**Division 44**
**Environmental management,**
**Water, Energy, Transport**
**Sector project: Transport Policy Advice**

Module 3b:

# Bus Rapid Transit

**Sustainable Transport:**
**A Sourcebook for Policy-makers in Developing Cities**

## About the author

**Lloyd Wright**
*University College London*

Mr. Wright is currently conducting transport planning research at University College London. Mr. Wright formerly directed the Latin American activities of the Institute for Transportation & Development Policy (ITDP). He also directed the organisation's International Bus Rapid Transit Programme. Additionally, Mr. Wright has worked with the International Institute for Energy Conservation, the US Environmental Protection Agency, the US Agency for International Development, and the United Nations on transport and environmental issues. He was also previously a fellow with the US-Asia Environmental Partnership in Bangkok, Thailand. Mr. Wright is currently working towards a PhD in Urban Transport Planning at University College London. He also possesses an MSc in Environmental Assessment from the London School of Economics, an MBA from Georgetown University, and a BSc in Engineering from the University of Washington.

## Acknowledgements

The development of this Bus Rapid Transit Planning Guide has benefited from the experiences of high-quality public transit projects from around the world. The Planning Guide has benefited greatly from lessons gained to date from the TransMilenio system in Bogotá (Colombia). TransMilenio represents perhaps the most complete and inventive BRT system in the world today. The assistance of Angélica Castro and Carlos Beltrán of TransMilenio SA has been instrumental in developing this guidebook. Further, the former Mayor of Bogotá, Enrique Peñalosa, has become an international champion of promoting the BRT concept.

Additionally, insights from municipal officials and consultants involved with the BRT systems in Quito (Ecuador) and Curitiba (Brazil) have added greatly to the quality and relevance of the Planning Guide. In many respects, BRT owes its existence to the creativity and determination of Jaime Lerner, the former mayor of Curitiba and the former governor of the state of Paraná. César Arias, who previously directed the BRT effort in Quito and is now a consultant on the Guayaquil (Ecuador) BRT project, has also lent considerable information for the Planning Guide. Likewise, Hidalgo Nuñez and Cecilia Rodriguez of Quito's Department of Transport have provided much assistance. In Asia, Kangming Xu and the Energy Foundation are contributing greatly to the development of BRT in China, as is Dr. Jason Chang who has previously led BRT efforts in Taipei. In India, Dr. Dinesh Mohan and Dr. Geetam Tiwari of the Indian Institute of Technology in Delhi are at the forefront of efforts there.

A number of consultancies have worked to improve the quality of BRT initiatives. Special thanks go to Luis (Pilo) Willumsen, Enrique Lillo, and German Lleras of Steer Davies Gleave who are involved in BRT projects worldwide. Also, Jarko Vlasak of StratCo, and formerly of McKinsey & Company, has helped to develop the BRT business model used in Bogotá. Dario Hidalgo, Ignacio de Guzman, and Juan Carlos Díaz at Akiris have played a central role in the development of TransMilenio, and they are now leading BRT efforts in several cities. Additionally, several consultancies in Brazil helped to create many of the original BRT concepts; these firms and individuals include Paulo Custodio, the consulting team at Logit, Pedro Szasz, and the consultancy of Logitrans.

The Planning Guide has benefited not only from leading developing-nation experiences but also from the growing level of interest in BRT in Australia, Western Europe, Japan, and North America. A similar compendium of experiences developed under the United States Transit Cooperative Research Program (TCRP) has been a rich source of world-wide experiences in BRT. Sam Zimmerman and the consultancy of DMJM & Harris have been leading these efforts.

The concept of BRT owes much to the persistent support of key organisations that have worked to raise overall awareness as well as provide direct assistance to interested developing-nation cities. The Institute for Transportation & Development Policy (ITDP) under the leadership of its Director, Dr. Walter Hook, has consistently been at the forefront of providing direct assistance to developing cities pursuing sustainable transport options. Likewise, Gerhard Menckhoff, a consultant with the World Bank, has played a key role in catalysing BRT projects in Latin America and

elsewhere. Also, Peter Midgley, a former World Bank transport specialist, has been a pioneer with developing-nation BRT efforts.

Finally, the Planning Guide and the entire Sustainable Transport Sourcebook would not be possible without the strong support and effort from the team at GTZ, the German Overseas Technical Assistance Agency. Karl Fjellstrom was particularly instrumental in developing ideas for the BRT Planning Guide as well as writing sections comparing different mass transit options. Stefan Nagelschmitt also played a key role in providing the layout and formatting for the final document. A great deal of thanks goes to Manfred Breithaupt, Director of GTZ's transport programme, who created the idea of the Sustainable Transport Sourcebook and who patiently oversaw the development of each module.

Lloyd Wright
University College London

## Contents

## Acronyms

| | |
|---|---|
| AGV | Automatic Guided Vehicle |
| AVL | Automatic Vehicle Location |
| BRT | Bus Rapid Transit |
| CIDA | Canadian International Development Agency |
| CNG | Compressed Natural Gas |
| DFID | UK Department for International Development |
| GEF | Global Environmental Facility |
| GTZ | GTZ Deutsche Gesellschaft fur Technische Zusammenarbeit (German Overseas Technical Assistance Agency) |
| IFC | International Finance Corporation |
| IPCC | Inter-governmental Panel on Climate Change |
| ITDP | Institute for Transportation & Development Policy |
| ITS | Intelligent Transportation Systems |
| JICA | Japanese International Co-operation Agency |
| LPG | Liquid Petroleum Gas |
| LRT | Light Rail Transit |
| MRT | Mass Rapid Transit |
| O-D | Origin-Destination |
| PRT | Personal Rapid Transit |
| QIC | Quality incentive contract |
| Sida | Swedish International Development Agency |
| TDM | Transportation Demand Management |
| TOD | Transit-Oriented Development |
| TRB | Transportation Research Board |
| UNDP | United Nations Development Programme |

| | |
|---|---|
| UNEP | United Nations Environment Programme |
| USAID | United States Agency for International Development |
| USFTA | United States Federal Transit Administration |
| USTCRP | United States Transit Cooperative Research Program |

# 1. Introduction

Effective public transit is central to development. For the vast majority of developing city residents, public transit is the only practical means to access employment, education, and public services, especially when such services are beyond the viable distance of walking or cycling. Unfortunately, the current state of public transit services in developing cities often does little to serve the actual mobility needs of the population. Bus services are too often unreliable, inconvenient and dangerous.

In response, transport planners and public officials have sometimes turned to extremely costly mass transit alternatives such as rail-based metros. Due to the high costs of rail infrastructure, cities can only construct such systems over a few kilometres in a few limited corridors. The result is a system that does not meet the broader transport needs of the population. Nevertheless, the municipality ends up with a long-term debt that can affect investment in more pressing areas such as health, education, water, and sanitation.

However, there is an alternative between poor public transit service and high municipal debt. Bus Rapid Transit (BRT) can provide high-quality, metro-like transit service at a fraction of the cost of other options (Figure 1). This module provides municipal officials, non-governmental organizations, consultants, and others with an introduction to the concept of BRT as well as a step-by-step process for successfully planning a BRT system.

This introductory section to BRT includes the following topics:

## 1.1 Defining Bus Rapid Transit

Bus Rapid Transit (BRT) is *a bus-based mass transit system that delivers fast, comfortable, and cost-effective urban mobility.* Through the provision of exclusive right-of-way lanes and excellence in customer service, BRT essentially emulates the performance and amenity characteristics of a modern rail-based transit system but at a fraction of the cost.

The term "BRT" has emerged from its application in North America and Europe. However, the same concept is also conveyed around the world through different names. These terms include:

- High-Capacity Bus Systems,
- High-Quality Bus Systems,
- Metro-Bus,
- Surface Subway,
- Express Bus Systems, and
- Busway Systems.

While the terms may vary from country to country, the same basic premise is followed: A high quality, car-competitive transit service at an affordable cost. For simplicity, the term "BRT" will be utilised in this module to generically describe these types of systems. However, it is recognised that the concept and the term will undoubtedly continue to evolve.

Perhaps the most telling difference between BRT and other transit services is BRT's central focus on the customer. BRT systems are designed around the customer-based needs of speed, comfort, convenience, cost, and safety rather than around a specific technology. In fact, BRT is really just a collection of best practice traits from a range of mass transit options. For this reason, this module will include examples from various mass transit applications in order to present a package of system characteristics that best satisfy customer aspirations.

While BRT utilises rubber-tyred vehicles, it has little else in common with conventional urban bus systems. The following is a list of features found on some of the most successful BRT systems implemented to date:

- Exclusive right-of-way lanes
- Rapid boarding and alighting
- Free transfers between lines
- Pre-board fare collection and fare verification
- Enclosed stations that are safe and comfortable
- Clear route maps, signage, and real-time information displays
- Automatic vehicle location technology to manage vehicle movements
- Modal integration at stations and terminals
- Clean vehicle technologies
- Excellence in marketing and customer service

Local circumstances will dictate the extent to which the above characteristics are actually utilised within a system. Small- and medium-sized cities may find that not

all of these features are feasible to achieve within cost and capacity constraints. Nevertheless, serving customer needs first is a premise that all cities, regardless of local circumstances, should follow in developing a successful transit service.

Today, the BRT concept is becoming increasingly utilised by cities looking for cost-effective transit solutions. As new experiments in BRT emerge, the state of the art in BRT will undoubtedly continue to evolve. Nevertheless, BRT's customer focus will likely remain its defining characteristic. The developers of high-quality BRT systems in cities such as Bogotá, Curitiba, and Ottawa astutely observed that the ultimate objective was to swiftly, efficiently, and cost-effectively move *people,* rather than *cars*.

## 1.2 History of BRT

### 1.2.1 The predecessors to BRT

BRT's history resides in a variety of previous efforts to improve the transit experience for the customer. The first wide-scale development of the BRT concept using bus technology occurred in Curitiba (Brazil) in 1974.

However, there were several smaller-scale efforts prior to Curitiba that helped to establish the idea. High-occupancy lanes and exclusive bus lanes appeared in the United States in the 1960s. For example, in 1963, express buses using contra-flow bus lanes were developed in the New York City area. The origins of the BRT concept can be traced back to 1937 when the city of Chicago outlined plans for three inner city rail lines to be converted to express bus corridors. Likewise, BRT plans were developed for several other cities in the United States, including: Washington, DC (1955-1959), St. Louis (1959), and Milwaukee (1970) (Levinson et al., 2003).

Actual construction of a dedicated busway first occurred in 1972 with a 7.5 kilometre line known as "Via Expresa" in Lima (Peru). One year later in 1973, busways were constructed in Runcorn (United Kingdom) and Los Angeles (USA). The 22-kilometre Runcorn busway played a central role in the urban form and development of the city's New Town area. The El Monte Busway in Los Angeles covered a distance of 11 kilometres.

### 1.2.2 Modern BRT systems

BRT's full promise was not realised, though, until the arrival of the "surface subway" system developed in Curitiba (Brazil) in 1974 (Figure 2). Ironically, the city initially aspired to constructing a rail-based metro system. However, a lack of sufficient funding necessitated a more creative approach. Thus, under the leadership of Mayor Jaime Lerner, the city began a process of developing busway corridors emanating from the city centre. Like many Latin American cities at the time, Curitiba was experiencing rapid population growth. Beginning at a level of some 600,000 residents in the early 1970s, the city now has over 2.2 million inhabitants.

