary systems. The basic idea is: It is not possible to provide high-quality public transport service to every part of the city, so bicycles fill in the gaps. Thus, the combination of a BRT system with a bike-lane network can do much to provide citywide mobility and improved access for users. For example, Bogotá is home to Latin America's largest bicycle network with some 320 kilometers of dedicated bike lanes. Ultimately, if one can move throughout a city without a car, then one will not need a car.

Figure 31.5. A bike lane along the BRT in Guangzhou, China, located between the roadway and trees. *Michael King.*

Techniques to merge BRT and bicycle systems include:

- Place bicycle facilities on higher-volume, higher-speed roads that lead to the BRT corridor. This will "collect" cyclists and deposit them at the BRT stations;

- Locate BRT stations along existing high-usage bicycle routes, such as greenways. This will allow cyclists to ride to the stations, or ride to a different BRT line;
- Upgrade the cycling infrastructure within 2.5 kilometers of BRT stations (discussed in Section 31.3.1 of this chapter).

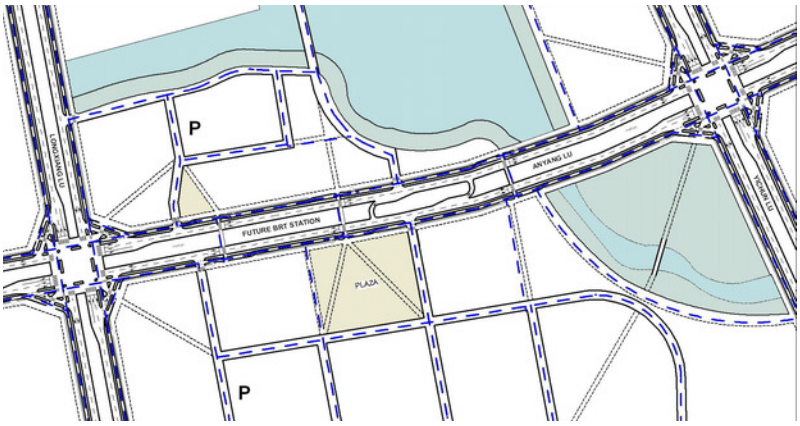

Figure 31.6. A design for a bicycle network in tandem with a BRT network in Harbin, China. Bicycle routes are denoted by dotted blue lines. *Nelson\Nygaard.*

31.1.5 Bicycles Onboard BRT

The viability of permitting bicycles to be brought on board the BRT vehicle depends on the level of crowding in the system, which is discussed in more detail in Chapter 7: Capacity and Speed. In general, folding bikes should be allowed on board at all times, in much the same way that luggage is. It may be prudent to require a bag, or that the bike be placed in a luggage hold. Some BRT systems, such as AC Transit serving the East Bay of California, USA, and C-TRAN in Vancouver, Canada, permit bicycles to be brought on board during nonpeak hours. There might be a requirement to board only certain cars (the first or last) or through certain doors. Some systems require a permit or extra fee; however, if the intention is to encourage cycling this might be counter-productive. Most important, the requirements for bikes on board need to be clear and consistent. For example, if the number of bikes on each vehicle is limited, a cyclist runs the risk of being denied entry, which leads to travel delays. Uncertainty tempers use.

Figure 31.7. The Las Vegas, Nevada, USA, MAX BRT system offers special entry points for customers with bicycles. *NBRTI.*

Figure 31.8. Bikes on Swift BRT vehicle in Seattle, Washington, USA. *Nelson\Nygaard.*

31.2 Bicycle Infrastructure

> *"The bicycle is the most civilized conveyance known to man. Other forms of transport grow daily more nightmarish. Only the bicycle remains pure in heart."*
>
> — Iris Murdoch, author and philosopher, 1919–1999

This section focuses on the design and operation of bicycle facilities—bike lanes, greenways, or low-speed streets—along BRT corridors and the infrastructure required for a successful bicycle network, namely parking and riding facilities. A BRT corridor is an ideal place to construct a bike lane. The primary reason is that the corridor is typically designed to facilitate through traffic; turns are banned, signals are timed to give priority to the BRT vehicles, and so on. Cyclists can benefit greatly from this. A second reason is that the BRT corridor can double as a spine of the bicycle network, especially if none exists. Lastly, co-joining the bike and BRT routes helps to integrate service. A cyclist riding to the BRT station may enter the corridor at a number of points, then ride along the corridor to the station. He or she might choose to bypass a local or crowded station in favor of an express station. BRT lines in Los Angeles; Eindhoven, Netherlands; Cape Town, South Africa; Delhi, India; and Guangzhou, China, all have parallel bicycle facilities.

Figure 31.9. A bike lane integrated with a BRT corridor in Eindhoven helps maximize the mobility options for residents. *Advanced Public Transport Systems.*

Figure 31.10. Parallel bicycle path along the Orange Line BRT (Los Angeles). *Xiaomei Duan, Far East BRT.*

31.2.1 Bicycle Infrastructure Planning

Collecting information about existing cycling activity and cyclist behavior is a useful first step before designing cycling facilities. Methodologies for doing this are roughly equivalent to methodologies for designing pedestrian facilities, starting with a review of existing cycling facilities, the identification of locations dangerous or illegal for cyclists to operate, mapping of popular cyclist routes, major origin and destination locations, identifying major severance problems, reviewing data about locations of high levels of cycling crashes, and targeting interventions to these locations. Engaging the public can identify unsafe cycling environments and preferred routes.

A few simple rules should be considered when planning cycling facilities:

- Cyclists are more sensitive to road surfaces than motorists, and prefer smooth surfaces. Cobblestones and rough brick may be aesthetically pleasing, but such surfaces can discourage cycling;

Figure 31.11. Cyclists are often quite exposed to delays, safety risks, and high levels of contamination when confined to using the curb lane. *Lloyd Wright.*

- Cyclists want to go straight. Cyclists want to get where they are going as fast as anybody else, and do not want to have to meander around trees and park benches;
- Cyclists will not use substandard, poorly maintained, obstructed, narrow bike lanes unless they must. Build high-quality bike lanes, greenways, off-street paths, or redesign the road for safe mixed bicycle and motorized vehicle traffic operation;
- Having a large vehicle bearing down upon a cyclist can be quite stressful. Stress-free cycling facilities encourage higher ridership, especially among women, older adults, families, and youth. Relocating buses into the central median resolves one of the most pressing conflicts faced daily by cyclists.

31.2.2 Bicycle Infrastructure Financing

Ideally, bicycle infrastructure, including parking, is seen as an integral part of an intermodal public transport system. Bicycles can substitute, augment, and expand the public transport network at little or no cost to the public transport agency. Nevertheless, there are a number of opportunities to finance bicycle parking:

- Advertising;
- Retail concessions in exchange for providing security, maintenance, and service;
- Public-private business partnerships;
- Sponsorship by public-health organization seeking to increase fitness;
- Cross-subsidies from auto-parking fees, congestion charging, and fuel taxes;
- Conversion of underutilized auto parking (ten bike parking spaces equal one auto parking space).

31.2.3 Design of Bicycle Facilities on BRT Corridors

BRT corridors tend to be located on reasonably wide primary or secondary urban arterials. In developing countries, which frequently lack a strong secondary road network, these arterials often serve a great diversity of trip types and modes, from intercity bus and truck trips, to medium- and long-distance intercity public transport trips, to short-distance cycling and walking trips. This complex multifunctionality of a BRT corridor makes road design reasonably difficult. As the lane widths and the number of lanes increase, vehicle speeds tend to increase, and hence the desirability of segregating modes of significantly different operating speeds increases.

Just like motorists on such an arterial, some cyclists are going longer distances and value uninterrupted higher-speed travel over access, while others are only going a short distance and value access to adjacent properties over speed. For motorists on such arterials, this conflict is frequently resolved by providing separate through lanes for long-distance vehicle travel and service lanes for property access. Adding BRT on such an arterial into the central road verge introduces no particular problems for motorists. Excluding bike lanes, the standard cross section would have bus lanes in the median, then higher-speed traffic lanes, a side median, a service lane for local-access trips, and then a walkway on the outside.

Generally, bicycle facilities are placed in the side median or service lane. The exact location and type of the facility (bike lane, shared street, etc.) depends on a number of factors, including the amount of space available, volume and speed of motorized traffic, number and location of cross streets and driveways, amount of bicycle traffic, and parking, among others. The images in Figure 31.12 and Figure 31.13 illustrate various options.

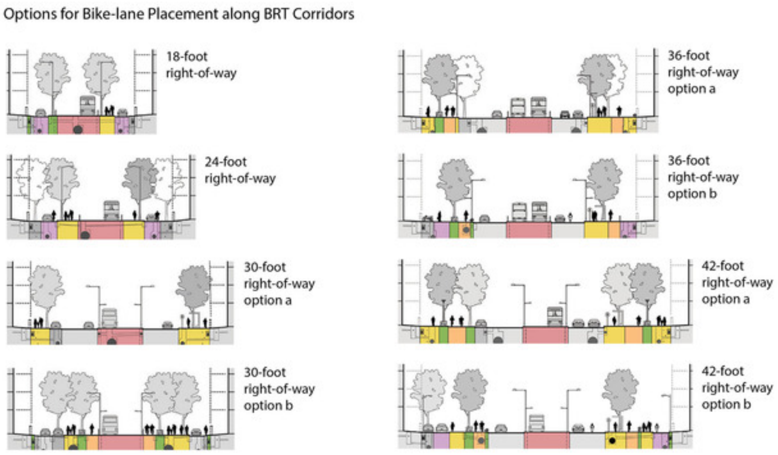

Figure 31.12. Cross-sectional views of various options for locating bicycle facilities along BRT corridors. *Better Streets, Better Cities, ITDP and EPC.*

Figure 31.13. Plan view of four options for locating bicycle facilities in the service road of a multi-way boulevard (from left): bike lane only at intersections; bike lane on right side; bike lane on left side against median; and two-way bike lane on left side against median. *Nelson\Nygaard.*

Figure 31.14. The bike lane along the Hangzhou, China, BRT system is sited between the BRT lane and the sidewalk. *Karl Fjellstrom.*

Figure 31.15. Bicycling in the "shared street" section of the BRT corridor in Bogotá. No bike facilities are necessary. *Michael King.*

31.2.3.1 Bike Lane in the Central Median

Another configuration is to give cyclists the same advantages that buses enjoy from central-lane operation: priority at intersections. Here, the bike lane is integrated along with the BRT in the central median. Accommodations must be made at the stations (to allow customers to access the stations), at U-turns, and at intersections. Signal priority is generally given to cyclists so that they can turn ahead of motorists.

This configuration removes many of the turning conflicts between bicycles going straight, and turning and stopping vehicles. It significantly reduces the risk of encroachments into the bike lane by street vendors. It provides a very high-speed cycling corridor. Bicyclists wanting to make local-access trips would simply exit the bike lane at the intersection or pedestrian crosswalk closest to their destination, and use the service lane or sidewalk for the remaining distance.

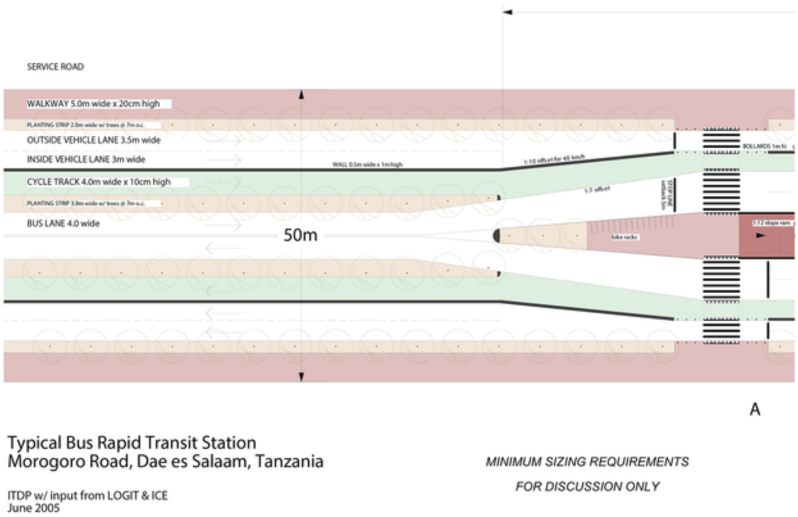

Figure 31.16. Option to place bike lane in the median alongside BRT lanes. *Nelson\Nygaard.*

Figure 31.17. Bike lane in the center of a boulevard in Bogotá. *Michael King.*

Figure 31.18. Bike lane in the center of a boulevard in New York City. *Michael King.*

Figure 31.19. A "mixing" zone at an intersection. Typically the cyclist swings to the left of the right-turning driver. *NACTO.*

Figure 31.20. A bike lane in Berlin curves to the edge of the roadway so that drivers and cyclists may interact more effectively at the intersection. *Michael King.*

Figure 31.21. A bike signal in Vancouver, Canada, turns green before the right turn signal for autos turns green. *Michael King.*

Figure 31.22. A left turn lane for bicycles in Changzhou, China. *Michael King.*

31.2.3.2 Bicycle Facilities at Intersections

Wherever the bicycle facility is placed, its treatment at intersections is crucial. The basic principles to consider include:

- Reduce auto speeds, especially turning speeds;
- Highlight bike facilities via markings, signs, and lights;
- Provide mixing and merge zones so that drivers and cyclists may interact with each other at low speeds;
- End visual obstructions before the intersections, so that drivers, cyclists, and walkers may have good visibility;
- Give preference to cyclists over motorized traffic via signals and advance stop lines;
- Provide road space for queued cyclists.

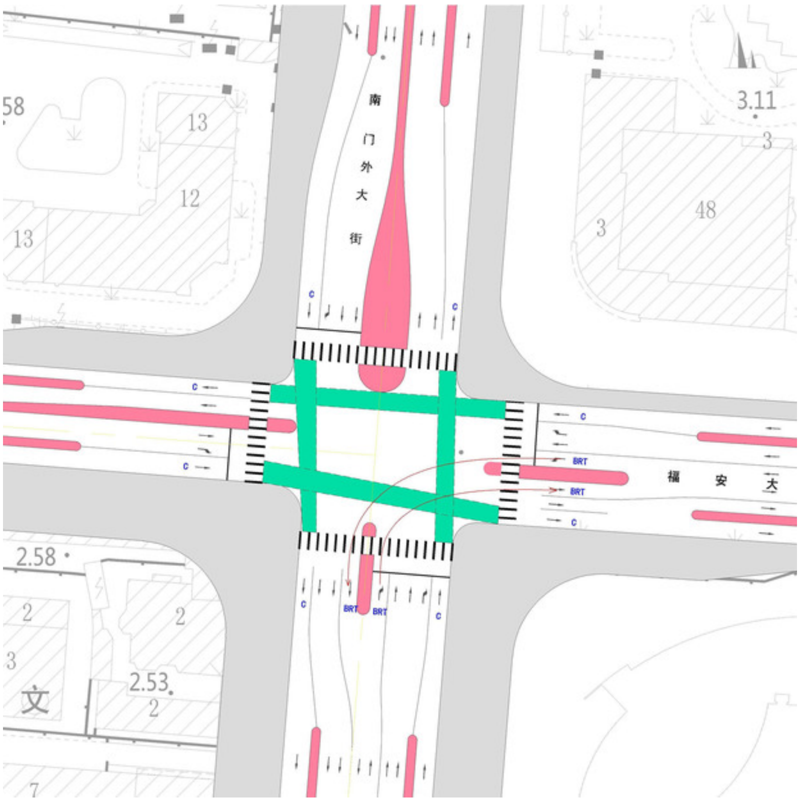

Figure 31.23. A design for cycle lanes and BRT at an intersection in Tianjin, China. Note the green bike lanes extend through the intersection, and that the side medians end, allowing for a center median. *ITDP.*

Figure 31.24. A fence between a bike lane and roadway in Changzhou, China, ensures that drivers turn more slowly. *Michael King.*

Figure 31.25. A bike lane painted through an intersection in Vancouver, Canada. *Michael King.*

Figure 31.26. A cyclist using a BRT corridor in Quito. *Lloyd Wright.*

Figure 31.27. A cyclist using the BRT corridor in Curitiba. *Michael King.*

Figure 31.28. A bike rack doubles as art installation in New York City. *Michael King.*

Figure 31.29. A U-shaped bike rack is a low-cost and relatively secure option. *Lloyd Wright.*

31.2.4 BRT Corridors without Bicycle Facilities

If no cycling facilities are provided, the likelihood of bicyclists using the busway as a bikeway is fairly high. Cyclists take advantage of the limited cross-traffic, favorable signal progression, and separation from auto traffic. This has led to serious bus-bike crashes in BRT corridors, especially along hilly corridors. As a matter of safety, it is preferable to either construct bike lanes within BRT corridors or design the busway such that BRT drivers can safety pass cyclists. Additionally, cities should develop strategies for enforcing lane violations, without discouraging cycling. Informational ticketing, public information campaigns, and using mascots or other humorous tactics are all positive means of enforcement and education.