In much of Latin America, private sector operators have dominated the transit market. However, left uncontrolled and unregulated such operators have not met

the needs of commuters in terms of comfort, convenience, or safety. Lacking the resources to develop either a rail-based transit system or a car-based urban form, Mayor Lerner's team created a low-cost yet high-quality alternative utilising bus technology. Today, Curitiba's modernistic "tubed" stations and 270-passenger bi-articulated buses represent a world example. The BRT system now has five radial corridors emanating from the city core. The system features 57 kilometres of exclusive busways and 340 kilometres of feeder services. The system annually attracts hundreds of city officials from other municipalities, all seeking to study the organisational and design features that have shaped Curitiba's success. The success of Curitiba's BRT system has propelled the career of Jaime Lerner, the political backer of the original concept, as he has been re-elected mayor several times as well as governor of the state of Paraná (Brazil).

The mid-1970s also saw a limited number of BRT applications being developed in other cities of North and South America (Meirelles, 2000). While not as sophisticated as the Curitiba system, variations on the concept were developed in Sao Paulo, Brazil (1975); Arlington, USA (1975); Goiania, Brazil (1976); Porto Alegre, Brazil (1977); and Pittsburgh, United States (1977). The Sao Paulo BRT system is currently the largest in the world with 250 kilometres of exclusive busways serving 3.2 million passenger trips each day.

Despite Curitiba's success and relative fame within the transport planning profession, the overall replication of the BRT concept was actually somewhat slow to gain momentum elsewhere. It was only in the late 1990s that BRT's profile became more widely known. Visits by technical and political teams from Bogotá (Colombia) and Los Angeles (United States) to Curitiba served to launch BRT efforts in those cities. In 1996, Quito (Ecuador) opened a BRT system using electric trolley-bus technology, and the city has since expanded the system with clean diesel technology.

However, it was the effort in Bogotá with its TransMilenio system that has particularly transformed BRT's perception around the world. As a large-sized city (7.0 million inhabitants) and a relatively dense city (240 inhabitants per hectare), Bogotá provided proof that BRT was capable of delivering high-capacity performance for the world's megacities. Today, with both Bogotá and Curitiba acting as catalytic examples, the number of cities with built BRT systems or with systems under development is quite significant.

In 1998, the administrator of the United States Federal Transit Agency (USFTA), Gordon Linton, visited the Curitiba BRT system. The qualities of the system enabled a conclusion that such a system could be applicable in the United States, where

high automobile usage makes it difficult to justify costly rail-based options. Since Linton's visit, the United States has embarked on a national BRT programme that includes 17 cities. Already, higher-quality bus systems are in place in Chicago, Honolulu, Los Angeles, Miami, Orlando, Philadelphia, Pittsburgh, and Seattle. Likewise, other OECD nations such as Australia, Canada, France, Germany, Japan, and the United Kingdom have seen the potential for BRT as a high-quality but low-cost mass transit option (Figures 3 and 4). The transfer of BRT technology from Latin America to OECD nations has made BRT one of the most notable examples of technology transfer from the developing south to the developed north.


There is no precise definition of what constitutes a BRT system and what represents simply an improved transit system. Table 1 lists the cities with bus transit systems that possess some of the qualities of BRT, as of July 2004. Most of the cities listed have some form of exclusive busways. The table distinguishes between cities with systems in operation and those in the planning or construction phase.

**Table 1 High-quality bus systems around the world (as of February 2004)**

| Region | Cities with a high-quality bus system in operation (some form of exclusive busway) |
|---|---|
| Africa | Abidjan, Cotê d'Ivoire; Saint-Denis, Reunion (France) |
| Asia | Ankara, Turkey; Istanbul, Turkey; Jakarta, Indonesia; Kunming, China; Nagoya, Japan; Taipei, Taiwan |
| Europe | Bescançon, France; Bradford, UK; Claremont Ferrand, France; Dijon, France; Eindhoven, The Netherlands; Essen, Germany; Grenoble, France; Ipswich, UK; Leeds, UK; Limoges, France; Lyon, France; Montpellier, France; Nancy, France; Rennes, France; Rouen, France; Runcorn, UK; Strasbourg, France; West Sussex, UK |
| Latin America | Belo Horizonte, Brazil; Bogotá, Colombia; Campinas, Brazil; Curitiba, Brazil; Goiania, Brazil; León, México; Porto Alegre, Brazil; Port of Spain, Trinidad; Quito, Ecuador; Recife, Brazil; Sao Paulo, Brazil |
| North America | Alameda and Contra Country, USA; Boston, USA; Chicago, USA; Honolulu, USA; Las Vegas, USA; Los Angeles, USA; Miami, USA; Ottawa, Canada; Orlando, USA; Philadelphia, USA; Pittsburgh, USA; Seattle, USA; |

| | |
|---|---|
| | Vancouver, Canada |
| Oceania | Adelaide, Australia; Brisbane, Australia; Sydney, Australia |
| **Region** | **Cities with a high-quality bus system in the design or construction phase** |
| Africa | Accra, Ghana; Cape Town, South Africa; Dakar, Senegal; Dar es Salaam, Tanzania |
| Asia | Bangalore, India; Beijing, China; Chengdu, China; Dhaka, Bangladesh; Delhi, India; Hangzhou, China; Shejiazhuang, China |
| Europe | Annecy, France; Brest, France; Caen, France; Cambridge, UK; Coventry, UK; Luton, UK; Maubeuge, France; Nice, France; La Rochelle, France; Toulon, France |
| Latin America | Barranquilla, Colombia; Bucaramanga, Colombia; Cali, Colombia; Cartagena, Colombia; Cuenca, Ecuador; Guatemala City, Guatemala; Guayaquil, Ecuador; Lima, Peru; Medellín, Colombia; Mexico City, México; Panama City, Panama; Pereira, Colombia; Puebla, Mexico; San Juan, Puerto Rico; San Jose, Costa Rica; San Salvador, El Salvador |
| North America | Albany, USA; Charlotte, USA; Cleveland, USA; Eugene, USA; Hartford, USA; Louisville, USA; Montgomery County, USA; Reno, USA; Salt Lake City, USA; San Francisco, USA; Toronto, Canada |
| Oceania | Auckland, New Zealand; Perth, Australia |

Despite this long list of cities with improved transit services, the number of cities with full BRT systems is actually more limited (Table 2). In this case, a "full" BRT system is defined as systems with the following characteristics:

- Exclusive busways utilised on trunk-line corridors
- Pre-board fare collection and fare verification
- Entry to system restricted to prescribed operators under a reformed business and administrative structure ("closed system")
- Clean vehicle technology
- Fare free integration between feeder services and trunk-line services

**Table 2 Full BRT systems (as of February 2004)**

| City | Total kilometres of exclusive busways |
|---|---|
| Bogotá (Colombia) | 58 |
| Curitiba (Brazil) | 57 |
| Goiania (Brazil) | 13 |
| Quito (Ecuador) | 26 |

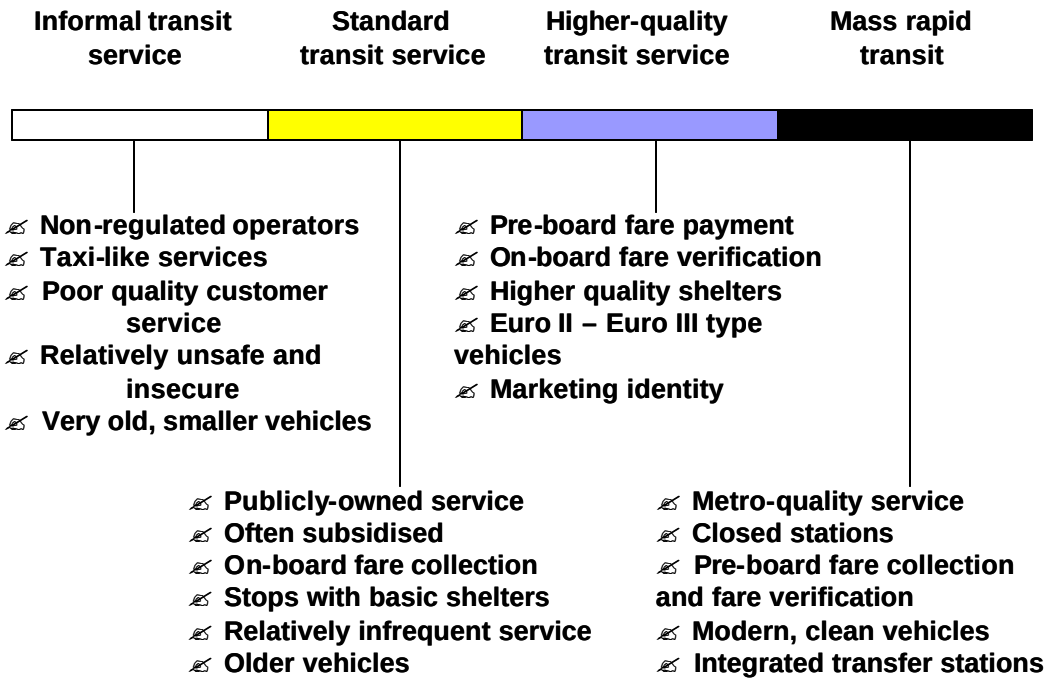
The Latin American cities of Bogotá, Curitiba, Goiania, and Quito probably possess the most complete systems, in terms of all aspects of BRT. The systems in Brisbane (Australia), Ottawa (Canada), and Rouen (France) probably provide the best examples of BRT in the developed-nation context. The experiences in Africa

and Asia are more limited in number and scope. The Taipei (Taiwan) and Nagoya (Japan) systems perhaps stand out as the more complete systems in the Asian region, although not quite reaching the level of full BRT systems.

### 1.2.3 Conventional bus systems

Conventional transit systems can vary significantly in size and quality, even within the same city. Transit ranges can range from relatively modest van services to bus systems approaching the performance of a BRT system. The quality of public transit can be seen as a spectrum of possibilities ranging from customer unfriendly informal operations to full-feature mass transit systems that achieve mass transit speeds and capacities (Figures 5 and 6). It is worth noting that this spectrum can encompass both road and rail transit options. In general, most developing cities should be attempting to move towards higher-quality services. BRT has provided a means to enter the higher-quality, higher-capacity end of the spectrum but at a substantially reduced cost in comparison to other options.

**Figure 5. The spectrum of public transport possibilities**




Mini-buses and vans, both formal and informal, are quite evident in cities of Africa and Latin America. While these services are sometimes of relatively low quality, they often provide transit options for communities with few other choices. Standard bus services encompass the conventional 70 passenger buses (12 metres) plying the streets in most parts of the developing world. These conventional services are typically safer than informal mini-buses, but nevertheless still are not an attractive, comfortable, or convenient option. The next stage in transit evolution is towards more organised and higher-quality bus services. Such services may feature newer and cleaner vehicles, more sophisticated fare collection systems, bus lanes, and improved stations.

Higher-quality conventional bus services, while not BRT, can be a significant improvement for residents of most cities. The conventional bus systems in cities such as Hong Kong, London, and Singapore have achieved considerable success without the full application of BRT attributes. London's bus network serves 5.4 million passenger trips each day, far exceeding the city's underground metro system. London is one of the few cities in the world in which bus ridership has consistently risen over the past ten years. London's success has been predicated upon four broad goals of service quality: 1. Frequency ("turn up and go" service with waits of 12 minutes or less); 2. Reliability (enforced bus lanes); 3. Comprehensiveness; and 4. Simplicity. To accomplish these goals, London has implemented many BRT-type features within a conventional bus service:

- Accessible low-floor vehicles for fast boarding and alighting
- Pre-board fare collection in central areas
- Real-time information displays at stations
- Quality incentive contracts with concessioned operators
- Enhanced driver training
- Priority lane measures


While London has not strictly implemented busways, the frequent use of well-demarcated bus lanes has helped to increase average speeds and overall reliability. Painted bus lanes with cameras to control private vehicle infringements have helped to

avoid many of the problems associated with standard bus lanes (Figure 7). Box 1 compares bus lanes to busways.

Hong Kong has achieved many of the same successes as London with priority bus lanes, integrated fare structures with other mass transit options, incentive-based contracts with concessioned operators, and higher-quality vehicles. Whether a system is termed "BRT" or not is less relevant than the quality of the service provided and the degree to which continual improvement is achieved. Most conventional bus services can be upgraded substantially by considering some of the low-cost customer service enhancements that are evident in BRT systems.

However, experiences with bus lanes have often failed to deliver desired results in developing cities. In many developing cities the bus lanes are regularly invaded by mixed traffic, even when the buses are travelling in a counter-flow direction (Figures 8 and 9). Without the strong enforcement environment and resources of a city such as London, bus lanes tend to lose their effectiveness. In fact, buses operating along highly-invaded bus lanes will in some instances leave the bus lane to travel more rapidly in a mixed traffic lane. Bus lanes also force unavoidable conflicts with turning vehicles. With bus lanes on the sides of the roadways, vehicles must cross the bus lane or even utilise the bus lane to enter or exit side streets.

**Box 1 Bus lanes or busways**

Bus lanes and busways are quite different in design and effectiveness. While some well-demarcated and well-enforced bus lane systems in developed nations have succeeded (e.g., London), in general, bus lanes do little to enhance the effectiveness of public transport.

*Bus lanes* are street surfaces reserved primarily for public transport vehicles on a permanent basis or on specific hourly schedule. Bus lanes are not physically segregated from other lanes. While the lanes may be painted, demarcated, and sign-posted, changing lanes is still feasible. In some cases, bus lanes may be shared with high-occupancy vehicles, taxis, and/or non-motorised vehicles. Bus lanes may also be open to private vehicle usage near turning points.

*Busways* are physically segregated lanes that are exclusively for the use of public transport vehicles. Entrance to a busway can only undertaken at specific points. The busway is segregated from other traffic by means of a wall, curbing, cones, or other well-defined structural feature. Non-transit vehicles are generally not permitted access to a busway although emergency vehicles often also may utilise the lane. Busways may be at surface level, elevated, or underground. BRT systems typically consist of busway infrastructure.

## 1.3 Public transport in developing cities

For much of the world's population, public transit is a necessary evil that must be endured rather than appreciated. For many families, the ultimate goal is to one day afford individual motorised transport, either in the form of a motorcycle or automobile. The state of public transit implies discomfort, long waits, risk to personal safety, and restrictions on movement. Customer satisfaction with the myriad of informal and formal vans, mini-buses, and full-sized buses that ply developing city streets is typically extremely low.

Under such conditions, it is not surprising that such services are losing passengers at alarming rates. The private vehicle continues to make gains in virtually every city. If present trends continue, public transport may have a rather doubtful future. As incomes rise in developing nations, private vehicles are gaining usage while public transport's ridership is almost universally declining. A selection of developing cities indicates that public transit systems are typically losing in the area of between 0.3 and 1.2 percentage points of ridership each year (Table 3) (WBSCD, 2001).

**Table 3 Changes over time in daily average public transport trips, selected cities (includes bus, rail, and paratransit)**

| | Earlier Year | | | | Later Year | | | |
|---|---|---|---|---|---|---|---|---|
| City | Year | Population (million) | Public Transport Trips/day | Percent of All Trips | Year | Population (million) | Public Transport Trips/day | Percent of All Trips |
| Mexico | 1984 | 17.0 | 0.9 | **80** | 1994 | 22.0 | 1.2 | **72** |
| Moscow | 1990 | 8.6 | 2.8 | **87** | 1997 | 8.6 | 2.8 | **83** |
| Santiago | 1977 | 4.1 | 1.0 | **70** | 1991 | 5.5 | 0.9 | **56** |
| Sao Paolo | 1977 | 10.3 | 1.0 | **46** | 1997 | 16.8 | 0.6 | **33** |
| Seoul | 1970 | 5.5 | | **67** | 1992 | 11.0 | 1.5 | **61** |
| Shanghai | 1986 | 13.0 | 0.4 | **24** | 1995 | 15.6 | 0.3 | **15** |
| Warsaw | 1987 | 1.6 | 1.3 | **80** | 1998 | 1.6 | 1.2 | **53** |

The reasons for public transport's demise are not difficult to discern (Figures 10 and 11). Poor transit services in both the developed and developing world push

consumers to private vehicle options. The attraction of the private car and motorcycle is both in terms of performance and image. Public transport customers typically give the following reasons for switching to private vehicles:

1. Inconvenience in terms of location of stations and frequency of service;

2. Failure to service key origins and destinations;

3. Fear of crime at stations and within buses;

4. Lack of safety in terms of driver ability and the road-worthiness of buses;

5. Service is much slower than private vehicles, especially when buses make frequent stops;

6. Overloading of vehicles makes ride uncomfortable;

7. Public transport can be relatively expensive for some developing-nation households;

8. Poor-quality or non-existent infrastructure (e.g., lack of shelters, unclean vehicles, etc.)

9. Lack of an organised system structure and accompanying maps and information make the systems difficult to use; and

10. Low status of public transit services.

However, the demise in public transport is not pre-ordained. BRT is public transport's response to this decline, with an attempt to provide a car-competitive service. With the introduction of the TransMilenio BRT system in Bogotá, Colombia, public transit ridership has actually increased in that city. Although the system had only opened two of its 22 planned lines in December 2000, the system achieved an immediate 6 per cent of transport mode share. Private vehicle usage declined from 18 per cent of daily trips in 1999 to 14 per cent in 2001 (Como Vamos Bogotá, 2001). A more detailed study along the TransMilenio corridor indicates that the system captured nearly 10 per cent of trips that would have been otherwise undertaken by private vehicle. (Steer Davies Gleave, 2003). Curitiba's BRT system

witnessed a similar increase when initially opened, and was able to increase ridership by over 2 per cent a year for over two decades, enough to maintain the public transit mode share when every other Brazilian city was witnessing significant declines.

BRT attempts to address each of the identified deficiencies in current services by providing a rapid, high quality, safe and secure transit option. Figures 12 and 13 present images of Bogotá, Colombia before and after the development of its TransMilenio system.

### 1.4 Barriers to BRT

When measured in terms of economic, environmental and social benefits, BRT's track record provides a compelling case for more cities to consider it as a transit priority. However, as a new concept, there remain several barriers that have prevented wider dissemination of BRT.

Specifically, these barriers include:

- Political will
- Existing operators
- Institutional biases
- Lack of information
- Institutional capacity
- Technical capacity
- Financing
- Geographical / physical limitations.

Political will is by far the most important ingredient in making BRT work. Overcoming resistance from special interest groups and the general inertia against change is often an insurmountable obstacle for mayors and other officials. Lobby groups from rail and automobile interests can make for a powerful political argument against BRT implementation. However, for those public officials that have made the commitment to BRT, the political rewards can be great. The political leaders behind the BRT systems in cities like Curitiba and Bogotá have left a lasting legacy to their cities, and in the process, these officials have been rewarded with enormous popularity and success.

While automobiles may represent less than 15 per cent of a developing city's transport mode share, the owners of such vehicles represent the most influential socio-political grouping. The idea of prioritising road space to public transport may appear to be counter to the interest of private vehicle owners. However, in reality, separating public transit vehicles from other traffic may often improve conditions for private vehicles. Since public transit vehicles stop more frequently, the separation of these vehicles from mixed traffic can actually improve flows for all.

Existing transit operators may also prove to be a substantial political barrier to BRT implementation. Such operators may be quite sceptical of any change, especially when the change may have ramifications on their own profitability and even viability. In cities such as Quito (Ecuador), the existing operators took to violent street demonstrations to counter the development of the BRT system. Likewise, in other cities the private transit operators have pressured political officials through recall efforts and intense lobbying. However, it should be noted that the threat to existing operators may 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.

The professional staff within municipal agencies may also represent a barrier to BRT implementation. Such staff often do not utilise public transit as the primary means to travel. Instead, municipal officials are part of a middle class elite who have the purchasing power to acquire a private vehicle. Thus, the professionals who are responsible for planning and designing public transit systems frequently do not use public transit. This lack of familiarity with transit user needs and realities can result in less than optimum public transit design. Such staff may also unwittingly give funding and design preference to individual motorised 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 realisation of BRT by other cities is evidence of this information shortfall. Through the assistance of international agencies and non-governmental organisations, awareness of BRT has risen sharply in recent years. Visits to Bogotá by city officials from Africa and Asia have helped to catalyse new BRT projects (Figure 14). Nevertheless, many developing cities still do not have basic information on understanding the potential of BRT.

The lack of information on BRT 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 BRT even when general awareness of the opportunity is present.

Financing is typically a lesser problem with BRT than other mass transit options. First, BRT is a relatively low-cost option that is within the funding capacity of most developing cities. Second, the operational cost effectiveness of BRT means that many regional and multi-lateral organisations are quite willing to finance such projects. Unlike other options, the lack of on-going operational subsidies with BRT implies that the sustainability of the project can often be assured at the local level.

Various local conditions, such as urban, geographical and topographical factors, can also present barriers to BRT 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 makes each BRT project unique in its own way.

### 1.5 Benefits of BRT

An effective public transit system can underpin a city's progress towards social equality, economic prosperity, and environmental sustainability. By leap-frogging past a car-dependent development path, cities can avoid the many negative costs associated with uncontrolled growth that ultimately disrupts urban coherence and a sense of community.

Table 4 outlines some of the direct benefits that BRT has provided to developing cities. Beyond these benefits, though, there exist multiplier impacts that can further increase the value of BRT to a municipality. For example, BRT can lead to reduced public costs associated with vehicle emissions and accidents. Such impacts include

costs borne by the health care system, the police force, and the judicial system. In turn, by reducing these costs, municipal resources can be directed towards other areas such as preventative health care, education, and nutrition.

**Table 4 The benefits of BRT**

| Category | Description |
|---|---|
| Economic | ✍ Reduced travel times<br>✍ More reliable product deliveries<br>✍ Increased economic productivity<br>✍ Increased employment<br>✍ Improved work conditions |
| Social | ✍ More equitable access throughout the city<br>✍ Reduced accidents and illness<br>✍ Increased civic pride and sense of community |
| Environmental<br><br><br>Urban form | ✍ Reduced emissions of pollutants related to human health (CO, SOx, NOx, particulates, CO2)<br>✍ Reduced noise levels<br>✍ More sustainable urban form, including densification of major corridors<br>✍ Reduced cost of delivering services such as electricity, sanitation, and water |
| Political | ✍ Delivery of mass transit system within one political term<br>✍ Delivery of high-quality resource that will produce positive results for virtually all voting groups |

Methodologies for estimating the economic, environmental and social impacts of BRT are included in later sections of this guidebook.

# 2. Choosing a Mass Transit System

Choosing the type of mass transit system for a city can be a difficult process. Given the various interest groups involved and the substantial private sector contracts at stake, the process can become highly politicised. However, it is quite possible to make such a decision within a rational framework. This section attempts to provide such a framework, as well as offer a discussion on each decision variable.

The choice of mass transit technology will affect travel times, personal transport expenditures, and commuter comfort and safety. The choice will also dramatically affect municipal finances and a city's economic efficiency. Ultimately, the selection will shape a city's urban form and the very lifestyle of its inhabitants. Thus, an objective and effective evaluation process is clearly a worthwhile goal.

The topics discussed in this section, include:



## 2.1 Introduction to mass transit options

*Mass Rapid Transit (MRT) is collective urban passenger service that operates at high levels of customer performance, especially with regard to travel times and passenger carrying capacity.* Mass rapid transit can achieve reduced travel times through the provision of widely accessible networks, higher speed vehicles, exclusive right-of-way infrastructure, efficient fare collection systems, and/or faster boarding and alighting techniques. Higher carrying capacities may be achieved through larger vehicles, multiple sets of vehicles (i.e., a train), and/or more frequent service.