31.2.5 Types of Bicycle Parking

Bicycle parking ranges from a simple rack to a bike station, where you can park your bike, have it repaired, and take a shower. The best type of bicycle parking is indoors, in a secure location. Yet, like cars, bikes are often parked on the street, as close to the BRT station as possible. Parking types are defined and compared below.

31.2.5.1 Bike Racks

Bike racks are the most abundant type of parking facility and generally the least expensive to install. Spatially, they are the most efficient and can accommodate the greatest number of bicycles. There are many different styles and forms of racks. The most effective racks:

- Support the bicycle while locked. The rack design should hold the bicycle upright while locked, without it falling or being able to be knocked over. It should also be oriented to allow sufficient access when locking the bicycle;
- Are immovable. Racks should not be able to be lifted, dragged, or removed from the site. They should be firmly secured or permanently installed;
- Accommodate locking both wheels. Racks that only hold one wheel require users to remove a wheel to lock it or risk having it stolen;
- Have no moving parts. These break and require maintenance.

Figure 31.30. The Lima, Peru BRT system Metropolitano uses a simple parking system at terminal stations, with no fee for users. *Carlos Pardo.*

31.2.5.2 Bicycle Lockers

Bicycle lockers provide a higher level of security than racks and protect bikes from weather. Users can also sometimes store clothing, helmets, and other bicycle accessories in lockers. Access to lockers varies, from single-key individual long-term use, to electronic card locks that allow for multiple users over an extended time period. Lockers are made of a variety of materials, including fiberglass, plastic, and steel.

In some areas, problems have been encountered with lockers being used for unintended purposes—for storage of items other than bicycles, or even people sleeping in them. These abuses can be prevented by using lockers with openings, which can also facilitate periodic cleaning.

Figure 31.31. The Orange Line BRT in Los Angeles includes both bicycle lockers and standard bicycle racks for overflow and for those unwilling to pay. *Nelson\Nygaard.*

Figure 31.32. A "Bicycle Secure Parking Area" directly adjacent to a terminal station in Portland, Oregon, USA. *Nelson\Nygaard.*

Figure 31.33. Upright bicycle parking at TransMilenio stations in Bogotá saves space, but can be difficult for some to use. *Carlos Pardo.*

Figure 31.34. Guarded bicycle parking in Portal Américas, TransMilenio, Bogotá. *Carlosfelipe Pardo.*

31.2.5.3 Shelters and Garages

Figure 31.35. Secure bike parking at a BRT terminal in Bogotá *Nelson\Nygaard.*

Shelters generally consist of rows of bicycle racks protected underneath a structure that is either fully or partially enclosed. Shelters and garages require more space than racks or lockers and have higher installation and maintenance costs, but provide a significantly higher level of security. If a sufficient number of cyclists are utilizing the station, it may be economically viable to offer a formal cycle storage area with a permanent attendant. This also allows for a valet system in which the bicycle can only be taken by providing the appropriate "claim ticket."

31.2.5.4 Bicycle Stations

A bicycle station is a combination of a bicycle repair shop, paid parking, and dressing facilities. There are a number of configurations, including being paired with gyms, bicycle rental, and retail opportunities.

Figure 31.36. Bike station in Long Beach, California, USA. *Brad Davis, Flickr Creative Commons.*

Figure 31.37. Bike station in Long Beach, California, USA. *Brad Davis, Flickr Creative Commons.*

Table 31.2. Comparison of Bicycle Parking Facilities

Facility type	Pros	Cons
Bicycle Racks	• Low installation and maintenance costs • Requires minimal space • Can be installed in numerous and varied locations • Possible to add more racks to meet additional demand • Can accommodate a large volume of bicycles, and be space efficient through stacking or vertical mounting of bicycles	• Provides a low level of security, especially for longer-te • No protection from weather conditions • No protection from vandalism
Bicycle Lockers	• Provides more security, especially in unattended areas • Protects bicycle from weather • Accommodates storage of additional bicycle gear, including helmet and clothing • Generally easy to install	• Requires cleaning and maintenance • Requires more space per bike than racks • Can become a storage facility for non-bicycle-related i • More expensive than racks; approximately US$300/loc
Bicycle Shelters and garages	• Provides greater security than racks or lockers • Protects bicycles from weather • Perceived to be convenient and secure by bicyclists	• Higher construction and installation costs • Susceptible to vandalism if unmanned
Bicycle Stations	• Can include a variety of amenities, including valet service, bicycle maintenance and repair, etc. • Income from services can support parking costs	• Requires business acumen

31.2.6 Bicycle Parking at BRT Stations

The challenge with bicycle parking facilities for BRT systems usually relates to the space available. For BRT stations located in the median of the roadway, space may be available in front of or behind the station structure. Underneath the entry ramp of a pedestrian bridge may also be a possibility. Alternatively, bicycle parking could be provided adjacent to the station, on the side of the road. At terminal sites, BRT systems typically have sufficient space to provide a higher-quality parking area for bicycles. In all cases, the security of the bicycle becomes an overriding consideration in order to encourage confident use.

31.2.6.1 Case Study: Bogotá, Colombia

When the Bogotá BRT system was originally planned, the bicycle network was seen as a separate system from the BRT. By the time the Avenida Americas terminal was built, cycling integration was clearly on the agenda. A covered, guarded, eight-hundred-space bicycle parking facility was built at the terminal, and bicycle users could leave their bicycles at no additional cost. A 4 percent increase in BRT ridership has been attributed to the addition of this facility. To date, no bicycle has been stolen. The

Figure 31.38. Commuter entrance to an 800-bike-capacity parking facility in the Avenida Americas Terminal, Bogotá. *Carlos Pardo.*

increase in bicycle connections to BRT has also reduced the need for feeder vehicles to the terminal. Following this success, bicycle parking was implemented in most terminal stations.

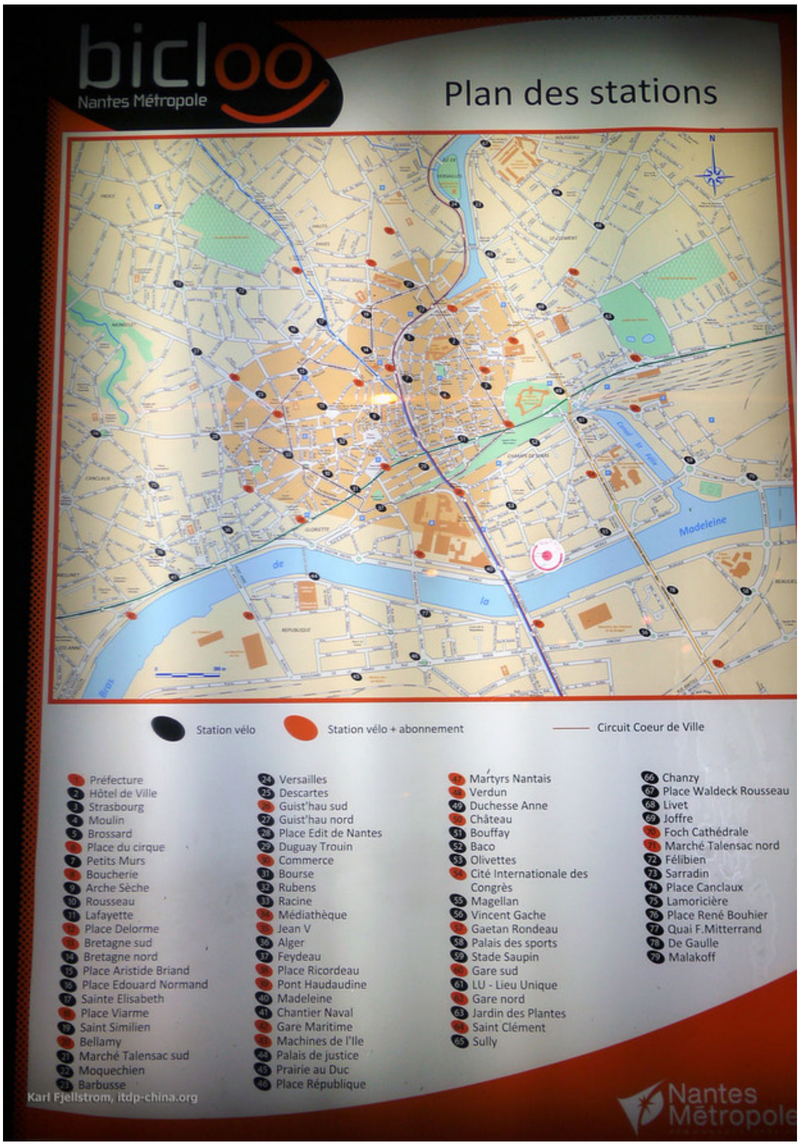

Figure 31.39. Map of bicycle parking stations in Nantes, France. *ITDP.*

31.2.6.2 Case Study: Guangzhou, China

The system in Guangzhou, China, has bicycle-parking stations at every BRT station, and the facilities include double-decker bicycle-parking infrastructure. After a rigorous study of current and future bicycle parking demand, the system planners built 5,500 covered bicycle parking spaces (3,500 covered and double-decker, 2,000 single with roof). This is the largest bicycle-parking integration in a BRT system in the world.

Figure 31.40. Guangzhou's study of bicycle parking demand. *ITDP China.*

31.2.6.3 Bicycle Parking away from the BRT Station

Besides being provided at stations, bicycle parking can be required in building, zoning, and development codes. This will increase the overall supply of parking, which is important because parking should be at one's origin and destination, not just at the BRT station.

Figure 31.41. Bike parking along a BRT and bike-lane corridor in Guangzhou, China. *Michael King.*

31.2.7 Operations and Management of Bicycle Parking

When bicycle parking is considered in BRT systems, there is the question of who will operate and manage it. In general, the three main options are: 1) Include bicycle parking as part of the overall BRT management; 2) Place bicycle parking with another government agency; or 3) Outsource bicycle parking to a private company.

It is beneficial to include bicycle parking within the responsibilities of the BRT management agency. The primary reason is that this agency has a better chance to accurately compare the costs of bikes versus public transport service (bike is much cheaper). Introducing an external party tends to duplicate certain costs (personnel, marketing, fare collection), and tends to bias the decision-making process. At the end of the day the consumer is key, and whether he or she rides a bike or the bus is immaterial.

31.2.7.1 Bicycle Parking Fees

Where the BRT system wants to encourage cycling, bike parking should be free. If there is a need to charge additional fees, these should be included in the cost of the fare. For example, one could offer a combined monthly BRT and parking pass.

31.2.7.2 Bicycle Parking Publicity

It is important to inform the riding public where bike parking and BRT access are. This information should be on maps, apps, and signs.

Figure 31.42. Visible bicycle parking can do much to promote the use of bicycles. *TransMilenio S.A.*

Figure 31.43. Bicycle parking within the TransMilenio BRT station in Bogotá. *Carlos Pardo.*

31.2.7.3 Bicycle Parking Security

Since bicycles are typically parked for six to eight hours, or longer, every day, in the same place at BRT stations, concerns about theft and vandalism are particularly strong. The tenets of Crime Prevention through Environmental Design (CPTED) offer guidance for creating secure and comfortable parking facilities.

- Locate the parking in view of security or public transport staff;
- Locate the parking inside the paid area;
- Locate the parking in full view of the public (which has the additional effect of a marketing tool to encourage bicycle use; potential patrons will see the parking and decide to try it on their next trip);
- Provide clear exit paths from the parking area, with no hidden corners or obstructed areas;
- Ensure there is enough space so that customers can lock and unlock their bikes without tripping over other bikes;
- Install security cameras if other measures are insufficient to deter theft and vandalism;
- Provide sufficient lighting, perhaps motion sensitive;
- Charge a fee for the parking, which can be used to fund a dedicated security person.

Cyclists may be willing to pay a fee for greater security, or the public transport operator can provide security as part of the service. The latter is preferable, since additional fees become barriers and, given a choice, fewer people will use this option if there is an additional cost involved. Some prefer to travel their whole route by bicycle rather than pay a fare and parking costs.

31.3 Bicycle Systems

> *"Riding a race bike is an art—a thing that you do because you feel something inside"*
>
> — Valentino Rossi, athlete, 1979–

This section provides an overview of bike-share (public bikes) and pedicab systems. These systems allow people to derive the benefits of cycling without bike ownership or maintenance.

31.3.1 Bike-Share

Bike-share systems consist of a fleet of bicycles available on demand at a network of stations throughout a designated service area. Users pick up and drop off bicycles at their convenience. When integrated into public transport, bike-share extends the reach of public transport and provides a "last-mile" solution to and from destinations that are beyond walking distance of the station. ITDP's *Bike-Share Planning Guide*, released in 2013, provides detailed guidance on how to plan and implement a successful bike-share system.

Figure 31.44. The Hubway bike-share station outside South Station in Boston is prominently positioned at the entrance to this bus and train terminal. *Will Sherman.*

Cities throughout the world are investing in bike-share as a relatively inexpensive and quickly implemented urban transportation option. Modern bike-share systems are characterized by providing subscription-based service, to ensure user identification and accountability against theft and vandalism. Subscribers unlock bicycles using smart cards or RFID keys, while walk-up users sign up with a credit card at a station or kiosk. To encourage short trips, users are charged a flat rate for thirty to sixty minutes of use, after which progressively higher fees are charged. Technology integration with bike-share systems often provides access to wayfinding information and station maps, including currently available bicycles and docks.

31.3.2 System Type

There are two basic bike-share system models: fixed and flexible programs. Fixed programs include docking stations where users can check out a bicycle at a known, fixed location. Flexible programs rely on existing bicycle racks throughout the service area.

Figure 31.45. A bicycle is unlocked by touching an RFID keycard to a dock in the Shanghai bike-share system. *ITDP.*

31.3.2.1 Fixed Programs

Stations may be fully automated, allowing users to unlock a bicycle with a RFID card or key, linking the bicycle to the user's account and recording when the bicycle was taken and returned. A kiosk at the station transmits data between the dock and control center to:

- Report the number of bicycles at the station;
- Record users taking out bicycles and returning them;
- Provide information to users about their subscription account;
- Process credit cards for walk-up users;
- Provide the location and capacity of nearby stations.