Box 2 defines the major categories of mass transit typologies. Of course, there is a wide range of permutations possible with each technology. Some LRT systems may blur the boundaries with the definition of a metro when LRT is utilised on grade-separated infrastructure. Likewise, some BRT systems have segments that go underground. Nevertheless, Box 2 provides a general typology for mass transit systems. The continued innovation from mass transit developers is likely to mean that these definitions will also continue to evolve.

Bus Rapid Transit (BRT) is just one of several types of mass rapid transit. Additionally, there are a range of rail-based transit systems that are possible,

including Light Rail Transit (LRT), trams, underground metro systems, elevated rail systems, and Personal Rapid Transit (PRT) systems. No one of these options is inherently correct or incorrect. Local conditions and local preferences play a significant role in determining the preferred system type.

Additional types of mass transit systems are also possible. While monorail and maglev train technologies could be considered a form of elevated rail transit, these technologies are also distinctive enough to be considered as separate transit categories. However, over the past forty years of the technology's existence, monorail systems have not been developed to any great degree. Other than in Japan, most existing current monorail applications are quite specialised such as in theme parks. However, Las Vegas (USA) is completing a monorail line in 2004, and Seattle (USA) is currently developing its second monorail project. Maglev technology is quite new and holds the potential to increase vehicle speeds considerably. The only current passenger application of maglev is found in Shanghai (China), where speeds of over 400 km per hour are reached on a 30 kilometre line between the city and its new international airport. However, at a cost of over US$ 300 million per kilometre, the technology is unlikely to be replicated elsewhere for the foreseeable future. Further, for many transport professionals, maglev technology is seen more as a competitor of air travel for inter-city travel rather than a practical solution within the urban transit sector.

**Box 2 Types of Mass Rapid Transit**

**Bus Rapid Transit (BRT)** – Bus-based technology typically operating on exclusive right-of-way lanes at the surface level; in some cases underpasses or tunnels are utilised to provide grade separation at intersections or in dense city centres.

**Light Rail Transit (LRT)** – Electric rail-based technology operating either as a single rail car or as a short train of cars, typically on exclusive right-of-way lanes at the surface level with overhead electrical connectors; a **tram** system can also be considered a type of LRT, but typically has smaller-sized vehicles and may share road space with other forms of traffic.

**Underground Metro** – A heavy rail transit system operating on grade separated tracks that are located principally underground.

**Elevated rail transit** – A rail transit system operating on grade separated tracks that are located principally on an aerial structure; elevated systems can also be considered a form of Metro.

**Suburban rail** – A heavy rail transit system operating on exclusive right-of-way tracks that are located principally at the surface level but generally grade separated; typically carries passengers between suburban and urban locations; differs from other urban rail systems by the fact that cars are heavier and the distances travelled are usually longer.

**Personal Rapid Transit (PRT)** – A rail- or wheel-based system carrying passengers in small Automatic Guided Vehicles (AGV); PRT typically operates on exclusive right-of-way lanes that may also be grade separated.

Personal Rapid Transit (PRT) is another relatively new phenomenon that is being developed as an option in lower-

density developed cities. PRT utilises Automatic Guided Vehicles (AGV) that avoid the need for a driver, and thus help developed cities to reduce their relatively high labour costs. These vehicles may be either rubber tyre- or rail-based, and are somewhat small in size with each vehicle carrying in the range of two to six passengers. To date, only a few experimental systems have been developed. For these reasons, PRT is not presented in any further detail in this document.

## 2.2 Criteria in technology selection

The decision to select Bus Rapid Transit (BRT) as opposed to other options depends upon many factors. Costs, performance characteristics, and personal preferences will all likely play a role. This section will outline some of the factors that should be considered in selecting the type of mass transit system for a city. While this document focuses upon BRT, many of its attributes and design lessons are transferable to other mass transit types as well. Additional information on different mass transit types can be found in Module 3a of the GTZ Sustainable Transport Sourcebook (Wright and Fjellstrom, 2003).

In recent years, significant debates amongst transport professionals have occurred on whether BRT or rail-based solutions are the most appropriate. Such competition between systems can actually be healthy as it implies an environment in which all technologies must strive to improve. A rigorous evaluation process will also help ensure that a city makes the most appropriate choice.

In truth, it may in fact be better to define basic transit characteristics prior to selecting a particular technology. By understanding customer needs with respect to fare levels, routing and location, travel time, frequency of service, quality of infrastructure, and issues of safety and security, system developers can characterise the most ideal type of service without prejudicing the result to any particular technology. Such a customer-orientated approach will likely have the best chance of producing a transit service that can effectively compete with the private automobile. In practice, though, a political official or technical official will often state a preference for a particular technology at the outset. In this case, the service is effectively being designed around a technology rather than the customer. Mass transit technology decisions can thus become a sort of self-fulfilling prophecy based upon political or personal preferences rather than customer needs.

The choice of transit technology should be chosen on a range of considerations with performance and cost being amongst the most important. As suggested, these requirements are ideally derived from an objective analysis of the existing and projected situation. Table 5 outlines categories of the characteristics that can help shape a city's decision towards the most appropriate type of mass transit system.

**Table 5 Factors in choosing a type of mass transit system**

| Category | Factor |
|---|---|
| Cost | Capital costs (infrastructure costs)<br>Operating costs |
| Design and operation | Planning and implementation time<br>System capacity |

| | |
|---|---|
| | Scalability<br>Flexibility<br>Diversity versus homogeneity<br>Management and administration |
| Performance | Travel time / speed<br>Service frequency<br>Reliability<br>Comfort<br>Safety<br>Customer service<br>Image and perception |
| Impacts | Economic impacts<br>Social impacts<br>Environmental impacts<br>Urban impacts |

This section attempts to provide an objective review of each of these characteristics. Again, no one mass transit solution is the right solution for all cities. The local circumstances and public policy objectives play a significant role in selecting the optimum transit solution for any city.

### 2.2.1 Costs

#### 2.2.1.1 Capital costs (infrastructure costs)

For most developing cities, the infrastructure costs will be a pre-eminent decision-making factor. Developing cities often face a borrowing cap which acts as a ceiling to the total amount of borrowing that can be undertaken, based upon lending regulations set by institutions such as the International Monetary Fund and the World Bank. The lending capacity is often a function of the amount of loans currently outstanding as well as the relative level of debt to gross domestic product (GDP). Additionally, lending in the transport sector will have a direct impact on a city's ability to borrow for all critical functions, including such areas as water, sanitation, education, and health care. Thus, the decision on a city's transit system will have broad ramifications affecting many facets of overall development.

The exact capital cost of a system will depend upon many local factors, including:

- Local labour costs
- Competitiveness of construction industry
- Quality of management and organisational capabilities
- Local physical conditions (topology, soil conditions, water tables, etc.)
- Design and safety requirements
- Financing costs
- Local content versus imported content of technology
- Requirements to retire existing vehicle fleets
- Levels of import duties
- Property prices and level of expropriation required for system development
- Level of competitiveness and openness in the bidding process

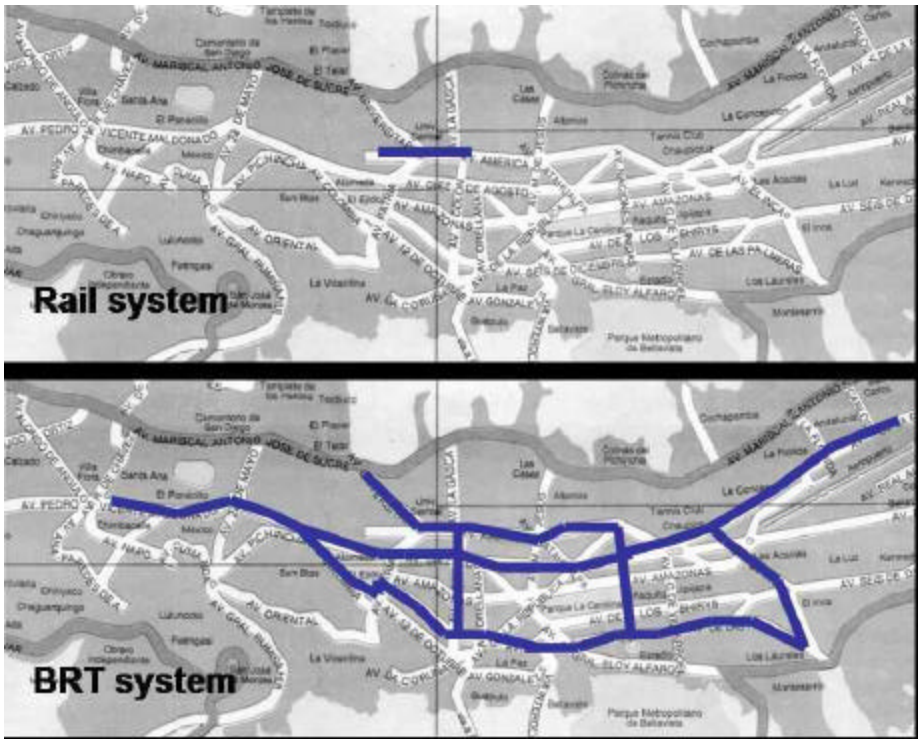
Thus, while it is possible to compare capital costs with other cities, the actual investment level will depend upon the nature of local conditions. Table 6 provides a sampling of capital costs from several different cities and several different mass transit technologies. In making such comparisons, one must take extra precaution that one is comparing the same set of cost factors. For instance, one technology bid may consider rolling stock (vehicles) to be part of capital costs while another bid may place the item in operating costs. Further, in some cases, rail systems may capitalise spare parts and regular maintenance activities while other transit systems will likely expense such items under operating costs. For the purposes of developing a decision-making matrix between system types, one must be strict in categorising each cost type consistently.

Table 6 indicates that BRT systems are typically in the range of US$ 500,000 per kilometre to US$ 15 million per kilometre. By comparison, at-grade light rail transit (LRT) appears to be in the range of US$ 13 million to US$ 40 million per kilometre. Elevated systems can range from US$ 30 million per kilometre to US$ 100 million per kilometre. Finally, underground metro systems seem to range from US$ 45 million per kilometre to as high as US$ 320 million per kilometre. The significant size of the various ranges again indicates the local nature of costing. Additionally, the range depends upon the individual features sought within each system (e.g., quality of stations, separation from traffic, etc.).

**Table 6 Capital costs for different mass transit systems**

| City | Type of system | Kilometres of segregated lines (km) | Cost per kilometre (US$ million / km) |
|---|---|---|---|
| Taipei | Bus rapid transit | 57 | 0.5 |
| Porto Alegre | Bus rapid transit | 27 | 1.0 |
| Quito (Eco-Via Line) | Bus rapid transit | 10 | 1.2 |
| Las Vegas (Max) | Bus rapid transit | 11.2 | 1.7 |
| Curitiba | Bus rapid transit | 57 | 2.5 |
| Sao Paulo | Bus rapid transit | 114 | 3.0 |
| Bogotá (Phase I) | Bus rapid transit | 40 | 5.3 |
| Tunis | Light rail transit | 30 | 13.3 |
| San Diego | Light rail transit | 75 | 17.2 |
| Lyon | Light rail transit | 18 | 18.9 |
| Bordeaux | Light rail transit | 23 | 20.5 |
| Portland | Light rail transit | 28 | 35.2 |
| Los Angeles (Gold Line) | Light rail transit | 23 | 37.8 |
| Kuala Lumpur (PUTRA) | Elevated rail | 29 | 50.0 |
| Bangkok (BTS) | Elevated rail | 23 | 73.9 |
| Las Vegas | Monorail | 6.4 | 101.6 |
| Mexico (Line B) | Metro rail | 24 | 40.9 |
| Madrid (1999 extension) | Metro rail | 38 | 42.8 |
| Caracas (Line 4) | Metro rail | 12 | 90.3 |
| Hong Kong | Metro rail | 82 | 220.0 |
| London (Jubilee Line ext.) | Metro rail | 16 | 350.0 |

Figure 15 presents a graphical way of looking at the same comparison based upon the amount of city area that can be covered by rail and BRT at equal investment levels. The relative coverage that each system can provide is not a trivial matter as it will greatly determine usability. A limited system of only a few kilometres will mean that most of a person's essential destinations are not reachable by the system. When systems are quite extensive across the expanse of a city, then the ability to function without purchasing a private vehicle is considerably higher.