Figure 31.46. A bike-share station in Nantes, France, is permanently installed in pavement along the BRT corridor. *ITDP.*

Figure 31.47. A bike-share station in Montreal is modular, allowing for seasonal removal during winter. *Will Sherman.*

Stationary docking stations can be permanent or modular. Permanent stations are installed into the ground, hardwired to utilities, and not movable. Modular stations are less expensive to install because they require little or no excavation. Modular stations can be adjusted more easily, adding or removing docks to accommodate user demand, events, and construction sites. The Bixi system in Montreal uses modular bike-share stations to allow the system to be removed during winter months, when demand is lower. Modular stations often rely on a combination of solar power and batteries, which increases the flexibility of station siting, as placement is not dependent on utility connections.

In some scenarios, station attendants are warranted. Large stations that have capacity or high turnover, and stations near tourist destinations that attract many casual and unfamiliar users, can warrant having attendants to assist with redistribution and customer service. At high-demand bike-share stations at BRT stations in Guangzhou, China, an overflow corral is managed by an attendant, who moves bicycles from docks to the corral, or replenishes the docks with the corralled bicycles.

Figure 31.48. An overflow corral at a Guangzhou, China, bike-share station is managed by an attendant, to ensure that empty docks and bicycles are available at peak periods. *ITDP.*

31.3.2.2 Flexible Programs

Flexible bike-share systems do not use stations, instead relying on a smart-lock system that utilizes GPS and wireless communications to communicate with the system control center. The security and checkout infrastructure is located on each bicycle, eliminating the need for kiosks or docking stations. The smart-lock handles check-in and check-out functions, transmits the usage and location of each bicycle as needed, and monitors maintenance needs and unauthorized use. Users typically preregister online, use a system map to locate a nearby bicycle, and check it out using a text message or mobile phone app. Without docking stations, the cost of a flexible bike-share system is greatly reduced. Compared to fixed systems, flexible systems can make bike-share travel between public transport and lower-demand destinations affordable and feasible, because docking stations are not required near every destination.

Figure 31.49. Social Bicycles' lock system is integrated into the bicycle frame and uses available bike racks. *Social Bicycles.*

Figure 31.50. Social Bicycles' lock system is integrated into the bicycle frame and uses available bike racks. *Social Bicycles.*

31.3.3 Service Area and Phasing

The coverage, or service area, of a bike-share system is typically determined based on areas that will generate the most users or serve a need for improved mobility. Factors in the development of the service area typically include the locations where people live, work, shop, play, and access public transport. In addition, social and geographic equity concerns are often considered on the basis of serving areas with low household income, low mobility, and poor access to public transport, among other factors.

To maximize success, bike-share systems often launch in phases, starting in areas with the highest demand to accelerate success of the system. The decision to expand beyond the first phase (and subsequent phases) will depend on available funding and the success of the system. System success is typically measured in terms of visible achievements, such as high ridership, positive public response, neighborhood and corporate requests for service-area expansion, and ongoing financial performance. Essentially, the system will grow if the expansion can be sustained through existing funding or an additional influx of user fees, private sponsorship, grants, and/or public funding.

Rollout should occur in manageable stages that match funding and organizational capacity. Later phases may introduce service to communities that are discontinuous from earlier phases, but will generate their own demand and provide a connection to public transport for longer trips. The Guangzhou, China, bike-share system opened in June 2010 with 18 stations and 1,000 bicycles along the Zhongshan Avenue BRT corridor. Over three phases, the system grew to include 15,000 bicycles around BRT stations and connect nearby residential and commercial areas.

31.3.3.1 Service Levels

The operator of a bike-share system should adhere to service levels that ensure an efficient and quality experience for the user, including:

- Maximum time periods the system or any part of it can be out of operation;
- Constant availability of bicycles and open docks to return bicycles to stations;
- Cleaning and maintenance schedule of the various aspects of the system;
- Longest time period faults are accepted and repairs can take.

Service levels can be enforced by both monetary penalties and rewards, with monitoring of service levels through the IT system. Both the operator and the government-oversight body should have access to the information database. If properly designed, this access by both parties allows for the service-level standards to become shared knowledge, so there are no discrepancies between the two organizations about the payment.

31.3.3.2 Station Density

The size of a bike-share system is a function of its service area and the desired spacing of stations. Successful bike-share systems rely on a high density of stations within the service area, to minimize the distances users must walk to pick up or drop off a bicycle near their final destination. The Vélib system in Paris places approximately ten stations per square kilometer, or approximately one station every 300 meters. On average, station spacing in European and North American bike-share systems is typically between 300 and 400 meters, with a station density of approximately six to ten stations per square kilometer. This range provides access to a bike within a short walk of anywhere in the service area, and provides a nearby alternative to return a bike if the destination station is full.

Figure 31.51. A bike-share station at Huajing Xincheng BRT station in Guangzhou, China, can accommodate hundreds of bicycles. *Karl Fjellstrom, Far East BRT.*

31.3.3.3 Station Size

Station size is a function of demand. It is important that there be sufficient empty docks for riders to return bikes. Bike-share systems in Europe and North America typically use a ratio of 1.5 to 2 docks per bicycle to allow high-demand areas to accommodate peak period travel patterns. In an optimized system, the bicycles are used six to nine times a day. Higher ratios of docks increase capital costs, while lower ratios of docks to bicycles generally result in higher rebalancing costs. Redistribution vehicles and associated personnel can help balance full destination stations by restocking empty stations with high checkouts. Redistribution is one of the greatest challenges in operating a bike-share system. Using electric vehicles to transport bicycles and offering free time and incentives to return the bicycles to low-demand stations are two ways that Vyste, in Paris, optimized its redistribution process to reduce costs and minimize environmental impacts.

31.3.3.4 Station Placement

Based on the target density or distance a user must walk, stations are sited throughout the service area near bicycle infrastructure, public transport, and other key destinations. Bike-share stations should be placed in safe, convenient, and highly visible locations. If stations are intended to serve a public transport station or hub, there should be clear sight lines between the entrance of the public transport station and the bike-share station. Bike-share stations should ideally be located a short distance from BRT stations, without obstructing pedestrian and vehicle circulation, or forcing users to cross streets. This creates seamless transfers for the user from one mode of public transport to another. BRT station design can facilitate unique integration of bike-share stations. Unused space under pedestrian overpasses and on medians created by the station platforms can offer good areas for a bike-share station.

Figure 31.52. Bike-share station in Guangzhou, China, located adjacent to a BRT station. *ITDP.*

31.3.4 Bicycle Design

The physical design of the bicycle will depend on environmental and social norms of bicycling in the service area. Common attributes of successful bike-share systems include:

- Bicycle-frame design that accommodates users of varying sizes, such as a step-through design, which can be easily mounted. Adjustable seats that can be raised or lowered for different-sized users;
- Concealed drive trains and cables to minimize wear and tampering;
- A front basket or rack to carry a bag, rather than a rear rack, which can be overloaded or improperly used to carry passengers. Front and rear reflectors and lights, usually powered by a dynamo attached to the wheel, for visibility and compliance with local laws;
- Fenders to keep users dry in the rain. Bicycles that are identical and constructed of customized components to limit their appeal to theft and vandalism. The availability of those spares should be written into the procurement contracts with suppliers.

Figure 31.53. Barcelona's bike-share system features sturdy bicycles with internal gearing, fenders, chain guards, and front baskets. *Nelson\Nygaard.*

Figure 31.54. Mexico City's sturdy bicycles with internal gearing, fenders, chain guards, and front baskets. *ITDP.*

31.3.5 Integration with BRT

31.3.5.1 Information Integration

Signage that shows transfers from bike-share to BRT expands the reach of the public transport network. Real-time information, including timetables, station location, capacity, and operating hours can be available to the user through information management systems (website, on-screen display, and smartphone apps), signage, and user service personnel. Maps and routing applications, which help plot origin and destination trips using BRT, bike-share, and other modes of public transport, allow users to plan multimodal trips effectively.

31.3.5.2 Payment Integration

Payment integration is an important means of creating an integrated public transport system. The same smart card that is used for BRT should also be used for the bike-share system and other forms of public transport. A single, integrated payment system that allows users to access BRT for longer distances and bike sharing for the "last mile" provides the experience of a unified public-transport system, even if payments are dispersed to various operators from a control center. The Navigo pass in Paris allows users access to Vélib bike-share, subway, and regional trains.

31.3.5.3 Case Study: Guangzhou, China

In Guangzhou the bike-share system was implemented and opened as part of the BRT project. Launched in June 2010, the Chinese city of Guangzhou inaugurated a bike-share system with 5,000 bicycles and 110 stations in the Tianhe District to complement the BRT, as well as the bicycle and pedestrian infrastructure along the corridor. A portion of the BRT trunk line acted as a backbone for the identified coverage area for Phase 1 of the system (Tianhe District), and the capital costs of the Phase 1 system were included in the overall BRT budget. The company operating the public bike system is owned by the same government agency that owns the company regulating the BRT operations, which is also in charge of regulating bus stops and bus terminals throughout Guangzhou. The Guangzhou Public Bicycle System has approximately 35,000 users and 21,000 rides per day, with one-third of users making trips by bike-share more than seven times per week.

Figure 31.55. Guangzhou's bike-share is integrated into the BRT station and allows for increased capacity and catchment. *ITDP.*

31.3.5.4 Pedicabs (Bicycle Taxis)

A pedicab (also known as a *cycle rickshaw*, *becak*, *velotaxi*, *trisikad*, *sanlunche*, or *trishaw*) provides low-cost, nonpolluting mobility while serving as an important source of employment in cities around the world. Pedicabs generally have three wheels and are manually powered. They are an ideal feeder service to BRT stations, especially for trips of 4 kilometers or less, and on streets that are too narrow for buses. They can be organized as a formal component of the BRT system, or encouraged informally through incentives. Finally, a system of pedicabs is an ideal tool to encourage entrepreneurship.

Figure 31.56. Pedicabs can help form part of a seamless package of integration options for BRT customers. Shown here are pedicabs queuing at a TransMilenio BRT station in Bogo-tá. *INSSA.*

Figure 31.57. Pedicabs can help form part of a seamless package of integration options for BRT customers. Shown here are pedicabs queuing at a TransMilenio BRT station in Bogo-tá. *INSSA.*

31.3.6 Pedicab Design

Similar to the regular bicycle, the design of pedicabs has advanced in recent years. Newer models are lighter, stronger, faster, and more comfortable than their earlier counterparts. In selecting a standard pedicab to complement a BRT system, every effort should be made to choose the most recent model and continue to update the models annually. This includes features such as customer shading systems, aerodynamic profiles, and advanced suspension, braking, and gearing systems.

Figure 31.58. Velotaxi in Berlin. *Michael King.*

Figure 31.59. Modern cycle rickshaw in Jaipur, India. *ITDP.*

31.3.6.1 Case Study: Agra, India

In the late 1990s, ITDP and several local partners initiated a program to develop a modernized cycle rickshaw for the Indian market. The initiative was launched in Agra, India, and quickly spread to other cities, including Delhi. The project produced a rickshaw that weighs 30 percent less than traditional rickshaws, at roughly the same cost (Figure 31.60). Drivers reported a 50 percent increase in earnings, because they could ply the modern rickshaw for a longer period of time and also due to superior comfort for customers. Today, over 300,000 modern pedicabs operate on the streets of Indian cities. In Indonesia, cities such as Yogyakarta are following the lead of the Indian cities and producing a modernized pedicab (Figure 31.63).

Figure 31.60. The redesigned Indonesian becak is lighter and more stable than traditional models. *ITDP.*

Figure 31.61. The modernized cycle rickshaw in India has revitalized the pedicab marketplace. *ITDP.*

31.3.7 Facilities

31.3.7.1 Additional Width

Because they are wider than a bicycle, there are special concerns for pedicabs in facility design. Ideally they should use the non-motorized roadway network, such as greenways, bike lanes, low-speed streets, or alleys. These facilities should be designed accordingly. A more spacious design also accommodates bike trailers, wagons, adult tricycles, and other nonstandard bikes. Note that there are varying vehicle widths, thus the dimensions below need to be verified for each country. Some general guidelines for pedicab facilities are:

- Pedicabs generally fit in a 1.5-meter-wide bike lane, but not narrower; 1.8 meters is preferred;
- Bicycles and pedicabs need to pass each other. In a striped lane this is accomplished by moving into the adjacent auto lane. A bike lane should be at least 2 meters wide, if not 2.5 meters;
- Bollards and other obstacles that allow a bicycle to pass through may restrict a pedicab. A 1.7-meter clearance generally does not restrict a pedicab;
- Ramps designed for bicycles need to be wider for pedicabs;
- Parking facilities need to be larger to accommodate pedicabs.

Figure 31.62. Cycle rickshaw (freight) on a narrow street in Bangkok, Thailand. *Michael King.*

31.3.7.2 Waiting Stands at BRT Stations

Whether formal or informal, waiting stands at BRT stations are integral to integrating pedicabs and BRT. It is here that drivers wait for customers, rest, and service their vehicles. These facilities are not unlike the bike stations described above and may be operated as a concession. Fundamental features include:

- Waiting areas for drivers;
- Toilet and washroom facilities;
- Bike washing;
- Basic maintenance, such as minor adjustments and air for tires.

The waiting stands should be situated near customer egress points, but not so close as to cause congestion. They should be within eyesight of patrons. Ideally they would be located closer than the MV taxi stand. It is best to separate them from bicycle parking and lockers.

31.3.8 Regulations

Unfortunately, many countries and cities took steps to reduce pedicabs during the latter part of the twentieth century. As such, there may be regulations that need to be altered as well as a lack of safety, pricing, and other standards. In any for-hire service, standardization is a good business practice. Key regulations to consider include:

- Posted fare information;
- Regular pricing schemes, either via a meter or zone. Licensing and registration of pedicabs to ensure a minimum vehicle condition, tire quality, and functional brakes;
- Permission for pedicabs to use both motorized and non-motorized facilities.

31.3.9 Operations

Formal operating structures can deliver enhanced customer service while improving working conditions for pedicab drivers. The experience in many places is of a hectic, informal pedicab queue at public transport stations. Should the drivers be organized, this disorderly system can be regularized, which makes for a more pleasant customer experience. A formal system includes driver training, uniforms, and unionization.

New technologies that improve the user experience and increase the efficiency of the service can be encouraged. As smartphone use spreads throughout the world, it is possible to integrate a smartphone app that connects to pedicab operators.

31.3.9.1 Case Study: Fazilka, India

In the town of Fazilka in northern India, the Ecocabs system provides a dial-a-rickshaw service for local residents. After a customer places a call, a cycle rickshaw is dispatched to the customer's address within minutes. The system features a network of driver facilities with food service, restrooms, and other amenities. Participating drivers can avail themselves of low-cost loans for vehicle purchase, medical and accident insurance, educational allowances for their children, and other benefits. The system also has a mechanism for handling customer grievances.

Figure 31.63. The Ecocabs system in Fazilka, India, features modern vehicles, phone-based dispatch, and financial benefits for participating drivers. *Ecocabs.*

32. Transportation Demand Management (TDM)

> *"The right to have access to every building in the city by private motorcar, in an age when everyone possesses such a vehicle, is actually the right to destroy the city."*
>
> — Lewis Mumford, historian, 1895–1990

Transportation Demand Management seeks to do two things: 1) promote efficient travel modes (those that consume less roadway space per passenger-kilometer) to increase the effective capacity of existing infrastructure; and 2) shift travel by inefficient modes to off-peak periods to reduce congestion.

TDM is a general term for strategies that increase overall system efficiency, most often by encouraging a shift from single-occupant vehicle (SOV) trips to non-SOV modes or by shifting trips out of peak periods. TDM seeks to reduce auto trips—and hopefully overall vehicle kilometers travelled—by increasing travel options, providing incentives and information to encourage and help individuals modify their travel behavior, and/or reducing the physical need to travel through transportation-efficient land uses.

TDM strategies tend to be far more cost-effective in relieving regional congestion compared to expanding roadway and parking infrastructure. In fact, two of the most effective TDM strategies—roadway pricing and parking fees—have the potential to generate significant public-investment revenue while substantially improving "rush hour" traffic flow. In more and more cities and regions, the cost, political liability, and poor past performance of roadway expansion options have also led to increased emphasis on managing demand rather than expanding supply. Traffic congestion is a concern largely for four reasons:

- Time and Money: congestion takes up valuable time and reduces quality of life for everyone involved. As congestion reaches certain levels, the person capacity of the overall transportation network declines sharply, resulting in reduced productivity. The Asian Development Bank estimates that road congestion costs Asian cities between 2 and 5 percent of gross domestic product (GDP) annually. This is consistent with worldwide trends in other regions. According to Eltis, which works in the field of sustainable urban mobility in Europe to facilitate the exchange of information, knowledge, and experiences, congestion amounts to US$316.6 billion (2 percent of GDP) as a result of delays, fuel use, and the resulting higher transport costs.
- Growth: congestion acts as a limit on future economic expansion. Fear of worsening congestion is one of the most common reasons new development projects fail to gain support, even when they are designed to shift growth from auto-oriented, outer regions to public-transport-rich, walkable city centers.
- Emissions: cars stuck in congestion produce significantly more local pollution and carbon dioxide per mile than free-flowing traffic.
- Mobility: when a freeway is heavily congested at peak times, it may be moving fewer cars than it does in the middle of the night. To keep people, cars, and buses moving, it is important that the street system be managed to avoid instances of severe congestion.

TDM and BRT

BRT, as well as public transport improvements in general, are considered forms of TDM, since they expand access to, and increase the performance of, alternatives to SOV travel. When such capital-intensive TDM investments are made, complementary TDM strategies can play a critical role in maximizing their congestion-relief benefits. These can include moderate-cost strategies such as public transport pass programs, no-cost strategies such as reduced parking requirements, or revenue-positive strategies such as roadway pricing.

From Bogotá to Paris, enhancements to public transport have been most successful when coupled with other TDM elements. Development banks, for this reason, increasingly favor BRT projects that are packaged with a series of TDM strategies designed to shift more travel away from SOVs and onto public transport. The following provides an overview of TDM strategies that can be particularly effective, not only in improving the efficiency of regional transportation systems, but also in enhancing the benefits of BRT and similar public transport investments.

Contributors: Michael Kodransky, *ITDP Global*

32.1 Cost-Based Strategies

> *"What if we fail to stop the erosion of cities by automobiles? ... In that case, we Americans will hardly need to ponder a mystery that has troubled men for millennia: What is the purpose of life? For us, the answer will be clear, established and for all practical purposes indisputable: The purpose of life is to produce and consume automobiles."*
>
> — Jane Jacobs, writer and activist, 1916–2006

One of the most significant barriers to TDM success is the trip-level cost disparity between personal auto and public transport modes. Most of the costs associated with driving come in the form of "sunk" costs, such as purchasing, insuring, and maintaining a car. Even fuel costs are a form of "sunk" cost, as most vehicles can complete several trips between refueling stops. This creates the perception that most individual SOV trips can be completed for free, especially where roadway and parking charges are uncommon.

This puts public transport at a significant competitive disadvantage, as nearly all systems require riders to pick up a substantial portion of their capital and operating costs in the form of trip-based fares. By incentivizing SOV use, these pricing cues have propelled the current global epidemic of gridlock, especially as private vehicle ownership rates rise within developing countries. As such, TDM strategies that reverse these cues tend to be the most effective in changing travel and mode-choice patterns. The most common among these are roadway pricing, parking fees, and public transport subsidies.

Figure 32.1. London's Congestion Charge zone has improved traffic congestion by dissuading driving into the city center during peak periods while also generating revenue for better bus service. *ITDP.*

Figure 32.2. Singapore's Electronic Road Pricing (ERP) system has been effective in curbing vehicle use, especially during peak periods. *Manfred Breithaupt.*

32.1.1 Roadway Pricing

Many economists agree that traffic congestion is the result of a failure to properly charge for the value of road access and see congestion-based roadway pricing as the optimal solution. Compared to traditional road pricing, which assesses a fixed toll on each driver at all times, congestion-based pricing focuses on peak travel periods. At all other times, fees are reduced or dropped altogether.

Congestion pricing places a monetary value on consuming roadway capacity during peak travel times. Motorists who wish to enter a congestion zone must pay a fee to gain legal access to the use of the road. By charging for the use of the road resource, only those who value road access more than the congestion charge will travel during the peak times.

When well executed, congestion charging can reduce traffic congestion and pollution and raise considerable revenue to expand mobility choices. London, Singapore, Stockholm, and Tehran have implemented pricing schemes in conjunction with new public transport investments. The results have shown a marked reduction in congestion as well as the generation of revenue for supporting sustainable transport options.

32.1.2 Parking Fees

Since all vehicle trips begin and end with parking, assessing parking fees may present a TDM alternative to roadway pricing that is simpler to implement but just as effective in attaching a cost to peak-hour SOV travel. Free or underpriced parking is one of the most significant factors in peak-hour mode choice, with a strong correlation between those who drive and those with a convenient, subsidized parking space waiting for them at the end of their trip. The fact that governments lack control over these subsidies may be one reason that cities try roadway pricing before comprehensive parking reform to combat congestion. The causes and conditions of parking subsidies, however, should be examined as part of any serious TDM effort.

32.1.2.1 Public Parking

Cities often deeply discount the parking that they control. While this is usually limited to on-street parking, many have gone so far as to build extremely expensive off-street parking that, upon completion, is offered up for free or at prices far too low to recoup its costs. Typically, this is done out of a sense that, without affordable parking options, city-center businesses will lose customers, employees, and tenants to more accommodating locations. For decades, this has led to hundreds of city centers sacrificing some of their best real estate for parking and, in doing so, eroding the very qualities people have historically sought in city centers.

On-street parking should always be priced based on demand, primarily to keep an optimal level of availability for arriving vehicles. This improves access to local businesses and reduces congestion created by long searches for underpriced parking. Furthermore, if most spaces are full, it is a clear indication that their cost is not an impediment to attracting customers. To avoid the political risks of supporting higher parking rates, many cities have shifted price-setting authority to planning departments or to third-party "franchisees."

While on-street parking emerged as an adaptive use of roadway curbs, off-street parking requires dedicated, and typically very costly, infrastructure. Paying off the cost of this infrastructure on parking fees alone is a challenge without a robust economy and repressed parking demand. This is why, in most cities where off-street parking is privately built, these spaces cost several times more per hour than on-street parking.

Complaints about the cost of these garages have led many cities to subsidize off-street parking construction with the intention of providing free or cheap parking. This can compound TDM setbacks created by underpriced on-street parking by reassuring travelers that, even if they cannot find a spot on the street, there will be a low-cost option nearby. When these facilities begin to attract more demand than they can accommodate, many cities are tempted to construct new facilities, rather than raising rates in the original facilities. Setting off-street parking rates based on demand, and forestalling any future expansions until rates are sufficient to pay for them, is a necessary first step in reversing this well-intended parking approach that has, nonetheless, proved disastrous to public transport ridership and service quality in so many cities.

32.1.2.2 Private Parking

Private developers have no interest in constructing unprofitable parking. As such, they are rarely the cause of either underpriced or oversupplied parking, especially where land values and/or construction costs are especially high. Rather, the biggest generators of such conditions, in most places, are regulatory controls that mandate excessive levels of off-street parking in conjunction with new land-use development.

The primary logic behind these mandates is that if developers are required to provide excessive amounts of parking for their projects, they will not be able to charge much for spaces, and, therefore, their tenants will not be tempted to park on the street. Particularly in cities where on-street parking is free or cheap, this tends to translate into a lot of extra parking and severely depressed parking rates. Meanwhile, the developer is left to find some way to extract value from dozens of unwanted parking spaces.

In these circumstances, the unwanted spaces are typically given away as free customer parking, or offered as housing or office space amenities. Because parking rates do not contribute to offsetting the cost of the unwanted parking, this cost must be recouped through sales and lease rates for housing or building space within the development. This "bundling" strategy increases the local cost of living, working, and operating a business. More important for BRT and TDM efforts, bundling removes a powerful incentive for all residents, tenants, or visitors to consider SOV alternatives, while creating an unfair and counterproductive burden on those who will use those alternatives regardless, whether out of choice or necessity.

Cities that are serious about BRT and/or TDM should eliminate all minimum parking requirements, at least near BRT and other public transport corridors, and in all walkable city centers. If such requirements do not lead to depressed parking rates and subsidized driving, then they were set below what developers would have provided anyway. Put another way, if minimum parking requirements have any effect at all on development, it will invariably be a net negative in terms of TDM and BRT support.

32.1.3 Public Transport Subsidies

In recent years, a growing number of public transport agencies have teamed with universities, employers, developers, and even residential neighborhoods to provide universal public transport passes. These passes typically allow unlimited rides on local or regional public transport providers for low monthly fees, which are often absorbed entirely by the employer, school, developer, or neighborhood association. Universal public transport–pass programs offer the opportunity to purchase deeply discounted public transport passes on the condition that there is universal enrollment of students, employees, tenants, and residents.

The principle of universal public transport passes is similar to that of group insurance plans. Public transport agencies can offer deep bulk discounts when selling passes to a large group, with universal enrollment, on the basis that not all those offered the pass will actually use it regularly. On the other hand, automatic group enrollment in a free public transport benefit increases the likelihood that many who would otherwise never try public transport will take advantage of the benefit. As such, several public transport pass programs have produced remarkable shifts toward public transport modes and away from driving commutes.

Other strategies for reducing the cost of public transport use include:

- Direct public transport-cost purchases/reimbursements;
- Allowing commuters to deduct public transport commute costs from income taxes;
- Operating free shuttles to public transport stations;
- Offering a cash benefit to employees who forego parking benefits.

32.2 Supply-Based Strategies

> *"As it turns out, we humans love moving around. And if you expand people's ability to travel, they will do it more, living farther away from where they work and therefore being forced to drive into town. Making driving easier also means that people take more trips in the car than they otherwise would."*
>
> — Adam Mann, writer and reporter

The cost-based strategies outlined above make use of intrinsic market mechanisms to affect travel mode choice. By increasing the cost of less efficient modes, these strategies can reduce SOV-travel demand and increase demand for more efficient modes, in the same way the demand/supply equilibrium is achieved for any good of limited supply. An alternative to this approach that makes use of similar market logic is to directly reduce the capacity of roadway and parking infrastructure.

32.2.1 Roadway Reductions

Priority public transport infrastructure on roadways serves an important purpose beyond providing a high-quality service to public transport customers. The simultaneous reduction in road space for cars creates a powerful incentive for motorists to shift to public transport use. While some may see the use of road space by public transport systems as a sacrifice, this consumption of car space may be one of the greatest overall benefits of a BRT service.

Figure 32.3. Before image of the Cheonggyecheon corridor project in Seoul, South Korea. Despite tearing down one of the principal expressways to the city, the resulting congestion impacts were minimal, especially since the new BRT corridors helped gain ridership from former car users. *Seoul Institute.*

Figure 32.4. After image of the Cheonggyecheon corridor project in Seoul, South Korea. Despite tearing down one of the principal expressways to the city, the resulting congestion impacts were minimal, especially since the new BRT corridors helped gain ridership from former car users. *Seoul Institute.*

Similar benefits can be secured for bicycle transport, improving both the level of service and utilization of in-road bike facilities by claiming more space for them within existing roadway networks. This can help ensure that city and regional networks are highly connective, consistent, and accommodating of cyclists with a wide range of abilities, experience, and confidence. Beyond improving the quality and utilization of alternate modes, however, roadway-capacity reductions can generate general traffic-reduction benefits.

Induced traffic is a well-documented phenomenon in which additional road construction results in more traffic and, eventually, more overall congestion. While additional road construction leads to a temporary reduction in congestion conditions, those improved conditions eventually attract additional traffic, especially when there is latent demand for, and few non-traffic barriers to, private vehicle usage. This pattern essentially means that a city cannot build its way out of gridlock.

History suggests that the process works in reverse as well. Experience from bridge, street, and highway closings around the world indicates that a reduction in road capacity tends to reduce overall traffic levels. This disappearance of traffic, known as "traffic degeneration" or "traffic evaporation," gives one of the strongest indications to the viability of developing BRT infrastructure. Particularly relevant for cities struggling with air quality and other emissions issues, this also points to the fact that a reduction in private auto lanes can have an overall beneficial impact on the city's urban environment.

32.2.2 Roadway Restrictions

Roadway access can also be reduced through temporal measures that restrict access to key roadways at specific times and/or on specific days, either arbitrarily or based on vehicle occupancy.

32.2.2.1 HOV/HOT Lanes

The most common of these restrictions is the high-occupancy vehicle lane (HOV), common on freeway systems across the world. These lanes are reserved for vehicles carrying a stated minimum number of travelers, in an attempt to encourage higher vehicle-occupancy patterns during rush hour periods. An increasingly common variation of this traditional TDM practice, known as a high-occupancy/toll lane (HOT), allows access to SOVs whose drivers pay a toll to avoid the more congested mixed-traffic lanes. Similarly, reducing bridge and other tolls for high-occupancy vehicles has been successful in promoting carsharing in places like San Francisco.

32.2.2.2 License Plate–Based Restrictions

Deteriorating bus speeds, severe traffic congestion, and air contamination in some developing cities have prompted officials to establish roadway restrictions based on license plate numbers. The last digit in a vehicle's license plate number determines the days during which the vehicle is permitted to operate in a particular zone of the city. The success of license plate restriction programs has been mixed.

In cities such as Mexico City and São Paulo, the programs had initial success that faded over time, and the crudeness of the approach had some unintended consequences. Many residents in these cities avoided the restrictions by simply purchasing a second vehicle with a license plate that ends with a different number. Thus, by possessing two vehicles with different numbers, the person is still able to travel each day by private vehicle. Further, since the second car was typically a lower-quality used vehicle, the end result meant that even more emissions were created.

Bogotá has developed a license plate restriction program that has succeeded in removing 40 percent of the city's private vehicles from the streets each workday during peak periods. The Bogotá approach has succeeded by carefully designing a system to discourage the purchase of second (or third) vehicles. First, Bogotá has chosen to prohibit four license plate numbers each day. Table 14.3 lists the license plate numbers that are restricted by the day of the week.

Table 32.1. License-plate restrictions in Bogotá

Day of week	License plates ending with these numbers are restricted from use
Monday	1, 2, 3, 4
Tuesday	5, 6, 7, 8
Wednesday	9, 0, 1, 2
Thursday	3, 4, 5, 6
Friday	7, 8, 9, 0

The restriction of four license plate numbers each day means that a driver would have to purchase three vehicles to cover every day of the week. Bogotá's vehicle prohibition only applies during peak hours. Thus, vehicles with prohibited numbers may still travel at nonpeak hours. The net effect is to encourage a shift either to using public transport or a private vehicle at a nonpeak time.

This flexibility in conjunction with the restriction applying to four plate numbers has meant that Bogotá has not experienced a problem with persons purchasing multiple vehicles to overcome the restriction. The measure has contributed to an estimated 10 percent of former car users shifting to public transport for their daily commute.