The relative robustness of capital cost projections is also an important consideration. Higher-cost options, such as rail technologies, also tend to demonstrate greater disparity between projected and actual costs. This disparity translates into greater financial risk for those undertaking the project. Table 7 illustrates the tendency for certain rail projects to under-estimate expected costs and to over-estimate the number of expected passengers.

**Table 7 Cost overruns and passenger projections of rail projects**

| Project | Cost Overrun (%) | Actual traffic as a percentage of predicted traffic, opening year |
|---|---|---|
| Washington metro | 85 | NA |
| Mexico City metro | 60 | 50 |
| Tyne and Wear metro | 55 | 50 |
| Kolkata metro | NA | 5 |
| Miami metro | NA | 50 |

Source: Flyvbjerg, B., Bruzelius, N., and Rothengatter, W. (2003)

There may a variety of reasons for the under-estimation of public transit projects, including economic self-interest, technological complexity, and psychological

factors. Project developers may under-estimate costs in order to win initial commitment to the project; the underestimation may particularly occur when there is no penalty or risk for doing so (Flyvbjerg et al., 2003). Projects that require tunnelling, elevated structures, and advanced technology probably also incur greater cost variance due to the relative project complexity that is related to the occurrence of unforeseen events and costs. Allport (2000, p. S-23) notes that "metros are a different order of challenge, cost and risk." Allport also draws similar cautions with LRT:

> "LRT is often considered a more affordable alternative to a metro, while having the up-market and 'green' image which busways have so far usually not had…[but LRT systems] comes at a very high cost, both capital and operating, and they can be risky: much needs to go right for a project to be successful, and a bad mistake can spell disaster." (Allport, 2000, p. S-6)

Additionally, overly-optimistic projections may also be due to psychological preferences for more grandiose and image-driven options.

In some instances, capital costs can be reduced through concessionary financing or grants from developed-nation governments and private firms. The concessionary funds are provided as a means to promote the exportation of developed-nation products such as vehicles, information technology, and consultants. Concessionary terms can also be an effective technique to lock a city into a particular technology. The financial concessions may even be recouped later as the particular city extends the system. The Mexico City metro system, the Medellín (Colombia) urban rail system, and the Delhi metro system have also benefited from finance provided by, respectively, France, Germany, and Japan at concessionary interest rates. Unfortunately, in the cases of Mexico City and Medellín the cost of extending the current rail system is prohibitively expensive since the concessionary terms are no longer available.

#### 2.2.1.2 Operating costs

The long-term financial sustainability of a transit project is highly dependent upon the on-going operating costs of the system. These costs can include vehicle amortisation, labour, fuel, maintenance and spare parts. If a system requires on-going subsidies, the financial strain can end up affecting the effectiveness of both the municipal government and the transit service to the customer. The level of operating costs will also be related to the expected fare levels of the service, and thus will ultimately affect affordability and issues of social equity.

Labour costs represent perhaps the greatest difference between systems in developed nations and systems in developing nations. Whereas labour can represent between 35% and 75% of operating costs in Europe and North America, the labour component of developing-nation systems are often well less than 20%.

This difference has greatly shaped the direction of public transport in each context. Systems such as light rail transit (LRT) have proven quite popular in developed nations, in part due to the reduced need for operating staff. With multiple rail vehicles being operated by one driver, the labour cost per customer is greatly

reduced. In contrast, the relatively low labour costs in developing city applications means that there is little penalty for modes requiring more operating staff. Further, for social reasons, maintaining or even increasing employment is often a fundamental objective of public transit projects in the developing-city context.

The difference in labour costs, in conjunction with the higher capital costs for rail-based solutions, largely explains the relative lack of LRT and metro systems in the developing world. Outside of major corridors in a few developing megacities, rail transit has not been implemented significantly in developing nations. Rail options are likely to never fully serve a city's full transit needs. Only corridors with the highest passenger throughputs can produce a competitive operating cost structure for rail. By comparison, bus-based systems can cost-effectively serve a wide spectrum of passenger numbers from lower-density residential areas to the high-density corridors of a megacity such as Bogotá.

In developing cities, the lower impact of wages on total costs means that these costs are largely overwhelmed by the other components. Porto Alegre, Brazil offers a unique opportunity to directly compare urban rail and BRT operating costs. The city has both types of systems operating in similar circumstances. The TrensUrb rail system requires a 69% operating subsidy for each passenger trip. By contrast, the city's BRT system has a comparable fare structure, but operates with no subsidies and in fact returns a profit to the private sector firms operating the buses (Figures 16 and 17).

In the developed cities of North America and Western Europe, rail solutions, particularly LRT, are now being implemented with increased frequency. The divergent technology paths between developing and developed cities do not suggest one solution is better or more appropriate than another. Instead, it merely reflects highly different local circumstances and cost structures.

Beyond labour costs, other operating components tend to favour BRT over rail-based options in developing cities. With rail cars typically in excess of US$ 2 million and Latin American articulated buses in the area of US$ 200,000, the vehicle amortisation costs are still in the area of three times more costly for rail than for bus, even accounting for the longer life of rail vehicles and the greater passenger carrying capacity. The more specialised nature of rail maintenance and spare parts also tends to increase these costs. Comparisons of fuel costs obviously depend upon the technology utilised for the BRT vehicles, which can be diesel, natural gas, hydrogen, or electricity.

Operating costs are also affected by the economies of scale of the given operation. In developed nations the lower demand for pubic transit services has largely translated into inadequate revenues to cover costs, especially with regard to rail-based services. In turn, this differential implies often heavy subsidisation of the system. Likewise, rail-based services in developing cities also frequently require subsidisation. With the exception of the metros in Hong Kong, Manila, Santiago, and Sao Paulo, there are relatively few examples of systems with fare box recovery ratios greater than 1.0 (i.e., revenues greater than costs). Further, crossing into the frontier of subsidies also brings with it additional costs. Managing the subsidy process, controlling misappropriation, and ensuring the right incentives for customer service all require personnel and resources.

Implementing a system that will require subsidies without end raises issues of inter-generational equity. A commitment to subsidies into the indefinite future places a potentially heavy burden on future generations. In the short term, such subsidies will reduce annual spending available for other development objectives such as healthcare and education. Gregory Ingram of the World Bank supports this possibility with (Ingram, 1998, p. 7):

> "The construction costs of Metros in developing countries are so high that they crowd out many other investments…Most systems have operating deficits that severely constrain local budgets, as in Pusan and Mexico City."

In this sense, future generations may be penalised twice by having a lower development base to build upon and by being forced to continue subsidies for a transit decision placed upon them by previous administrations.

Developing-city BRT systems typically operate without subsidies. Revenues cover all BRT operating costs in cities such as Bogotá, Curitiba, Quito, and Porto Alegre. Further, the fare levels are often quite affordable with BRT; the customer fare is approximately US$ 0.40 per passenger in Bogotá and is US$ 0.25 in Quito. The lack of subsidies also allows these cities to easily accommodate and manage private sector concessions on the corridors. Thus, not only are all operating costs recovered within the affordable fares, but a healthy profit is realised by the private operating companies.

### 2.2.2 Design and development factors

#### 2.2.2.1 Planning and implementation time

The window of opportunity for transit projects is sometimes quite limited. The terms in office of key political champions may only be 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 development period also means that a host of other special interest groups will have more opportunity to delay or obstruct the process.

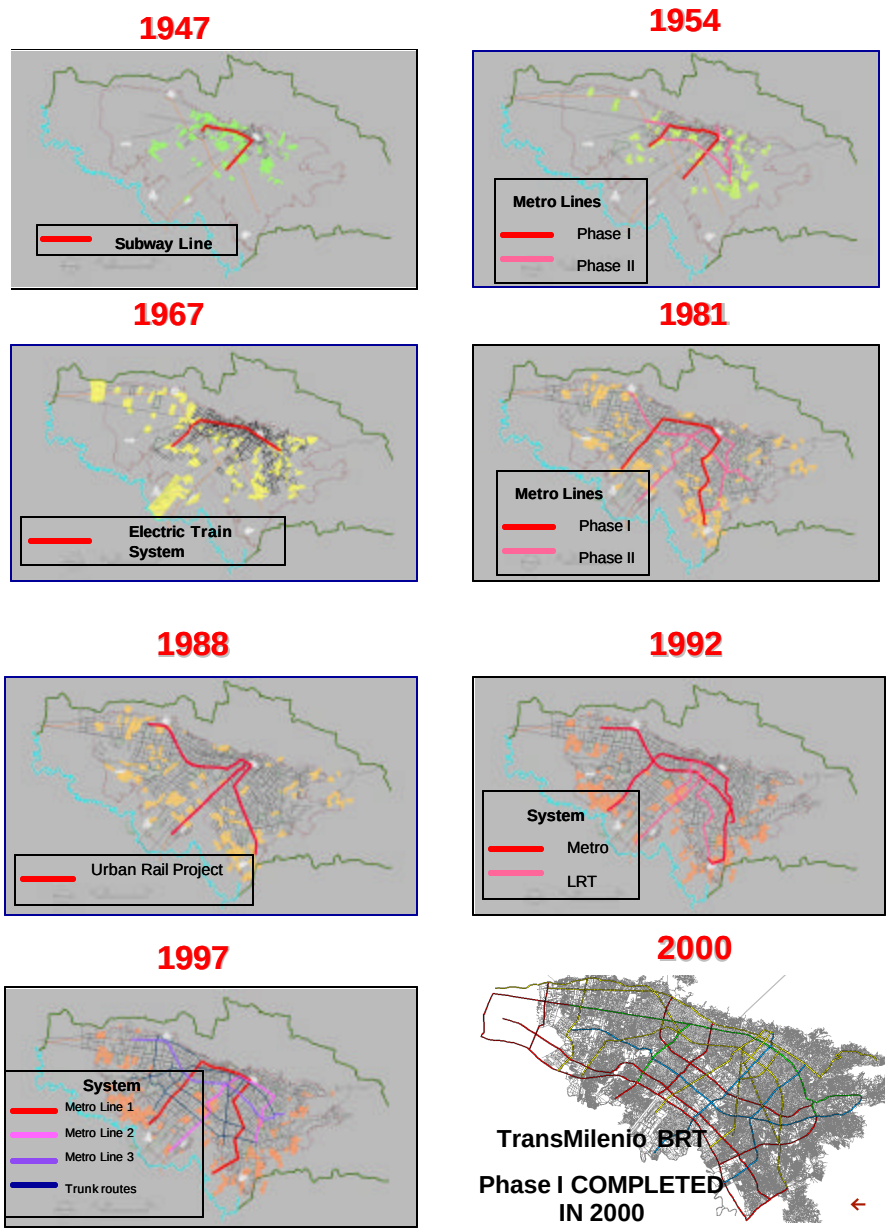
Ideally, a transit project can be planned and implemented within a single political term. This short time span would provide an additional incentive, as the project's initiator would want to finish the project in time to reap the political rewards.