Figure 32.5. A well-designed license plate scheme can easily avoid the problem of second-car purchases. *Fundación Ciudad Humana.*

32.2.3 Parking Reductions

32.2.3.1 Public Parking

Removing on-street parking is almost always necessary to implement effective BRT lines. Beyond what is necessitated by the operating needs of the BRT service, however, removing parking can further support general public transport use by reducing the overall parking supply along public transport corridors. When not serving as BRT lanes, these spaces can be replaced with a mixed-traffic lane, a bicycle lane, a footpath, a parklet, or streetscaping (landscaping, lighting, seating, way-finding/signage, etc.).

Figure 32.6. Parklet in what was formerly a parking lane in São Paulo. Photo *ITDP.*

Bogotá provides an example of aggressive on-street parking reductions in support of BRT. The government removed approximately one-third of all parking spaces in the city's central areas, prior to the start of its TransMilenio system. The end result was the termination of free city parking and the reclamation of public space along public transport corridors. In many instances, the previous parking spaces have been converted to attractive new pedestrian environments (Figures 32.6 and 32.7).

Figure 32.7. Bogotá has eliminated much of its previous on-street parking in order to deter private vehicle use. The former parking spaces are being converted into more attractive public space. *Lloyd Wright.*

Where parking restrictions are poorly enforced, formally provided spaces may represent only a portion of the overall on-street parking supply (Figure 32.8). In such places, the use of physical structures like very high curbs and bollards may be necessary to keep motorists off the footpaths. In general, though, use of trees or other streetscape elements offer a more aesthetically pleasing form of protective barrier.

Figure 32.8. Illegal parking on sidewalks discourages walking and sends a message that private vehicles are more important than people. Dhaka, India. *ITDP.*

Some countries use bicycle parking as a bollard, which provides a useful additional TDM amenity (Figure 32.9).

Figure 32.9. Bicycle-parking facilities can double as bollards and useful infrastructure for cyclists. Copenhagen, Denmark. *ITDP.*

32.2.3.2 Private Parking

In most cities, the majority of off-street parking is privately controlled, and therefore outside the direct control of municipal governments. There are several ways, nonetheless, for governments to influence general off-street parking supplies within their city centers and public transport corridors. While each option is indirect, their overall impact on parking supplies can be even more substantial than removing on-street parking.

32.2.3.3 Development Regulations

A prerequisite for reducing off-street parking supplies is to stop requiring developers to provide it in conjunction with land-use projects. In many cases, cities require more parking than developers would choose to provide on their own. As a rule, developers will include as many parking spaces as possible, up to the point where the added value of the next space falls below its construction cost. Requiring developers to provide parking beyond this point depresses area parking prices through supply saturation.

Conversely, where city planners have legitimate concerns that strong market demand may lead developers to provide more parking than is desired, cities should consider establishing parking maximums. These regulations operate on the same premise as minimum requirements—establishing acceptable levels of off-street parking linked to the scale and nature of each development. As opposed to minimums, however, maximums focus on mitigating problems associated with parking provided above, rather than below, these levels.

Another option for using development regulations to reduce off-street supplies is to include parking areas in the calculation of maximum development densities. To the substantial cost of constructing parking spaces, such a regulation would add the cost of losing a square meter of residential or commercial space for every square meter of parking provided.

In 2014, São Paulo adopted into law a master plan that addresses parking with density and transit. The plan is now mandatory as a law sanctioned by Mayor Fernando Haddad after being approved by the City of São Paulo House of Representatives. It eliminated parking minimums citywide and set limits on how much parking can exist around transit corridors, paving the way for a new legacy in one of the world's largest and most congested cities.

Maximum parking ceilings have been instituted around the public transport corridors. Developers building above this ceiling must pay an impact fee and the parking provision comes out of the allowable building space rather than functioning as an accessory to the main use.

32.2.3.4 Taxes and Levies

Governments can also reduce privately controlled off-street supplies by increasing the cost of maintaining each space. Taxing parking revenue is a common practice that can effectively reduce commercial-parking profitability, and thus commercial-parking supplies, in economically vibrant city centers and public-transport corridors. In areas where most off-street parking is subsidized or provided at cost, however, taxes may have limited impact on supplies.

A parking levy, by contrast, can increase the cost of all parking, regardless of demand. A levy works by assessing an annual fee on all nonresidential parking spaces. Property owners are thus presented with a recurring incentive to convert underutilized or unprofitable spaces to other uses. Cities that have implemented this strategy include Sydney and Perth, in Australia, and Nottingham, England, which has pegged all levy revenue to funding the expansion of its tram network.

Figure 32.10. With a parking space levy, shops have an inherent incentive to only provide the number of parking spaces that are truly required. Ahmedabad, India. *ITDP.*

Figure 32.11. A parking levy can also lead to the redevelopment of surface and setback parking such as the one pictured in Ulaanbataar, Mongolia, to activate sidewalk frontages improving public transport access. *ITDP.*

32.3 Supportive Strategies

> *"We are all here on earth to help others; what on earth the others are here for I don't know."*
>
> — W. H. Auden, poet, 1907–1973

32.3.1 Ride Share and Ride Matching

One of the greatest impediments to carpool and vanpool formation can be finding suitable partners with similar work schedules, origins, and destinations. Facilitated ride share matching can overcome this obstacle by enabling commuters who are interested in ride sharing to enter their travel preferences into a database and receive a list of potential ride share partners. The success of these programs is largely determined by the number of participants and, in turn, the number of potential matches that can be made. Ride share programs may be administered through individual employers, but are often most effective when coordinated through a transportation management association or other larger-scale program.

32.3.2 Carsharing

Shared-vehicle programs are gaining wider and wider application across the globe. Carsharing enables commuters to use non-car modes for most trips while retaining driving options for work-related trips. It allows users to access a car and pay based on use, taking away the burdens of ownership, parking, maintenance, and acquiring liability insurance. According to extensive research conducted by Susan Shaheen at the University of California, Berkeley, round-trip carsharing has an overall net effect of decreasing car ownership. Even while some driving increases, other users decrease their driving trips, leading to an overall driving decline that removes an average of eight to thirteen private cars from the road. Vehicles placed near transit stations help bridge last/first mile gaps in the conventional transport network, supporting investment in public transit and a shift away from private car use.

32.3.3 Guaranteed Ride Home

Guaranteed Ride Home (GRH) provides a limited amount of free taxi rides or use of carshare vehicles for unplanned trips home (e.g., working late past the last scheduled bus, carpool passenger with sick child at school) by employees who commit to non-driving commute modes. Statistics on such programs indicate that although they tend to have relatively low employee utilization rates, they have very high satisfaction rates from participants, providing a high benefit at low cost. Originating as an employer-based benefit, GRH is increasingly offered through regional planning and transportation organizations.

32.3.4 Leadership and Coordination

Highly successful TDM programs often have a strong local or regional champion and leader. Some regions have dynamic political leaders who eloquently make the case for collective action in managing travel demand. In other places, a major institution leads by example, encouraging other area employers or traffic generators to join in the effort.

In 2010, the city of Rochester, Minnesota, USA, adopted a comprehensive mobility plan that included aggressive mode-split goals for 2030. The Mayo Clinic, recognizing its prominent role in the city's economy and the value that the city's goals held for the clinic, partnered with the city to establish a voluntary member-based organization to implement a series of commuter-benefit programs, including an extensive commuter-bus system. The Mayo Clinic has continued to collaborate with the city on a bicycle master plan and a bike-share feasibility study.

32.3.5 Performance Monitoring

Equally important to leadership is defining measurable goals and regularly evaluating progress toward them. We cannot manage what we do not measure, goes the adage. Today's leading regions set mode-split targets, define strategies and policies to achieve them, establish appropriate measures for performance, and standardize data collection and reporting schedules and responsibilities. This not only helps clarify the purpose of TDM investments and initiatives, but, by highlighting what has been the most/least successful, it also improves the effectiveness of future efforts.

32.3.6 Development Practices and Processes

Cities are dominated by "durable infrastructure" that allows land use to evolve over time in response to changing populations, interests, and market demands. Some of the most dramatic and effective TDM programs have anticipated cumulative growth impacts and established expectations and requirements for development to incorporate appropriate TDM measures. Establishing clear, consistent, and predictable policies can ensure equitable review and approval processes for diverse developments, whether they occur next year or next decade, and reduce the ultimate cost and traffic consequences of growth. The best examples have adopted comprehensive public policies and established development review processes that require TDM for all major developments that include bold strategies like maximum parking allowances and funding for bicycle infrastructure.

32.3.7 Trip Planning Assistance

Uncertainty is a tremendous deterrent to change. One of the largest obstacles to non-SOV travel is the lack of information on alternate-mode options. Many commuters simply do not know the range of travel options available to them, their cost, how to use them, or when they are available.

Disseminating information broadly is a major challenge and can require substantial funds, but it can also bring about the largest return on investment. Advertisements and promotional campaigns, such as carpool days, commute challenge weeks, or ride share months can encourage commuters to try different modes once or twice, which is sometimes all it takes to change behavior.

Technology has been an enormous boon in encouraging and enabling management of travel demand. Travellers now have available to them an array of trip-time and cost calculators—many of which include environmental or social-cost calculations as well. Emerging tools include dynamic ride sharing and other social media connections. These convenient tools allow travellers to determine the right mode of travel for them on that particular day according to their particular needs.

One challenge, however, is that every system seems to have its own website, forcing travellers to consult multiple sources in order to plan their trip most efficiently. Several cities however, have begun to integrate information across a variety of modes and systems including public transport, bicycle, taxi, and driving. In November 2012, the Regional Transportation Authority of Chicago launched a dedicated website and app that combine the information of multiple public transport providers, as well as weather and traffic updates and information on major area attractions.

32.3.8 Education and Outreach

Social marketing and incentive programs are proving increasingly popular and effective at promoting non-SOV travel. Social marketing seeks to influence individuals' behavior to achieve a broad social good (in the case of TDM, reducing SOV trips). Awareness and educational programs, workshops, and community-outreach efforts may take the form of promotional campaigns similar to product advertising.

Incentive programs build on this marketing effort to frame non-motorized, public transport, and high-occupancy travel as a social norm, by offering prizes or cash rewards to residents who use non-SOV modes. In Seattle, Washington, USA, the Metro's bi-annual Wheel Options campaign gives commuters a chance to register and win a large variety of prizes for getting to work any way other than driving alone. The county's In Motion programs extend this opportunity to residents in general.

The weekly "no driving day" program in Seoul, South Korea, is another leading example. People can get free parking, reduced-cost car washing, reduced taxes, and avoid congestion charges if they use alternative transport at least one day every week. Participants receive stickers for the rear windows of their car, which is monitored using radio-frequency-identification (RFID) technology to assess compliance. According to the city, the program reduced traffic volumes by 3.7 percent since 2003 with a CO_2 reduction of 10 percent, and fuel savings amounting to USD$50 million.

32.4 Case Studies

> *"Yesterday I parked my car in a tow-away zone... when I came back the entire area was missing."*
>
> — Steven Wright, comedian and actor, 1955–

32.4.1 BRT and Parking Management in Ottawa, Canada

The Ottawa Transitway is perhaps the most successful busway in North America. In a city of 800,000 people, the daily ridership on the Transitway is 240,000. Like the five true BRTs in the United States, the Ottawa Transitway's four corridors score as bronze on *The BRT Standard*. The success of the Ottawa Transitway can be attributed to three factors:

1. Federal government offices are concentrated in the city center;
2. Free parking was discontinued for civil servants in 1975;
3. Zoning bylaws have decreased required parking spaces.

Parking reductions along with density increases are viewed as incentives for developing near the public transport stations, subject to individual approval. As a result, development did occur around the BRT stations. At the same time, park-and-ride facilities were permitted only at the termini of the Transitway.

When the Transitway opened in 1983, the federal government, Ottawa's largest employer, began eliminating free parking for its employees and reduced parking availability downtown by 15 percent. Additionally, retail centers receive a reduction of twenty-five parking spaces for every bus stop provided either on-site or through a physically integrated Transitway station.

Today, the City of Ottawa's zoning bylaw includes progressive parking policies such as:

- Reduced parking minimums in the central area and downtown;
- Parking maximums within 600 meters of public transport stations (BRT or LRT) and reduced maximums in the central area and downtown;
- A shared parking policy in which users that generate parking demand at different times of the day are able to share spots that count toward their minimum;
- The ability for developers to pay cash that will allow them to reduce their parking requirements;
- Priority to short-term parking in developments so that commuters are more likely to use public transport.

The city also employs a parking pricing strategy that discourages long-term parking.

Figure 32.12. Motorists have a range of options for paying the London congestion charge, including local shops. *Lloyd Wright.*

Figure 32.13. Camera technology is utilized in London to enforce the congestion charge. *Lloyd Wright.*

32.4.2 Congestion Pricing in London

The introduction of congestion charging in London helped broaden the appeal of congestion charging to transport planners worldwide. Over the past decades, London's traffic congestion had worsened to the point that average traffic speeds were similar to speeds of the horse carts utilized in London during the nineteenth century. In response, London's Mayor Ken Livingstone decided to implement a congestion charging scheme in the center core of the city.

As of 2012, a US$16 fee is imposed upon vehicles each time they enter the central zone from 7:00AM to 6:00PM, Monday through Friday. Motorists can pay through a variety of mechanisms including the internet, telephone, mobile text messages, self-service machines, post, and retail outlets (Figure 32.12). Those who take advantage of Autopay only pay US$14.25 each time that they are billed to a debit or credit card. Motorists have until midnight on the day of entry to pay the charge. Payments can still be made the next day, although the price increases to US$19. Subsequently, a US$190 fine is applied to motorists who fail to pay by midnight of the following charging day. If paid within fourteen days, the penalty is reduced to US$95. If no payment is made after twenty-eight days, the fine increases.

The London system differs from the Singapore system in several ways. First, the London system does not require an in-vehicle electronic unit, and requires no system of cash cards. It is an enforcement-only system. London does not utilize gantries but instead relies upon camera technology to identify the license plates of all vehicles passing the point and sends this information to a central computer (Figure 32.13). At the end of each day, the list of vehicles identified entering the zone is compared to the list of vehicles that have made payments to the scheme operators. Any unpaid owners are referred for enforcement actions.

London adopted a camera-based system rather than an electronic-gantry system for several reasons. First, the elimination of the in-vehicle electronic system and cash card would hopefully reduce administration costs. Second, London also had aesthetic concerns over the large overhead gantries employed in Singapore. Third, officials were concerned over the limitations of GPS-based systems to operate without interference in narrow urban roads lined by tall buildings.

London's system has some disadvantages. Unlike the Singapore system, London's system has to charge a flat fee for a carefully defined area. To win political support, residents with motor vehicles inside the charging zone were given a 90 percent discount. This exemption has made expanding the zone difficult, as expanding the zone would also increase the number of people eligible for the discount. After the implementation of a western extension in 2007, it was dismantled by the new administration in 2011. Congestion is not uniform around a zone, particularly a larger zone. For a larger zone, it may be that there is minimal congestion on access roads serving lower-income areas and higher congestion on access roads serving higher-income populations. A point-specific charging system like Singapore has much greater potential to optimize charges to specific points of congestion.

The license plate detection is not required to ensure payment, but rather it is only required to enforce nonpayment. For this reason, the system does not have to be 100 percent accurate; the system is only accurate enough to induce people to pay the fee voluntarily. The London system also has some trouble charging motorcycles, which are therefore exempt. The cameras incurred a failure rate of between 20 and 30 percent in reading motorcycle license plates due to the smaller size of the plates and the fact that motorcycles do not always operate in the center of the lane. Some license plates can be difficult to read due to bright glare or obstructions from trucks. In London motorcycles are exempted to ensure a high level of consumer confidence in the system, but in other cities with a large number of motorcycles they would need to be included.