Rail-based options and BRT have significantly different planning and implementation time horizons. Examples of planning and construction times vary greatly by local circumstances, but the duration from start to completion is significantly shorter for BRT. BRT planning typically can be completed in a 12 month to 24 month time horizon. The construction of initial corridors can likewise be completed in a 12 month to 24 month period (Figure 18). Phase I (40 kilometres) of Bogotá's TransMilenio system was planned and constructed within the three-year term of Mayor Enrique Peñalosa. By contrast, planning a more complex rail project will typically consume three to five years of time (Figure 19). Examples such as the Bangkok SkyTrain and the Delhi Metro also show that construction can also require another three to five year time horizon.

Bogotá (Colombia) makes for an interesting case study as the city has pursued both rail-based options (metros and LRTs) and BRT. Bogotá spent over four decades developing metro and LRT plans (Figure 20). Not a single project advanced beyond the planning stage. While the years of rail planning provided regular incomes to consulting firms, it did little to address the city's growing transport crisis. BRT brought the first sense of implementation reality to the city's public transit objectives. As noted, Mayor Peñalosa did in a single three-year term what could not be accomplished by forty years of metro dreams.

A longer time horizon can also mean greater city disruption during the construction phase. As portions of the city are under construction, road traffic and businesses will sometimes need to make inconvenient changes to their normal behaviour. The ensuing congestion and loss of sales caused by such disruption can do much to harm the goodwill that a transit project can otherwise deliver.

Obtaining the project financing can be another significant time delay. Because rail-based options typically have higher capital requirements, arranging the financing can be more complicated and more time consuming. Further, since rail-based options typically involve some form of public sector subsidy, the involvement of the private sector becomes a more complicated structural issue to design and negotiate.




2.2.2.2 Passenger capacity

The ability to move large numbers of passengers is a basic requirement for mass rapid transit systems. This characteristic is particularly important in developing cities where mode shares for public transit can exceed 80 per cent of all trips. Passenger capacity is affected by several factors that can differ between types of transit systems:

- Size of vehicle (passengers per vehicle)
- Number of vehicles that can be grouped together
- Headway between vehicles (amount of time that elapses between vehicles in safe operation)
- Boarding and alighting techniques

In many developed cities, passenger capacity is a less vital issue as the lower density of the cities along with lower market shares for public transit creates less peak demand. By contrast, developing cities often have both high population densities and high market share for public transit.

Concerns are sometimes raised whether bus-based options such as BRT can handle the passenger flows that are often required in denser, developing-nation cities. Both the Bogotá (Colombia) and São Paulo (Brazil) BRT systems handle over 30,000 passengers per hour per direction (pphpd) using additional passing lanes. Bogotá's Caracas Avenue corridor actually serves an estimated 36,500 pphpd. Such figures are achieved due to the following characteristics:

1. Use of articulated vehicles with a passenger capacity of 160;
2. Stations with multiple stopping bays that can handle up to five vehicles per direction simultaneously;
3. Multiple permutations of routing options that include local, limited stop, and express services;
4. Average vehicle headways per route of three minutes, and as low as 60 seconds during peak periods; and,
5. Station dwell times of approximately 20 seconds (achieved by use of at-level boarding and alighting, pre-board fare collection and fare verification, and three sets of large double doors on each vehicle).

Systems such as Quito (Ecuador) and Curitiba (Brazil) that utilise just one lane in each direction reach capacities of approximately 10,000 pphpd. However, Porto Alegre (Brazil) also has only one lane available in each direction but reaches capacities of over 20,000 pphpd through the clever use of multiple stopping bays and the platooning of vehicle movements. In general, these results indicate that BRT can achieve slightly higher passenger capacities than light rail systems but somewhat less than elevated rail and metro systems. Table 8 provides a comparative capacity analysis between different mass transit options.

**Table 8 Actual peak capacity, selected mass transit systems**

| Line | Type | Ridership (passengers / hour / direction) |
|---|---|---|
| Sao Paulo Line 1 | Metro | 60,000 |
| Mexico City Line B | Metro | 39,300 |
| Santiago La Moneda | Metro | 36,000 |
| London Victoria Line | Metro | 25,000 |
| Buenos Aires Line D | Metro | 20,000 |
| Bogotá TransMilenio | BRT | 36,500 |
| Sao Paulo 9 de julho | BRT | 34,911 |
| Porto Alegre Assis Brasil | BRT | 25,000 |
| Belo Horizonte | BRT | 21,100 |
| Curitiba Eixo Sul | BRT | 15,100 |
| Bangkok SkyTrain | Elevated rail | 22,000 |
| Tunis | LRT | 13,400 |

As surface systems with no mobility beyond the rail corridor, LRT systems face some practical limitations in terms of passenger capacities. This conclusion is supported by the findings from the research of Allport (2000, p. 38):

> "Typical at-grade LRT throughputs were about 4,000-6,000 passengers per hour compared to busway average of 15,000 at about the same commercial speed. There were no known LRT's operating at-grade which approach the passenger carrying capacity of the existing Curitiba, Quito or Bogotá busways."

Allport then goes on to explain the reasons for LRT's capacity limitations:

> "LRT achieves high speed by using a signalling system to avoid bunching, and by obtaining priority at traffic signals over other traffic; and it achieves high capacity by having large vehicles which take advantage of the signal cycles. In practice the distance between signals defines the maximum vehicle size, and the need to provide for crossing traffic limits the number of vehicles per hour. However, LRT systems are operationally vulnerable to the everyday events that happen in the centre of developing cities. Whether this is junctions being partly blocked, or road maintenance work, or a breakdown, or an accident, while bus systems are often able to get round the problem (they can overtake, leave the busways etc), LRT is not.
>
> We conclude that an LRT capacity of 10-12,000 pphpd at an operating speed of 20kph is likely to be the limit to what is achievable."

LRT systems generally are not able to introduce the same measures that allow BRT systems to reach higher capacities. The application of passing lanes at stations and express services for LRT requires a degree of switching technology that is quite complicated in urban settings, particularly in developing cities. However, if an LRT system was grade separated from mixed traffic (i.e., become a metro-like service), then higher capacities would be possible. In general, though, capacity is not a major constraint since the principal application of LRT is in developed nations of Europe and North America. Cities in these nations rarely have public transit demand in excess of 10,000 pphpd.

For passenger capacities in excess of 40,000 pphpd, grade separated rail is currently the only option available. Passenger volumes of this magnitude have been recorded in only a handful of cities such as Hong Kong, New York, Sao Paulo, and Tokyo.

Interestingly, in cities that have both a metro system and a bus network, the metro generally only carries a small portion of the cities public transport ridership. Table 9 compares mode shares for several cities with both a metro and a bus network. This result is surprising since it is generally assumed that metros possess a greater carrying capacity. While it is true that the peak capacity of metros and elevated rail systems surpass other modes, their ability to serve large overall numbers of passengers is limited due to cost reasons. Bus transit, as both a standard service and an enhanced BRT service, continues to serve as the principal transit backbone of most cities. Even cities with metros and elevated rail systems, such as Mexico

City and Bangkok, the numbers served by the rail systems are typically less than 15 per cent of the daily trips (Table 9). Such systems typically can only be cost justified in a few corridors, and thus actually serve fewer overall numbers of passengers. Thus, while metro systems often receive the largest share of public transport investment as well as political attention, the reality is that underfunded bus systems still carry the vast share of customers.

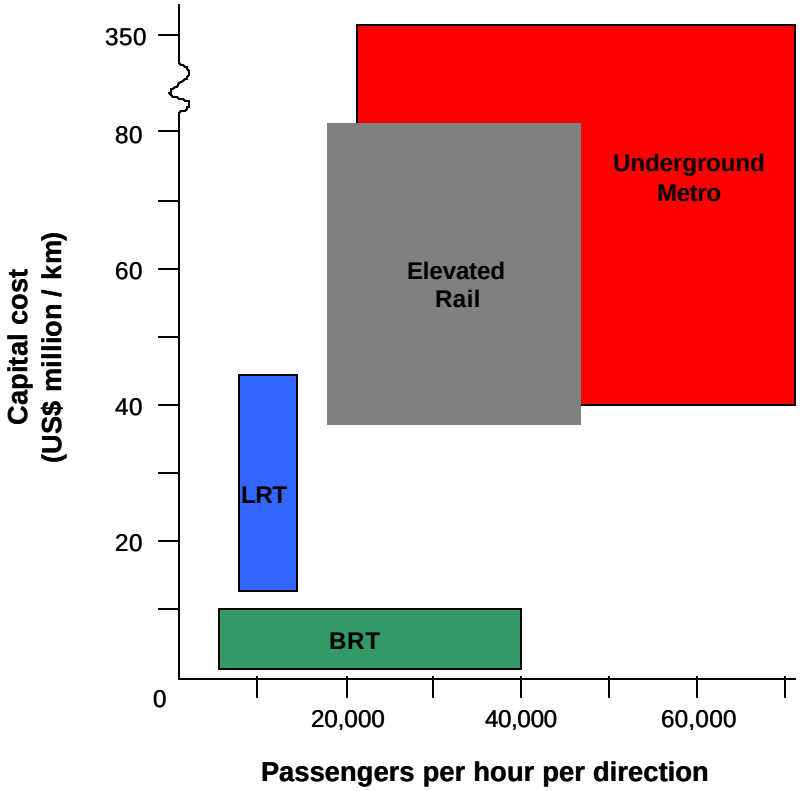
**Table 9 Mode share comparison**

| City | Bus | Metro | Train | Car | Motor -cycle | Taxi | Walk | Bi-cycle | Other |
|---|---|---|---|---|---|---|---|---|---|
| Bangkok[1], 2003 | 31 | 3 | 0 | 30 | 32 | 4 | - | - | - |
| Beijing[2], 2000 | 15 | 2 | 0 | 16 | 2 | 6 | 33 | 26 | - |
| Buenos Aires[3], 1999 | 33 | 6 | 7 | 37 | 0 | 9 | 7 | 0 | - |
| Caracas[3], 1991 | 34 | 16 | 0 | 34 | 0 | 0 | 16 | 0 | - |
| Mexico City[4], 2003 | 63 | 14 | 1 | 16 | - | 5 | - | - | - |
| Rio de Janeiro[5], 1996 | 61 | 2.3 | 3.1 | 11.5 | 0.2 | - | 19.7 | 1.3 | 0.9 |
| Santiago[6], 2001 | 28.4 | 4.5 | - | 23.5 | - | 1.3 | 36.5 | 1.9 | 4.0 |
| Sao Paulo[3], 1997 | 26 | 5 | 2 | 31 | 1 | 0 | 35 | 0 | - |
| Shanghai[2], 2001 | 18 | 2 | 0 | 4 | 2 | 2 | 44 | 28 | - |

Sources:
1. OTP (2003)
2. Xu, K. (2004)
3. Vasconcellos, E. (2001)
4. SETRAVI (2003)
5. IplanRio (1996)
6. Ciudad Viva (2003)

Figure 21 compares the range of passenger capacity for each technology measured against the range of capital costs. The ranges presented in Figure 21 are based on actual not theoretical data. From this data, BRT is positioned as the lowest-cost option that provides a relatively wide range of capacity options. BRT can economically function in cities with low passenger demand to higher capacities of 40,000 pphpd.

**Figure 21 Passenger capacity and capital cost for mass transit options**




The area of the rectangles in Figure 21 are also revealing with regard to the relative risk and uncertainty involved in a transit technology choice. The range of the cost variable for LRT, elevated rail, and metros indicates that local conditions can spiral costs several multiples from original estimations.