In addition to exempting motorcycles, the London congestion charge is also not applied to taxis, public transport, police and military vehicles, physically disabled persons, certain alternative-fuel vehicles, certain health-care workers, and tow trucks. As of 2011, vehicles that emit 100 grams per kilometer or less of CO2 and meet the Euro 5 standard for air quality will only need to pay US$15.83 a year per vehicle to receive the exemption. This measure is in line with London's vision to improve air quality and tackle climate change. The exempted vehicles represent 23 percent (twenty-five thousand vehicles) of the total traffic in the zone.

London's congestion charge has produced some impressive results. Congestion levels have been reduced by 30 percent after the first year, and the total number of vehicles entering the zone has dropped by 18 percent. Average speeds increased from 13 kilometers per hour to 18 kilometers per hour. Perhaps the most unexpected benefit was the impact on the London bus system. With less congestion, bus journey speeds increased by 7 percent, prompting a dramatic 37 percent increase in bus patronage. The revenues from London's program are applied to supporting bus-priority infrastructure and bike-lane projects.

32.4.3 Congestion Charging in Stockholm

Stockholm joined London and Singapore in January 2006 as a large global city employing a congestion charge. Stockholm borrowed concepts from its two predecessors while also invoking several more recent technological innovations. The Stockholm charge was implemented after a seven-month trial period, with a majority of support from a public vote on whether to keep it.

Stockholm's charge zone includes the entire central area of the city, with a total of nineteen different gantry points permitting entry into the zone (Figure 32.14). Like Singapore, Stockholm has a fortuitous location, with bodies of water restricting the number of actual access points to the city center. Such naturally restricted entry eases the technical tasks of controlling a large number of entry points.

Figure 32.14. The Stockholm charge zone and the nineteen points of entry. *City of Stockholm.*

The amount of the Stockholm charge depends on both the number of times a vehicle enters the central zone as well as the time of day (Table 32.2). For vehicles entering and exiting the charge zone multiple times per day, the maximum amount to be paid is US$9. Like London and Singapore, several types of exemptions are permitted, including emergency vehicles, public-transport vehicles and school buses, taxis, vehicles with disability permits, environmentally-friendly vehicles (e.g., electric, ethanol, and biogas), and motorcycles. The capital cost for the six-month trial period of the charge was SEK 3.8 billion (or US$572 million in 2013 equivalent value) (Pollard, 2006).

Table 32.2. Fee schedule for the Stockholm congestion charge

Time of crossing zone boundary	Cost (SEK)	Cost (US$)
06:30 – 07:00	10	US$1.50
07:00 – 07:30	15	US$2.30
07:30 – 08:00	20	US$3.00
08:30 – 09:00	15	US$2.30
09:00 – 15:30	10	US$1.50
15:30 – 16:00	15	US$2.30
16:00 – 17:30	20	US$3.00
17:30 – 18:00	15	US$2.30
18:00 – 18:30	10	US$1.50

18:30 – 06:30	0	US$0

Stockholm uses two different types of vehicle-detection technologies, which are similar to both the technologies used in London and Singapore. For regular travelers to the central area, motorists can obtain an electronic tag that automatically reads the vehicle's entry into the area. With this electronic tag, the appropriate fee is automatically deducted from the person's bank account. Approximately 60 percent of the people entering the zone utilize the electronic tag.

Alternatively, for vehicles not employing the electronic tag, a camera technology similar to that of London is utilized. The camera detects the plate number on the vehicle, and the motorist has five days to pay the charge by post or at a shop. If the charge is not paid within five days, then a fine of US$11 is assessed. After four weeks, the unpaid charge results in a fine of US$80 (Webster, 2006).

In the first month of operation, Stockholm's congestion charge reduced congestion levels by 25 percent, which is equivalent to reducing private vehicle travel by approximately 100,000 cars each day. While London's charge only applies once per day, in Stockholm drivers must pay each time they enter the congestion zone. The congestion charge has both influenced the time that people travel as well as their mode of choice. Approximately 2,000 drivers now travel to work earlier in order to enter the zone prior to the 06:30 start of the charge. Another 40,000 private motorists have now switched to public transport (Public CIO, 2006).

Perhaps the most instructive lesson from Stockholm has been the manner of implementation. The congestion charge was applied as a six-month trial that ended in July 2006. In September 2006, the public voted on whether to continue with the charge. At the outset of the congestion charge experiment, approximately two-thirds (67 percent) of the public was opposed to it. On September 17, 2006, 52 percent of the public approved the referendum to make the congestion charge permanent.

The referendum approach can thus be an effective mechanism to gain public support, permitting an initial trial. Otherwise, protests at the outset may prevent a project from happening at all. This approach, though, is not without its risks. As people experience the benefits of reduced congestion, support for the measure may dramatically increase, as was the case in Stockholm. Nevertheless, any city employing a referendum approach to project approval and project continuance must be prepared for a negative vote. However, giving people a democratic voice in applying TDM measures can be an approach that warrants serious consideration.

32.4.4 Congestion Charging in Tehran

The success of the London, Singapore, and Stockholm pricing plans has attracted interest for similar projects in developing cities. The high-tech nature of congestion charging can increase its attractiveness to officials seeking to increase modern technologies in their cities.

Tehran, Iran, is the most successful city to implement congestion pricing since London. The system first began operation at the end of April 2010, using Automatic Number Plate Recognition (ANPR) technology that takes photos of license plate numbers as they cross the cordon. Drivers must purchase a permit prior to entry in the charging zone. The plate numbers are cross-checked with registered vehicles at a control center. Daily permits cost US$11.60, weeklong permits are US$70, and annual permits cost US$174. Payment can be done online or by phone. Drivers who do not pay in advance must pay a maximum penalty of US$6,500. Disabled drivers can get a discount for the permit. Meanwhile, government and commercial vehicles all must pay, with a bigger charge for vehicles registered to companies. Tehran's system includes 104 entrance points. Now, enforcement personnel circulate in the charging area to stop vehicles travelling without a permit. Initially, the system was enforced with police stationed at select intersections at the perimeter of the charging zone. Similar to Singapore, the system evolved to a more technologically driven solution.

The area charge complemented the BRT that started operation in 2008. By 2011, the system already carried 1.8 million customers per day. During this time, it was reported that pollution decreased by 45 percent and travel times had decreased by 55 percent, largely due to the removal of private cars from the road. According to a Global Mass Transit report, nearly 35 percent of riders on the BRT system had never used public transport before it was implemented.

32.4.5 Roadway Restrictions in Seoul

Perhaps one of the most spectacular examples of this concept in practice is the Cheonggyecheon corridor project in Seoul. The Cheonggyecheon stream was historically a defining part of Seoul's environment, and in fact was the reason why Seoul was selected as the capital of the Joseon Dynasty in 1394. In the face of modernization, the waterway was covered in 1961 to provide better access for private vehicles. By 1968, an elevated expressway provided another layer of concrete—erasing the memory of the waterway.

Figure 32.15. and Before image of the Cheonggyecheon corridor project in Seoul. Despite tearing down one of the principal expressways to the city, the resulting congestion impacts were minimal, especially since the new BRT corridors helped gain ridership from former car users. *Seoul Institute.*

Figure 32.16. Fig 32.16 After image of the Cheonggyecheon corridor project in Seoul. Despite tearing down one of the principal expressways to the city, the resulting congestion impacts were minimal, especially since the new BRT corridors helped gain ridership from former car users. *Seoul Institute.*

Upon his election in 2002, Seoul Mayor Myung Bak Lee decided it was time to bring back the Cheonggyecheon stream. The Cheonggyecheon project has meant the restoration of 5.8 kilometers of waterway and historical pedestrian bridges, the creation of extensive green space, and the promotion of public art installations (Figures 32.15 and 32.16). Based upon a study by the Seoul Development Institute (2003), now known as the Seoul Institute, the Cheonggyecheon restoration project was predicted to produce economic benefits of between US$8 billion to US$23 billion, and create 113,000 new jobs. More than forty million visitors experienced the Cheonggyecheon stream during the first year after restoration.

Further, despite the elevated expressway being the principal access way for cars into the city center, there were no significant congestion impacts. In part, the new Seoul BRT system helped defray some of the traffic impacts (Figure 32.17).

Figure 32.17. The new Seoul BRT system has helped make it possible to reduce road space dedicated exclusively to cars. *City of Seoul.*

Softer "pull" tactics on this front include the weekly no driving day program in Seoul. People can get free parking, reduced-cost car washing, and reduced taxes and congestion charges if they use alternative transport at least one day every week. Participants receive a sticker for the rear window of their car, which is monitored using RFID technology to assess compliance. According to the city, the program has reduced traffic volumes by 3.7 percent since 2003, with a CO_2 reduction of 10 percent and fuel savings amounting to USD$50 million.

32.4.6 Travel Blending in Santiago, Chile

Several cities in Australia and Europe have developed a new technique for achieving dramatic changes in mode shares at very low costs. The technique, known as "travel blending," is a form of social marketing. The idea is to simply give people more information on their commuting options through a completely personalized process, and then facilitating changes in travel behavior. This can help decrease the number of private motor vehicles on the road, as drivers decide to shift to BRT. More information on this technique is provided in Chapter 11: Marketing.

33. Transit-Oriented Development

Overview

> *"In spite of its diverse and often conflicting meanings, all parties superficially endorse 'smart growth' because it is clearly superior to the alternative: 'dumb growth'."*
>
> — Anthony Downs, writer and public administration scholar, 1930-

When the concept of what would later be called BRT first emerged in Curitiba in the late 1960s, it was not initially conceived as an autonomous urban transport technology. It was part and parcel of a plan to manage urban growth and motorization and experiment with an alternative model of compact, high-density walkable neighborhoods served by rapid and efficient public transport. Pragmatic and resourceful, Curitiba's planners conceived of using buses as an easily deployable and highly effective *metrô de superfície* (surface metro). The system worked to an impressive extent. Linear high-rise corridors soon sprouted up alongside the new BRT lines. Today, more than ever, BRT technology is meaningful for its potential to provide cities with extensive, affordable, and high-quality public transport grids on which to redirect urban growth into walkable, convenient, well-connected, small-footprint, and highly livable districts.

Not all BRT projects need to be part of large and ambitious plans. BRT projects small and large bear the seeds of the walkable and public transport oriented city. Their corridors and stations areas present concrete opportunities to address and enhance land development and urban design practices.

Because of their size, visibility, and transformational character, BRT projects have the capacity to focus the attention of decision makers, institutions, and stakeholders. BRT projects have the potential to transform the dynamics of local development due to the intensification of land uses that improvements in transport service support. There are many potential benefits in anticipating these changes and accompanying them with proper planning and useful adjustments to the regulatory framework. Too often, outdated planning concepts and regulations meant to accommodate rising car use are counterproductively left in place, resulting in chronic underutilization of the power of public transport to serve and enhance the uses of the land it traverses.

BRT systems are not self-contained, and the benefits of integrated planning for their internal workings are great. The viability of BRT requires a ridership base that is numerous and sustained. It also depends on competing transport modes, such as private vehicles, not to erode its ridership. Effective and efficient at transporting large numbers of people from station to station, BRT depends on other modes to bring sufficient numbers of customers to its stations, with the complete trip, including walking, plus-public transport and any additional intermediary modes, being the relevant comparison at the time of the traveler's modal choice.

The location and configuration of buildings and structures around stations, the mix in uses and activities, and the design of connected streets and public space, have direct ramifications on the feasibility and attractiveness of the walking segment. The safety, directness, interest, comfort, ease, and productivity of the walk all weigh on the individual's decision to walk down the local streets to public transport.

Moreover, urban places where a subtle and essential *ecology of walking and being in public places* is achieved draw people out in the street for more than simply functional commuting reasons. Once in the public realm, using public transport for traveling beyond walking range becomes a natural extra step.

The present chapter introduces transit-oriented development (TOD) as the method to combine transport and land development so that they support and reinforce each other, while giving rise to better streets and cities.

Figure 33.1. The BRT corridor in Curitiba, Brazil, is visible from this picture because it is where there are denser land uses. *ITDP.*

33.1 Why TOD: Problems and Solutions

> *"Let's have a moment of silence for every American stuck in traffic on their way to a health club to ride a stationary bicycle."*
>
> — Representative Earl Blumenauer, United States Congress, 1948-

Figure 33.2. Traffic congestion in Jakarta, Indonesia. *Karl Fjellstrom.*

Figure 33.3. Cars overwhelm pedestrian area in Taiyuan, China. *Karl Fjellstrom.*

The forms of land development that best support pedestrians—and therefore public transport riders—are often not in place or complete at the time of a prospective BRT corridor's planning or construction. These characteristics are in fact rarely found outside historic districts and older transit suburbs of the pre-automobile age.

Urban spaces that have been designed or retrofitted since the advent of the mass-automobile age are generally adverse to pedestrians in two key aspects. First, cars degrade the pedestrian realm through direct nuisances ranging from air pollution and noise pollution to collision hazards and the severance of pedestrian routes by fast-moving car lanes. Second, the basic structure of urban space that fits automobile travel is of a very different scale than that fitting pedestrian travel.

The mass-automobile age started as early as the 1910s in the oldest industrialized nations and began massively impacting cities across the world in the second half of the 20th century. Severe conflicts between the speed and spatial needs of automobiles and those of pedestrians and animals were largely solved by prioritizing motor vehicles at the expenses of pedestrians.

Figure 33.4. Cyclists squeeze by heavy automobile traffic in Nanjing, China. *Let Ideas Compete, Flickr Creative Commons.*

The rise of personal automobiles triggered rather different effects on city streets than the mechanized public transport that had appeared in industrial metropolises of the 19th century. Railroads and streetcars allowed vast metropolitan expansion and a heightened degree of separation between residential and workplace uses, but they still relied on a strong pedestrian realm to provide access to stations at both ends of trips. Mechanized urban public transport expanded the reach of people on foot by providing rapid connections from walking area to walking area. Automobiles allowed door-to-door transport to the privileged segments of population that could afford them and led to the neglect and decline of the public realm of pedestrians and cyclists.

Figure 33.5. Cars are prioritized over pedestrians, who have to walk up and across a bridge to get to the other side of the highway in Kawasaki, Japan. *ykanazawa1999, Flickr Creative Commons.*

Figure 33.6. Streetcar in Jersey City, New Jersey, USA, in the 1940s. *LennyNJ, Flickr Creative Commons.*

The combined availability of affordable cars and government-supplied roads led to an ever-increasing number of motorists and lengths of their motorized trips. Consequently, driving became the norm in many cities around the world. Congested urban roads were widened and ended up severing communities. The standards and regulations governing the arrangement and design of roads, streets, and new buildings were codified to fit personal cars as a primary mode of transportation. Automobile-centric suburbs, soon dubbed “urban sprawl” for their low density and their disconnection from human scale and aptitude developed, while older, pedestrian-scaled urban areas fell out of favor, often being razed and redeveloped according to so-called “urban renewal” policies.

In a vicious circle, the policies, regulations, and design methods put in place to cope with the traffic, nuisances, and safety issues resulting from motorization triggered more motorization. The generalization of driving-based lifestyles in turn required the construction of ever more roads, interchanges, driveways, garages, and parking facilities, the supply of which was never enough, since traffic increased as soon as new roads or lanes were built. Conceptions of the "good life" now were centered on the ownership and use of cars. Households equipped with multiple cars expected to drive and park them.

Motorization left many behind. Public transport declined along with the pedestrian realm in *urban sprawl* and *urban renewal* areas. Low-density settlement patterns did not generate sufficient ridership, resulting in poor service, if any public transport service at all. In dense urban areas, trams and bus speeds went down, as cars jammed the streets, as well as the frequency, connectivity, and quality of service, as riders shifted in numbers to private vehicles. Urban spatial segregation was reinforced, since places characterized by functional and social aspects could be kept physically distant, and yet still be integrated through the use of cars. Meanwhile, the poor who could not afford to maintain an automobile, the young, the old, the women who lacked access to and resources to procure motor vehicles, and all who were unable or unwilling to drive, faced increased travel time and costs while losing access to urban resources.

The negative impacts of car-dependent urban development became obvious as early as the 1950s and 1960s in some countries, with the increase in number of trips and distances traveled, along with a cohort of negative impacts, ranging from road congestion, road casualties, noise and air pollution, and fossil energy consumption to the health ramifications of insufficient physical activity, social segregation and exclusion, unnecessary land consumption, and greenhouse gas emission. Road revolts sprang up in many communities traversed by high-volume road projects.

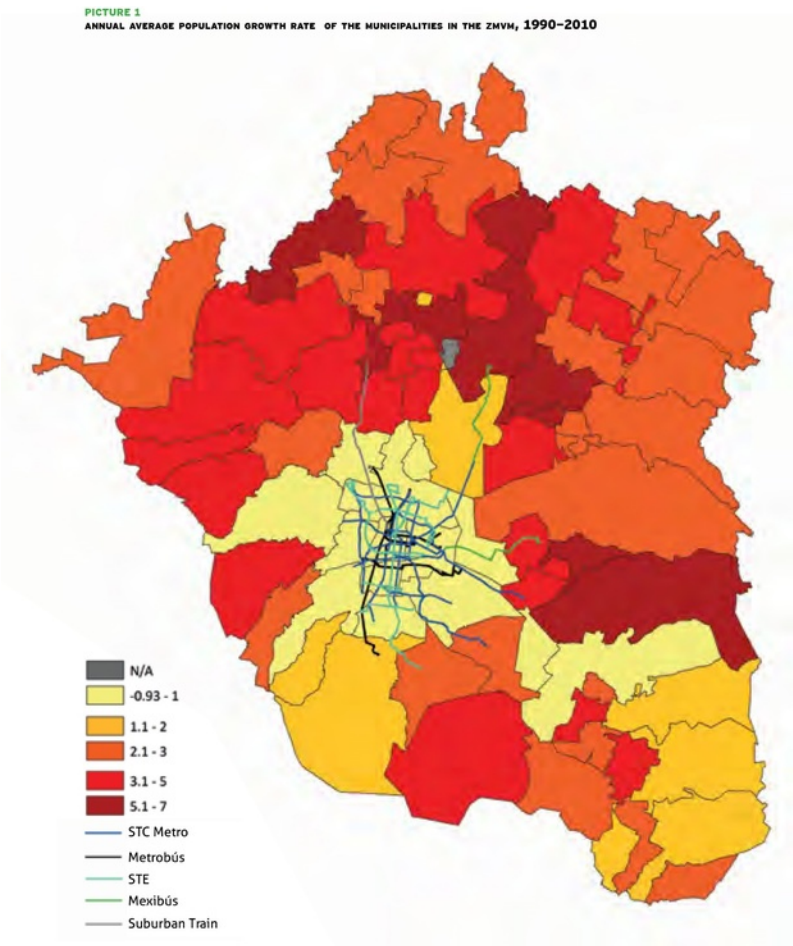

Figure 33.7. The disconnect between where urban growth is occurring in Mexico City and where rapid transit is startling. *ITDP Mexico.*

Today, similar processes of car-dependent urbanization are still rolling on in cities around the world, blind to their well-documented, long-term unsustainability. Motorization is massive in many emerging and developing economies.

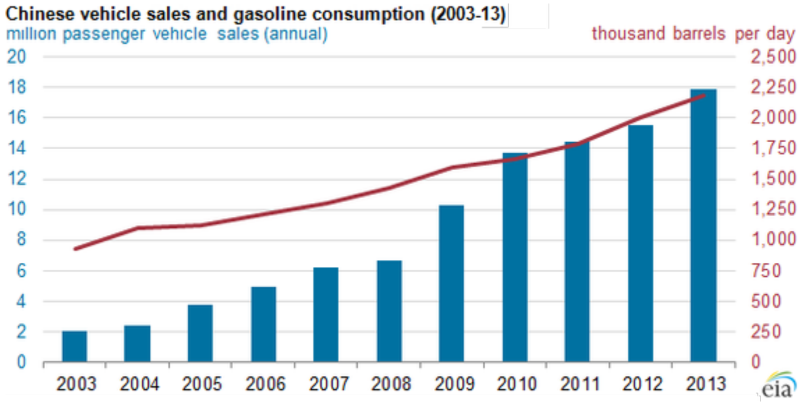

Figure 33.8. Chinese vehicle sales and gasoline consumption(2003-2013) *United States Energy Information Administration (EIA).*

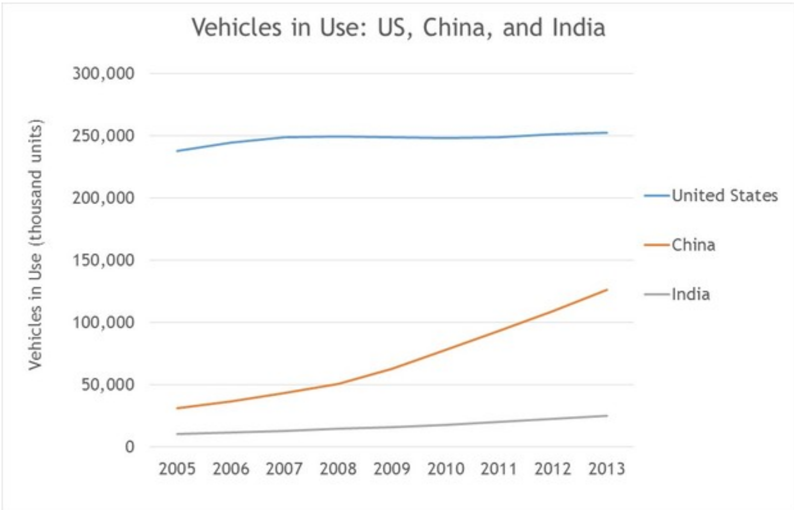

Figure 33.10. Vehicles in use in the United States, China, and India. *International Organization of Motor Vehicle Manufacturers: http://www.oica.net/wp-content/uploads//total-inuse-2013.pdf*

Figure 33.9. Number of Registered Motor Vehicles in India (1951-2011). *Offices of State Transport Commissioners/UT Administrations, Ministry of Statistics and Programme Implementation.*

Many cities still fall into the trap of prioritizing car-oriented infrastructure.

Figure 33.11. Traffic jam in Lanzhou, China. *Gergely Sipos, Flickr Creative Commons.*

Figure 33.14. Traffic backed up in Quito, Ecuador. *alh1, Flickr Creative Commons.*

Figure 33.12. Traffic congestion in Nairobi, Kenya. *Dan Kori, Flickr Creative Commons.*

Figure 33.13. Traffic congestion in Mumbai, India. *Maciej Dakowicz, Flickr Creative Commons.*

Solutions to car-dependent urban development, insufficient public transport, and degraded pedestrian realms lie in the revamping of public transport, the restoration of urban public realms where people want to be on foot, and the curbing of excessive traffic and parking. The solutions come from bringing people and activities closer together in functional, walking- and cycling-oriented places that can be effectively and efficiently linked by rapid public transport.

These goals have been on the agenda of a small but growing number of cities for at least the past 60 years. The most advanced concepts of modern urban development have evolved considerably in the second half of the 20th century towards more people-friendly and less car-dependent forms. New development, as well as the revitalization of pre-automobile urban fabrics, have been implemented with increasing sophistication and success in cities around the world, from Curitiba, Bogotá, and Singapore to Stockholm, Copenhagen, Barcelona, Portland, Oregon, USA, Vancouver and Toronto, Canada, and Melbourne, Australia, to name a few. In the 2000s, major world cities such as London, Paris, and New York overturned their policies on transport, urban development, and the pedestrian and cycling realm quite spectacularly. From China to Argentina, cities around the world are turning to a new era of walking-, cycling-, and transit-oriented urban development.

Figure 33.15. Cyclists riding across an intersection in a bike lane in Copenhagen, Denmark. *Mikael Colville-Andersen, Flickr Creative Commons.*

Figure 33.16. A light-rail tram pulls up to a station in Barcelona, Spain *Flickr Creative Commons.*

Figure 33.17. Pedestrian-only street in Guangzhou, China. *Karl Fjellstrom.*

Figure 33.18. Rapid-transit vehicles in São Paulo, Brazil. *Embarq Brazil, Flickr Creative Commons.*

Figure 33.19. Buenos Aires recently created slow zones, where car speeds were reduced and some of the street was reclaimed for pedestrians to use a public space. *ITDP.*

Figure 33.20. Along Yichang's BRT corridor, space for cyclists and pedestrians are prioritized. Here, a covering was built to help shade pedestrians from the direct sun. *ITDP.*

33.2 Defining TOD

> *"Development has become something to be opposed, instead of welcomed; people move out to the suburbs to make their lives, only to find they are playing leapfrog with bulldozers. They long for amenities that are not eye-sores, just as they long to give their kids the experience of a meadow, that child's paradise, left standing at the end of a street. Many communities have no sidewalks, and nowhere to walk to, which is bad for public safety, as well as for our nation's physical health. It has become impossible in such settings for neighbors to greet one another on the street, or for kids to walk to their own nearby schools. A gallon of gas can be used up just driving to*

get a gallon of milk. All of these add up to more stress for already over-stressed family lives."

— Al Gore, former United States Vice President, 1948-

TOD Defined

TOD is land development that is specifically designed to integrate, work with, and prioritize the use of public transport for daily urban mobility needs. Mere closeness to public transport stations is not sufficient for a development to qualify. TOD specifically denotes a proactive orientation towards public transport through particular land use and design characteristics known to facilitate and prioritize walking, cycling, and other non-motorized and intermediary modes of access to the stations. Key attributes of TOD include the optimized development intensity and land-use mix within the walkable zone around the public transport stations; a complete, easily accessed, well-connected, and well-protected system of walkways; safe cycling and secure cycle parking conditions; and the minimization of the impact of vehicular traffic and parking. When synthesized through high quality design, these elements have been proven to result in attractive and successful urban forms, where access to public transport is short, easy, pleasant, and safe, and eventually, the public transport supports a high and sustained ridership at stations (Europe's Vibrant New Low Car(bon) Communities, ITDP).

Research in both developed and developing countries shows that the combination of raised density, mixed land use, street connectivity, and walkability improvements reduces automobile travel and increases both non-motorized and public transport travel per capita. (Kenworthy and Laube, 1999; Ewing, Pendall and Chen, 2002; Mindali, Raveh and Salomon, 2004; and Litman, 2004). For example, residents of the most urbanized neighborhoods in Portland, Oregon, USA, have been shown to use public transport about eight times as much, walk six times as much, and drive only about half as much as residents of the least urban areas.

In order to understand relationship between transport and the urban environment, some basic principles were needed to explain on what this intersection depends. ITDP distilled eight basic principles of sustainable and equitable transport in urban life which form the core definition of TOD (Our Cities Ourselves: Principles for Transport in Urban Life, ITDP):

Eight basic principles of sustainable and equitable transport in urban life:

[WALK] - Develop neighborhoods that promote walking

[CYCLE] - Prioritize non-motorized transport networks

[CONNECT] - Create dense networks of streets and paths

[TRANSIT] - Locate development near high-quality public transport

[MIX] - Plan for mixed use

[DENSIFY] - Optimize density and transit capacity

[COMPACT] - Create regions with short commutes

[SHIFT] - Shift away from car dependency and increase mobility by regulating the use and reducing the supply of parking and roadway space.

Figure 33.21. The eight principles for transport in urban life work together to create inclusive and sustainable communities and cities. *ITDP.*

Those principles form the foundation, but still were not enough to understand what this meant in practice. To give meaning to what those principles were supposed to achieve and what were the key criteria to achieving those, ITDP further developed those principles into *The TOD Standard*, which elaborates a set of key performance objectives that are essential to the materialization of these principles, along with a series of measurable performance indicators, or metrics, and a scorecard. This can then be used to assess plans and designs, station areas, and understand how well a neighborhood or a development is doing when creating inclusive transit-oriented and people-oriented places.

Slightly adapted excerpts from *the TOD Standard* introduce the principles and performance objectives system that follow in this section. Refer to the original publication for details on metrics and the scorecard (www.todstandard.org).

Figure 33.22. The TOD Standard elaborates performance objectives and metrics for evaluating if a development is achieving inclusive TOD. www.todstandard.org *ITDP.*

Figure 33.23. The TOD Standard's principles, objectives, and metrics in summary. *ITDP.*

33.2.1 Principle 1 | WALK | Develop neighborhoods that promote walking

Walking is the most natural, healthful, clean, efficient, affordable, and inclusive mode of travel to destinations within short distances, and it is a necessary component of virtually every transit trip. As such, walking is the foundation for sustainable and equitable access and mobility in a city. Restoring it or maintaining it as the primary mode of travel is pivotal to the success of inclusive TOD.

Walking is also potentially the most enjoyable, safe, and productive way of getting around, if paths and streets are attractive, populated, secure, uninterrupted, well protected from vehicular traffic, and if useful services and destinations are conveniently located along the way.

Walking requires moderate physical efforts that are beneficial for most people within reasonable distances but can be challenging or infeasible to some when body ability combines with obstacles, steps, or steep ramps to form barriers. In the TOD Standard, the terms "walking" and "walkability" should always be understood to be inclusive of users of walking or carrying aids, such as wheelchairs, white canes, baby strollers, and shopping carts. Complete walkways and crossings must fully support all users in compliance with locally applicable or international standards.

Objective A: The pedestrian network is safe, complete, and accessible to all

The most basic feature of urban walkability and inclusivity is the existence of a complete, continuous, and safe walkway network including safe crossings at desire lines that links origins and destinations together and to the local public transit station. The network must be accessible to all persons, including older people and people with disabilities, and well protected from motor vehicles.

Objective B: The pedestrian realm is active and vibrant

Activity feeds activity. Walking is attractive and secure and can be highly productive when sidewalks are populated, animated, and lined with useful ground-floor activities and services, such as storefront retail and restaurants. In turn, high foot traffic increases the exposure of local retail outlets and services and improves the vitality of the local economy. Visual interior–exterior interactions promote security in the pedestrian realm through passive and informal observation and surveillance. All types of land uses are relevant to street activation and informal observation—not only shops and restaurants but also informal vending, workplaces and residences.

Objective C: The pedestrian realm is temperate and comfortable

The general willingness to walk, and the inclusion of people of all bodily abilities, can be significantly improved by the provision of shade and other forms of shelter from harsh climate conditions—such as street trees, arcades and awnings—or by street orientation that mitigates sun, wind, dust, rain, and snow exposure. Trees are the simplest, most effective, and most durable way of providing shade in most climates, and they have well-documented environmental and psychological co-benefits. Highly recommended, but not measured in this standard, for the sake of simplicity, are amenities such as benches, public toilets, drinking fountains, pedestrian-oriented lighting design, wayfinding signage, landscaping, and other street furniture and streetscape-enhancing elements.