In reality, the debate over capacity is a bit misleading. The capacity required on a particular corridor is principally determined by the population density along the corridor, the total catchment area for passengers, and the origin and destination profile of the residents. When a system consists of a network that covers the majority of central districts and main corridors, this catchment area typically extends to an area of one kilometre around stations as well as the passenger traffic collected by feeder services. Thus, while the central areas of London and New York host dense populations, the extensive coverage of the system network distributes demand across many parallel and connecting lines. In London, the demand handled by the mass transit system does not exceed 30,000 pphpd. This lower capacity occurs not because there is little demand, but rather because the relatively large demand has been well-distributed around an overall network.

However, in cities such as Hong Kong and São Paulo, where a limited network is provided, capacities can reach 60,000 pphpd and higher. In this sense, costly metros can become a self-fulfilling prophecy with respect to capacity. Since developing cities can only afford a few metro lines, the passenger demand is drawn from a much wider area and thus creates a capacity requirement that only metros can fulfil. Hong Kong draws large numbers of passengers from Kowloon and the New Territories into a single metro line on Nathan Road. There are disadvantages to this approach. By requiring passengers to travel farther to enter the system, the system developers are making conditions less convenient to the customer, which

will ultimately result in captive users seeking alternatives such as private vehicles. Also, when operating at a capacity of over 60,000 pphpd, the system is far less robust with respect to delays and technical problems. A two-minute outage in such a system can create extremely difficult conditions and backlogs.

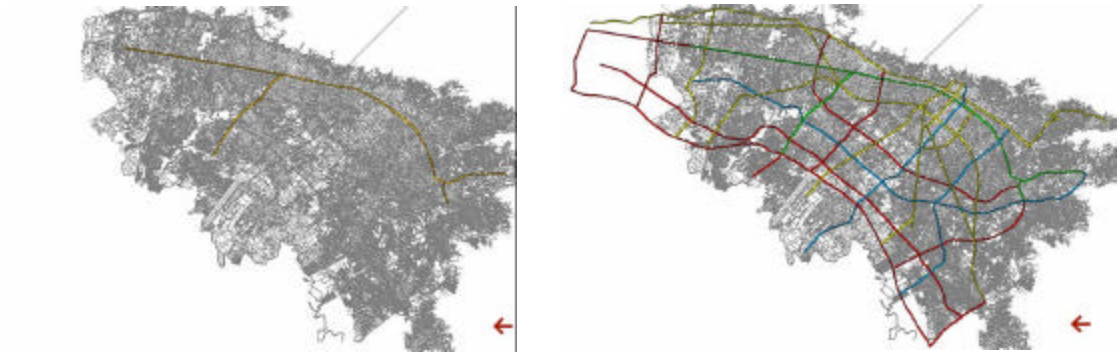
For most cities, even cities with high population densities, a BRT system provides adequate capacity if the system is designed as an effective network. The extreme densities claimed by rail advocates are often only possible by creating a highly-limited corridor structure that satisfies scale at the cost of customer service. Bogotá is a large, densely populated city with 7 million total inhabitants and approximately 240 persons per hectare, and yet the city's BRT system manages these volumes. Few cities have a population density higher than that of Bogotá, and thus passenger capacity is rarely the over-riding factor in choosing a rail-based system. However, if a city has one or more of the following characteristics, then an underground Metro may be an appropriate option from a capacity standpoint:

- Population densities in an area of trip origins or trips destinations above 270 persons per hectare in a megacity environment with demand of over 40,000 passenger per hour per direction in key corridors;
- Extremely tight structural densities that do not permit use of the surface for dedicated transit lanes (although some cities have placed BRT corridors underground in the densest sectors);
- Geographical constraints (e.g., a narrow strip of land bounded by water or a hillside) that do not permit sufficient space to use surface roadways for dedicated transit infrastructure.

#### 2.2.2.3 Scalability

Scalability refers to the ability to match the size and scope of a system to the particular urban environment. Rail-based systems tend to require a relatively large scale to operate economically. The high costs of rail infrastructure and operations mean that relatively high passenger numbers are needed. For the same reasons, rail-based systems often necessitate a larger network in order to operate effectively. The required economies-of-scale for metro construction implies that one would not construct many small segments over different time periods. If one brings in the tunnelling equipment and construction teams, it would be extremely costly to just construct just a very short segment.

BRT's lower costs and greater flexibility permits system developers to closely match current needs with actual construction. Since construction techniques for BRT are not so different than normal roadway construction, the required economies-of-scale are far less acute than those for rail-based projects. BRT has been developed in cities with populations of 200,000 to megacities with over 10 million inhabitants. Even relatively small system additions can be economically accommodated by BRT. Thus, BRT allows cities to have a transit system that grows and evolves in close step with the demographic and urban form changes that occur naturally in a city. Figure 22 illustrates the planned system expansion taking place within the Bogotá TransMilenio system.



2.2.2.4 System flexibility

Modern modelling and planning practices have greatly aided the objective of matching public transit design to customer 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 transit system that can grow and change with a city.

During the start-up phase of a new system, customer reactions and preferences are sometimes different 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. Routes may require adjustments to account for future changes in urban form.

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 the system. By contrast, routing and service changes to rail-based systems are far less adaptable. Once the expense and engineering effort of tunnelling and laying rail is made, the flexibility to make changes is rather limited. Thus, rail-based systems require a good deal more certainty in terms of the required demand and service preferences.

The combination of lower capital costs and greater scalability of BRT means that the system will preserve greater *option value* for future political administrations and future generations. Rather than committing a city to a prescribed path for the foreseeable future, BRT permits changes in city form, demographics, and public priorities to allow different options to be viable at a later date. Once a city has committed to an expensive rail option, both the psychological and the financial flexibility for making later changes becomes limited.

As has been noted, the state-of-the-art in BRT continues to evolve in a dynamic environment of experimentation and municipal creativity. Each new project brings with it the potential to alter what is considered best practice. It has also been noted that there is no fixed agreement on what even constitutes a BRT system. A highly

strict definition (closed system, fully segregated busways, fare-free transfers, and pre-board fare collection) may produce only four true BRT systems in existence: Bogotá, Curitiba, Goiania, and Quito. A more expansive definition (open and closed systems, higher-capacity vehicles, low emission standards, improved customer information) can imply a total of approximately 50 systems.

BRT can fulfil a range of roles within an integrated transit service. Some cities with existing rail-based systems are viewing BRT as an economical means to extend or augment their systems. Medellín (Colombia) and Beijing (China) are both developing BRT corridors that will act in concert with an existing rail-based system. For Medellín, the high capital and operating costs of the city's existing elevated rail system meant that there was no possibility of using rail in other corridors. Sao Paulo (Brazil) uses BRT as a means to extend the reach of the metro system to satellite cities. Table 10 outlines the different types of roles that BRT can assume within a city's public transport strategy.

**Table 10 Potential BRT roles within an integrated mass transit strategy**

| Service type | Explanation |
|---|---|
| Principal mass transit service | BRT can serve as the principal mass transit technology for a city, covering all trunk-line corridors and providing feeder routes |
| Metro extension | BRT can provide an economical means to extend metro services to outer areas |
| Mass transit in-fill | BRT can provide an economical means of adding mass transit lines within a city that already has some rail-based corridors |
| Feeder service | BRT can provide a feeder service connecting with existing metro corridors |
| Future conversion | BRT can serve as an economical entry into a mass transit system while also allowing for the future conversion to rail |

Bogotá has demonstrated that a densely-populated megacity can in fact be quite well-serviced by BRT alone. Nevertheless a range of cities with existing rail systems may find BRT a compatible addition to an integrated system. As noted above, employing multiple technologies does bring with it added costs and managerial complexity. However, for cities with existing rail infrastructure and few financial resources the choice may be either BRT or waiting decades for further system expansion.

BRT does not necessarily represent the endpoint in terms of city's ultimate transit choice. The relative flexibility of BRT means that other options are not closed to a city at a later time. A city may elect to replace a BRT corridor with a rail-based option. This change may be in response to improved municipal financial conditions that allow a more capital intensive option to be implemented. The reasons for such a conversion may be related to an increase in mass transit usage that results in corridor demand over 40,000 passengers per hour per direction. Alternatively, a BRT to rail conversion may also be based upon a desire to upgrade towards a system with a higher perceived visual image. In either case, BRT provides the flexibility for such a conversion to take place. The segregated busways and high-

quality stations of BRT may be directly transferable to another technology. Thus, the earlier BRT investment is largely not lost in the conversion process.

Of course, once a BRT system has been put in place a city may not consider a conversion to rail to necessarily be regarded as an upgrade. It is unlikely that residents of cities with high-quality BRT systems such as Bogotá, Curitiba, and Quito feel that they possess an inferior service. In fact, there is no recorded example of a city moving to rail once a BRT system has been put in place.

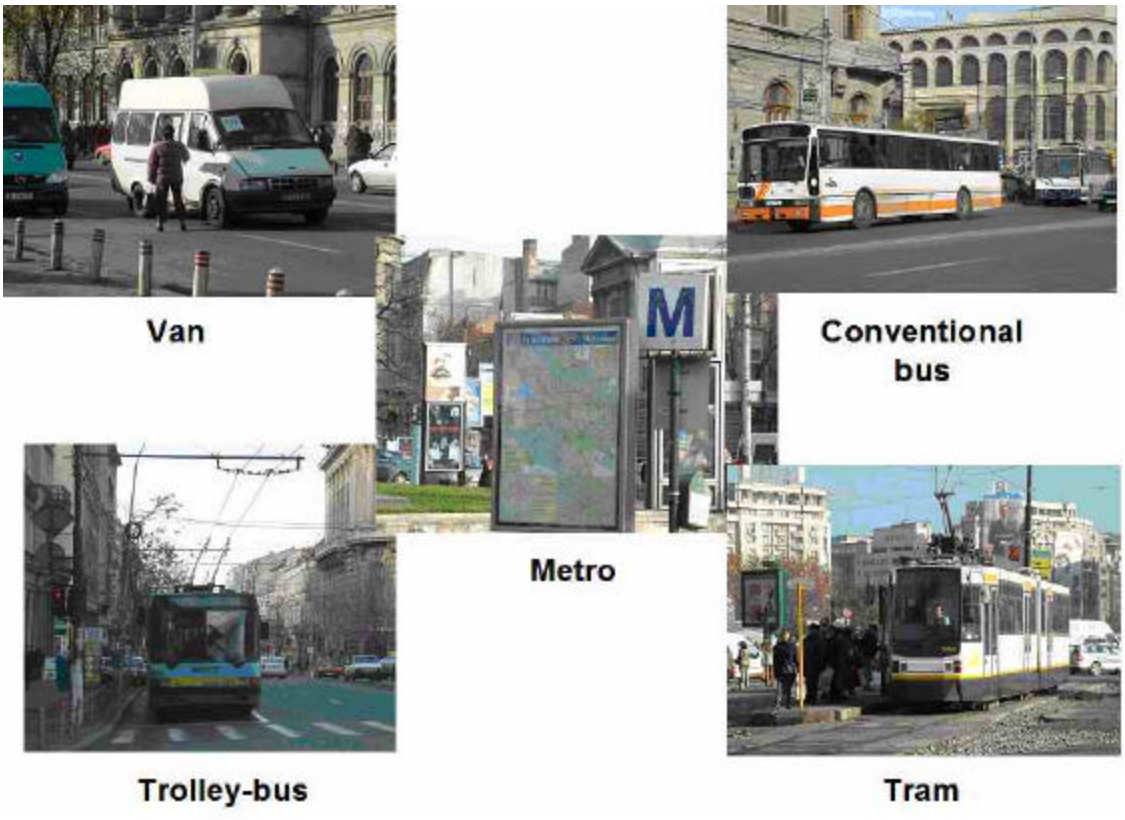
The previous conventional wisdom within transport planning was to employ rail-based systems wherever it was financially feasible to do so. This philosophy is tantamount to spending as much as possible on a given corridor, even if the same service is achievable with a lower-cost solution. This preference can result in rail systems "cherry-picking" the most lucrative corridors with virtually no possibility of covering other areas of the city. In turn, this result can imply higher fares for low-income citizens, difficulties in effective integration between modes, and a long-term commitment to a single solution.