33.2.2 Principle 2 | CYCLE | Prioritize nonmotorized transport networks

Figure 33.24. Wide, pleasant walking environment with shade and places to sit in Nairobi, Kenya. *ITDP Africa.*

Cycling is one of the most healthful, affordable, and inclusive mode of urban mobility. It combines the convenience of door-to-door travel and the route and schedule flexibility of walking with ranges and speeds that compare to or surpass local transit services. Bicycles and other means of people-powered transport, such as pedicabs, also activate streets and greatly increase the ridership catchment area of transit stations. They are highly efficient and consume little space and few resources. Cycling friendliness is therefore a fundamental principle of TOD. Cyclists, however, need protection as they are among the road users most vulnerable to crashes with vehicular traffic. Their bicycles are also vulnerable to theft and vandalism and require secure parking and storage. The key factors in promoting cycling are thus the provision of safe street conditions for cycling and the availability of secure cycle parking and storage at all trip origins and destinations and at transit stations.

Objective A: The cycling network is safe and complete

A safe cycling network connecting all buildings and destinations by the shortest routes available is a basic TOD requirement. Various types of bike infrastructure, including bike paths, bike lanes on roads, and slow-traffic streets, can be part of the network.

Objective B: Cycle parking and storage are ample and secure

Cycling can be an attractive daily travel option only to the extent that bicycles can be securely parked at all destinations, and that bicycles can be secured within private premises at night and for longer periods.

33.2.3 Principle 3 | CONNECT

Figure 33.25. Cycling in Curitiba next to the BRT corridor. *Gabriel T. de Oliveira.*

Short and direct pedestrian and cycling routes require a highly connected network of paths and streets around small, permeable blocks. This is primarily important for walking and for public transport station accessibility, which can be easily discouraged by detours. A tight network of paths and streets offering multiple routes to many destinations can also make walking and cycling trips varied and enjoyable.

Short, direct walking and cycling require dense, well-connected networks of paths and streets around short city blocks. Walking in particular can be easily discouraged by detours and is particularly sensitive to network density. A tight network of paths and streets that offers multiple routes to many destinations, frequent street corners, narrower rights of way, and slow vehicular speed make walking and cycling trips varied and enjoyable and invigorate street activity and local commerce. An urban fabric that is more permeable to pedestrians and cyclists than to cars also encourages the use of nonmotorized and transit modes with all the associated benefits.

Objective A: Walking and cycling routes are short, direct, and varied

The simplest proxy for the connectivity of the pedestrian walkway is the size of city blocks, defined as sets of contiguous properties that prevent public pedestrian passage. This block definition might be distinct from the blocks defined by mapped streets, since open pedestrian paths can exist through superblocks and buildings, regardless of public or private property status.

Objective B: Walking and cycling routes are shorter than motor vehicle routes

Although high pedestrian and cycling connectivity is an important feature of TOD, road connectivity enhancing motor vehicle travel is not. An urban fabric that is more permeable to pedestrians and cyclists than to cars prioritizes non-motorized and public transport modes and provides safer, nuisance-free route options.

Figure 33.26. Walking and cycling flourish when those connections are made safe and prioritized. *Luc Nadal.*

33.2.4 Principle 4 | TRANSIT | Locate development near high-quality public transport

Walkable access to rapid and frequent transit, defined as rail transit or bus rapid transit (BRT), is integral to the TOD concept and a prerequisite for TOD Standard recognition. Rapid transit service connects and integrates pedestrians with the city beyond walkable and cycling ranges and is critical for people to access the largest pool of opportunities and resources. Highly efficient and equitable urban mobility and dense and compact development patterns mutually support and reinforce each other.

Rapid public transit plays an important role not only in providing quick and efficient trips but also in weaving into other frequent and alternative transit options for a complete transit network. These transit options support the entire spectrum of urban transport needs and may come in various modes, including low- and high-capacity vehicles, taxis and motorized rickshaws, bi-articulated buses, and trains.

Objective: High-quality public transport is accessible by foot

For TOD Standard status, the maximum acceptable walking distance to the nearest rapid transit station is defined as 1,000 meters and 500 meters for a frequent local bus service that connects to a rapid transit network within less than 5 kilometers. The transfer station should be designed for short, convenient and all-accessible connections with the rapid transit service.

Figure 33.27. High quality transit, like the BRT in Yichang, is foundational for creating inclusive TOD. *Liu Xianwei.*

33.2.5 Principle 5 | MIX | Plan for mixed uses, income, and demographics

When there is a balanced mix of complementary uses and activities within a local area (i.e., a mix of residences, workplaces, and local retail commerce), many daily trips can remain short and walkable. Diverse uses peak at different times and keep local streets animated and safe. They encourage walking and cycling activity, support extended hours of transit service, and foster a vibrant and complete human environment where people want to live. People of all ages, genders, income levels, and demographic characteristics can safely interact in public places. A mix of housing options makes it more feasible for workers of all income levels to live near their jobs and helps prevent lower-income residents dependent on lower-cost public transit from being systematically displaced to poorly-served outlying areas. Inbound and outbound commuting trips are more likely to be balanced during peak hours and throughout the day, resulting in more-efficient transit systems and operations. The two performance objectives for the MIX Principle therefore focus on the provision of a balance of complementary activities and land uses and on a diverse mix of resident income levels and demographic attributes.

Objective A: Opportunities and services are within a short walking distance of where people live and work, and the public space is activated over extended hours

To allow many daily trips to be short and walkable, inbound and outbound transit trips to be balanced, and neighborhoods to be active and secure day and night. A mix of uses, services, and incomes helps ensure vibrant and inclusive. If an area has only one type of use, or a heavily dominant use such as office buildings in a business district, the best contribution is to bring new uses and activities that help counterbalance that dominance. Development for locating in, or contributing to, complete neighborhoods, also needs to ensure that access to local sources of fresh food, primary schools, and healthcare facilities or pharmacies. Fresh food is not only a necessity of daily life, but—equally importantly—a reasonably simple-to-assess and reliable litmus test for the wider availability of basic supplies, because it has more rigorous supply chain requirements than nonperishable necessities. Very different processes govern the provision of primary schools and local healthcare services, which are essential local services especially important to poor households. Being able to walk to school, of course, carries health and cost benefits for all. Public parks and playgrounds have multiple benefits—from improved air quality, to reduced heat island effects, to the increased physical and mental health and comfort of residents. Access to parks and playgrounds is particularly important to the urban poor, who have little access to private facilities and few opportunities to break away temporarily from urban life

Objective B: Diverse demographics and income ranges are included among local residents

Social equity is no less important to long-term sustainability than reduced environmental footprints. Mix of incomes is as important to mix of activities and uses to achieve more equitable and sustainable communities and cities. *The TOD Standard* promotes social equity not only through inclusive access and mobility but also through inclusionary housing and its equitable distribution over the different areas of the city. The Standard also promotes upgrading substandard informal housing in situ, where safe, and generally promotes the protection of residents and communities from involuntary displacement caused by redevelopment. One goal is to avoid creating neighborhoods that reinforce social separation and the concentration of poverty. Another goal is to avoid displacement, which is extremely detrimental to communities. Involuntary displacement leads to the breaking of community ties, the destruction of social capital and networks, and the loss of access to familiar resources and local employment opportunities.

33.2.6 Principle 6 | DENSIFY | Optimize density and match transit capacity

Figure 33.28. Mix of uses, from office to restaurants and shops to residential creates complete communities. *Luc Nadal.*

A dense model of development is essential to serving future urban development with transit that is sufficiently rapid, frequent, well connected, and reliable at most hours to ensure a satisfactory life free of dependence on cars and motorcycles. Urban density is needed to both accommodate growth within the inherently limited areas that can be served by quality transit and to provide the ridership that supports and justifies the development of high-quality transit infrastructure. From this perspective, urban areas must be designed and equipped not only to accommodate more people and activities per hectare than is usually the case in this age of vehicle-oriented sprawl but also to support highly desirable lifestyles.

Transit-oriented density results in well-populated, lively, active, vibrant, and secure places, where people want to live. It delivers the customer base and the foot traffic that makes local commerce thrive and supports a wide choice of services and amenities. Densification should generally be encouraged to the full extent that it is compatible with daylighting and the circulation of fresh air, access to parks and recreational spaces, the preservation of natural systems, and the protection of historic and cultural resources. As many of the most well-loved neighborhoods in great cities around the world attest, high-density living can be highly attractive. The challenge is to generalize the best aspects of urban density at an affordable cost, mobilize the resources to make it happen with appropriate infrastructure and services, and reform the frequent bias of land use codes and other development policy frameworks toward low densities. And a combination of residential and nonresidential density is needed in support of high-quality transit, local services, and vibrant public spaces.

Objective A: High residential and job densities support high-quality transit, local services, and public space activity

Transit-oriented density results in well-populated streets, ensuring that station areas are lively, active, vibrant, and safe places where people want to live. Density delivers the customer base that supports a wide range of services and amenities and makes local commerce thrive. The limits to densification should result from requirements for access to daylight and circulation of fresh air to living rooms and workplaces; access to parks and open space; preservation of natural systems; and protection of historic and cultural resources. This objective measures both of residential and commercial densities.

Figure 33.29. An example of a dense, active, and pleasant neighborhood. *Luc Nadal.*

33.2.7 Principle 7 | COMPACT| Create regions with short transit commutes

The basic organizational principle of TOD is compactness: having all necessary components and features fitted close together, conveniently and space-efficiently. With shorter distances, compact cities require less time and energy to travel from one activity to another, need less extensive and costly infrastructure (though higher standards of planning and design are required), and preserve rural land from development by prioritizing the densification and redevelopment of previously developed land. The COMPACT Principle can be applied on a neighborhood scale, resulting in spatial integration by good walking and cycling connectivity and orientation toward transit stations. On the scale of a city, compact means the city is covered and integrated spatially by public transit systems.

Objective A: The development is in, or next to, an existing urban area

Development should take place on sites within or at the immediate edge of an existing urbanized area, particularly through the efficient use of vacant, previously developed lots, such as brownfields.

Objective B: Traveling through the city is convenient

Development should prioritize areas that offer diverse public transport options and easy commute time to the closest major center of employment and specialized urban services. Developers and project promoters have control over this aspect when making location decisions in the early stage of projects.

Figure 33.30. Infill development is preferable to expanding into greenfields where possible. *Will Collin via Flickr.*

33.2.8 Principle 8 | SHIFT | Increase mobility by regulating parking and road use

In cities shaped by the above seven principles, the use of personal motor vehicles in day-to-day life becomes unnecessary for most people, and the various detrimental side effects of such vehicles can be drastically reduced. Scarce and valuable urban space resources can be reclaimed from unnecessary roadways and parking and re-allocated to more socially and economically productive uses. Conversely, a gradual but proactive reduction of roadways and parking space availability in urban space is needed to lead to a shift in transport mode shares from private motor vehicles to the more sustainable and equitable modes, if matched by sufficient walking, cycling, public transit, and occasional support vehicles.

Objective: The land occupied by motor vehicles is minimized

Off-street and on-street parking space for motor vehicles should be reduced along with the overall street space occupied by traveling motor vehicles. Space should be reallocated to the more economically and socially productive uses of public space and sustainable transportation.

Figure 33.31. When many driveways cut through the pedestrian space, it adds potential for conflict between the modes and disrupts the safety of the sidewalk. *Karl Fjellstrom.*

Figure 33.32. Mexico City reclaimed from of the road to create spaces for people to sit and relax. *ITDP.*

VOLUME VIII

About the Guide

The Bus Rapid Transit Planning Guide is the most comprehensive resource for planning a BRT system, beginning with project preparation all the way through to implementation. It is a huge effort by the Institute of Transportation and Development Policy, and dozens of authors and reviewers.

This [work in progress] volume focuses on the goals and functionality of the *Online* edition on the BRT Planning Guide, a project that, essentially, aims to make the guide more accessible and constantly up-to-date:

- the guide is now available online in a website format that is easy to navigate
- PDFs are also available to those that need to print them
- the online publication of updates is automatic
- the entire history of the guide is with Git
- revisions and contributions are easier with GitHub

34. Understanding How it Works

The publication system used in this online guide is based on version controlling all the content – text, tables and figures – and on automatically generating from each version – in parallel – both website and PDF renderings of the guide.

This [work in progress] chapter gives an overview of the project and the role of each tool.

Essentially, the project is divided in two top-level folders: the `/guide` and the `/generator`.

The first has the files for the entire contents of the guide (text, images, tables, etc). The text is written in a simple but powerful format, that at the same allows ease of use, independence of content from style and is compatible with version control.

The second contains the source-code for the special purpose generation tool – *manu* – that takes the text for the guide and the assets and builds the PDF and the complete website.

All content is versioned in *Git*, a powerful and proved distributed version control system used extensively in software development, and the project lives in GitHub, a platform for collaboration on projects using *git*.

A robot that lives in our server constantly monitors GitHub for events in this project – such as new commits or changes in pull requests – and automatically runs *manu* for each new version.

35. Manual to Collaboration

The project lives in GitHub, a platform widely used for collaboration to projects using *Git*: https://github.com/ITDP/the-online-brt-planning-guide. You can ask questions or report problems in the guide by opening an issue.

If instead you want to propose changes to either the guide (e.g. a typo fix or a new section) or, if you're a programmer or a designer, to the generator tool, please (fork the repository and) open a pull request.

This [work in progress] chapter goes into more detail on how each tool works, including a definition of the sytanx for `.manu` files.

More documentation on how to work with the guide and with GitHub will gradually become available. In the mean time, if you need help, do not hesitate to contact the geeks behind the curtain at contato@protocubo.io.

35.1 Getting started

To do...

35.2 Basic text

Simple, continuous text is the most basic and essential element, and can *usually* be simply typed in the source files.

Paragraphs can be split into several lines for improved readibility. Instead, paragraphs end at blank lines, or more specificaly, visibly empty lines.

```
This is the first paragraph. This previous line break didn't end this para-
graph.
Now *this* is a new paragraph, because of the previous empty line.
```

35.2.1 Reserved characters and escaping

The most important character with special meaning is the backslash (\). It's used to indicate with instructions are special commands (like the `\item` command), and to use special characters like normal characters.

The backslash itself can be typed as regular text, as in "a \ backslash", by typing `a \\ backslash`. By preceding any special character, such as the backslash itself, with another backslash, we indicate that we want that otherwise special character to appear in the output; this is called escaping.

35.2.2 Commands

In other to provide more than simple text, but at the same time keep the input readable in simple text editors and compatible with version control systems like git, the backslash (\) can be used to denote calls to some available commands. These range from text annotation commands (like `\code` or `\emph`) to more complex elements (like `\figure` or `\begintable`).

Commands can take (and usually require) arguments, and those can be typed wraped in braces (`\emph{some important text}`), when they are mandatory, or in brackets (`\figure[small]`), if they are optional.

35.2.3 Subscripts and superscripts

Subscripts and superscripts, such as in 1^{fst} or n_{th}, can be added to text by using, respectively, the `\sup` and `\sub` commands. Some examples are show in table X.

Table 35.1. Example subscript and superscripts

Result	Source
1^{fst}	`1\sup{fst}`
n_{th}	`n\sub{th}`
$brown^{tm}$	`brown\sup{tm}`
$lazy_{ish}$	`lazy\sub{ish}`

35.2.4 Emphasis and highlight

35.2.5 Math and equations

35.2.6 Comments and annotations

35.2.7 Code

35.3 Content hierarchy

To do…

35.3.1 Organizing the sources

35.4 Other visual elements

To do…

35.4.1 Boxes

35.4.2 Figures

35.4.3 Tables

35.4.4 Equation blocks

35.4.5 Code blocks

35.5 Formal specification

To do…