This preference for limited rail service can also create a sort of transport apartheid within a city. Wealthier citizens are whisked about in an expensive, high-technology system that absorbs the vast majority of the city's transit resources. However, for most of the population, the metro system or elevated rail system is beyond their level of affordability. Instead, lower-income groups are bunched in an under-funded (or non-funded) paratransit or conventional bus system that operates with little in terms of customer service amenities. Examples of such dramatic intra-city inequities include the elevated rail systems in Bangkok and Kuala Lumpur as well as the costly metro system in Kolkata.

The ultimate decision on a mass transit system should not be based on a particular type of technology. Instead, the needs of the customer should be paramount above all. Building a single, limited corridor of rail does little to provide a meaningful network for those persons who depend upon public transport for their daily mobility needs. A city with few financial resources may wish to consider developing a full mass transit network with BRT prior to a limited rail-based corridor. In time, if the desire to convert to rail is strong, then this possibility is always there as a future conversion option. However, BRT can give a city a complete network over the medium term and thus do much to relieve the pressures of congestion, contamination, and access that are evident in much of the developing world.

#### 2.2.2.5 Diversity versus homogeneity

In the past, the conventional wisdom for mass transit services implied that a wide diversity of transit types in a city could be useful. Thus, there are cities such as Buenos Aires (Argentina) and Bucharest (Romania) that simultaneously possess virtually all types of transit technologies (metros, elevated rail, trams, trolleys, standard buses, mini-buses, etc.) (Figure 23). The idea behind this abundance of diversity is that each transit type can be matched with the corridor characteristics that best match the technology's optimum operating characteristics.




The reality, though, is often a plethora of services that are not integrated with each other and not understood by the majority of the population. Instead of serving the public in the most efficient manner, the variety of transit types mostly just serve the interests of technology vendors and public officials who are enamoured with the latest innovations.

The justification for a diverse set of technologies has largely been based on the assumption that each mode (LRT, BRT, elevated rail, metro, etc.) had a fairly narrow band of operational viability. However, with BRT systems now operating cost effectively at capacities ranging from 4,000 passengers per hour per direction (pphpd) to 40,000 pphpd, there is less strength in this argument.

Further, the high costs of multiple technologies are now becoming increasingly evident. First, the difficulty in integrating each transit type has already been noted. Each technology has a different cost structure. Some systems operate without the need of public subsidy while others require a continued stream of public funding. Coordinating fare structures and distributing revenues in such an environment can be quite complex and require a high level of managerial and administrative skills. Physically integrating different technologies that involve separate grade levels (underground, surface level, elevated), boarding techniques, and customer flow levels can be a challenge as well.

Second, operating several technology types implies higher maintenance costs than if a single technology is utilised. Different technologies means different skills and personnel are needed for maintaining and operating each; there are fewer opportunities for synergies that reduce personnel costs. The various technologies

will each likely require their own costly set of spare parts. Economies of scale are typically lost when purchasing multiple types of vehicles and components. Instead of one large order, smaller orders of different technologies are needed. The opportunity for reduced pricing through bulk procurement is limited.

Third, the complexity of managing many technology types often results in a different public agencies being created for each service. An expanding bureaucracy can increase overall administrative costs, reduce coordination, and establish "turf" that is later politically difficult to efficiently consolidate. This administrative complexity can also breed an environment where corruption is more prevalent. As the number of contracts for different technologies expands, so does the opportunity for misappropriation.

Perhaps the best example of how technological simplification can result in a multiple of benefits can be seen in today's airline industry. The recent success of so-called "low-cost" or "no-frills" airlines can in part be tied to a fairly simplified business model. These airlines typically only maintain one type of aircraft, and thus have greatly reduced maintenance costs and spare part costs. The simplified operating environment also permits faster turn-around time between routes which leads to more revenues per passenger-vehicle kilometres. As a result such airlines (Southwest Airlines, JetBlue, EasyJet, and Ryan Air) have become leaders in terms of profitability and market capitalisation (i.e., value). The business model for these companies may in fact offer a host of lessons that may provide insights into how public transit can succeed:

**Table 11 Characteristics of highly-profitable airlines**

| Category | Product and operating features |
|---|---|
| Vehicle (aircraft) | Single type |
| Routes and airports | Uncongested |
| Fares | Low, simple, and unrestricted |
| Distribution | Ticketless |
| Service | Single-class, high-density |
| Frequency | High |
| Punctuality | Very good |
| Staff | High productivity, high morale |
| Customer service | Friendly and responsive |

Source: Adapted from Doganis (2001)

While urban public transit is clearly quite different from the airline industry, there a sufficient number of parallels to consider aspects of this model. Simplicity in conjunction with excellence in customer service can be a powerful combination.

In some extreme cases of population densities and topographical constraints, a city may indeed require multiple technologies to meet its transit needs. However, these cases are relatively rare. If a single transit technology can adequately serve a city's mobility needs, then the ensuing cost and managerial savings can be significant.

2.2.2.6 Management and administration

The degree of managerial and administrative oversight required by a transit system is related to the relative complexity of the operations. As noted earlier, the complexity of rail options has tended to make projections of capital costs and passenger numbers highly variable. This degree of complexity can also imply that more managerial and administrative oversight is required. Allport (2000, p. S-19) points out that the level managerial experience to oversee such complexity is sometimes difficult to find:

> "Without high standards of operations, maintenance and administration [metros] will rapidly deteriorate…The culture, managerial standards and attitudes often found in bus companies and railway corporations of developing countries are unsuitable for a Metro."

In turn, the complexity of the operating environment may require a greater number of public agency staff to properly control and administer the system.

### 2.2.3 Performance

A transit system's performance characteristics will play a large role in determining customer usage levels. It does little good to have an economical system if nobody is willing to use it. The ability of a system to attract ridership is thus a prime decision-making determinant in selecting a mass transit technology.

#### 2.2.3.1 Affordability

As discussed earlier, the customer tariff is related to operational costs and the level of subsidies (if any). Given the lower labour costs in developing cities, BRT can typically deliver relatively low operating costs. Further, the realities of municipal revenues in developing cities also mean that long-term subsidisation is not an attractive or viable option. Thus, BRT is often capable of delivering non-subsidised services for fares of less than US$ 0.50 per passenger. In the developing city context, rail-based systems have proven to largely require subsidies and/or higher fare levels.

#### 2.2.3.2 Travel time / speed

Travel time and operating speed are related but distinct concepts. From the customer standpoint, the actual door-to-door travel time is probably the more important variable rather than top speeds. Thus, one must also consider the time travelling to and from stations, the time spent walking from transit entry points to the vehicle platforms, and the time spent waiting for a vehicle. For example, metros may deliver a rapid on-vehicle service, but it can take greater time to access a metro station as well as walk between the surface and the vehicle platform. Equation 1 summarises each of the variables that contribute to calculating total travel time.

**Equation 1 Total travel time**

Total travel time = Travel time from origin to transit station

+ Travel time from entering station to vehicle platform

+ Vehicle waiting time

+ Vehicle boarding time

+ Vehicle travel time

+ Vehicle alighting time

+ Travel time from vehicle platform to station exit

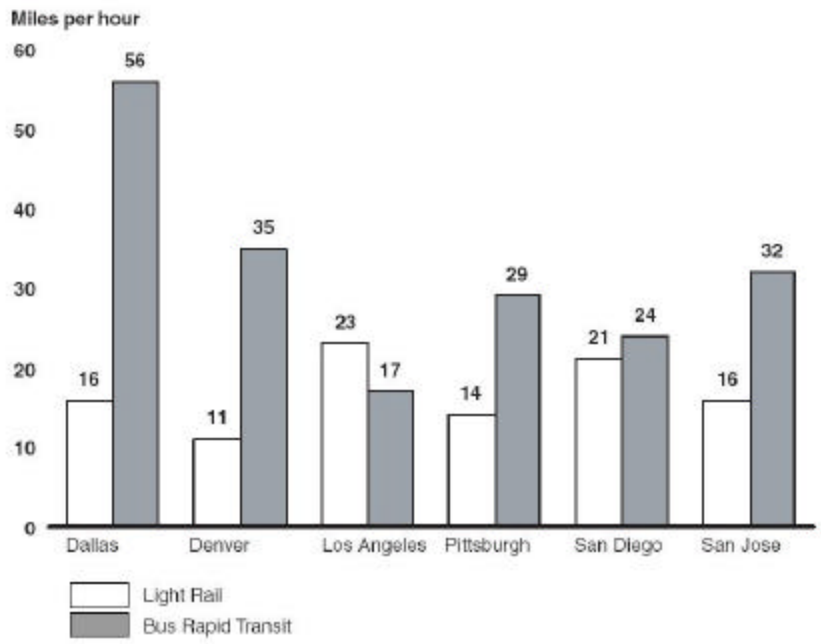
+ Travel time from station exit to final destination

The "commercial speed" of the vehicle is often more important than the "maximum speed". The commercial speed represents the average speed including the dwell time at stations. Thus, a system with short distances between stations or with long boarding and alighting times will be comparatively penalised in terms of average speed.

As surface modes, BRT and LRT are advantaged with relatively accessible entry and exit points. In contrast, metros and elevated systems typically require more time to enter and leave the stations. Further, the higher cost of metros sometimes implies that there is less coverage of the city's total area since it is not typically financially feasible to construct metro lines in all corridors. Thus, distances to arrive at a metro station may also require additional time or even an additional transit trip on a feeder service.

The commercial speed of metros, though, is quite often superior to that of either BRT or LRT. Underground and elevated metro systems may reach average speeds of 40 to 50 kilometres per hour. Commercial speeds for BRT and LRT systems can be in the range of 20 to 30 kilometres per hour. These values will vary depending upon the number of intersections to be crossed and whether signal prioritisation technologies are being utilised.

A comparison of light rail systems and BRT systems in the United States revealed higher average speeds for BRT in five of the six cities investigated (Figure 24). The US study noted the use of high-occupancy vehicle (HOV) lanes and the ability to augment local services with limited stop services as the reason for BRT's superior performance (US GAO, 2001).




Source: National Transit Database and six transit agencies.

The provision of "limited stop" and "express" services in addition to "local" services can also be a significant factor in reducing travel times. Limited stop services imply that the transit vehicle will skip several stations between more major travel nodes. Express services imply that even more stations are skipped allowing the service to go between major points of origins and destinations. Local services typically involve stopping at each of the stations in a particular corridor. A few metro systems, such as the New York subway, do in fact have second sets of tracks to permit limited stop services. However, these services are relatively rare for metro and LRT systems for reasons of both cost and technical complexity. The ability to safely control passing at stations is difficult with high-frequency rail services. Further, the requirement of a switching device in the track means that passengers will be subjected to an additional jolt in their ride. The relative flexibility of BRT permits greater ease in developing passing lanes at stations. BRT systems in cities such as São Paulo and Bogotá operate with either passing lanes and/or second sets of exclusive busway lanes in order to permit more direct services.

The relative advantage of rail-based options and BRT with respect to travel time depends greatly upon local circumstances and system design. Metros may produce the highest maximum velocities, but may entail longer access and departure times. BRT's ability to provide limited stop and express services is advantageous in terms of delivering reduced travel times.

2.2.3.3 Service frequency

Travel time is also greatly affected by the frequency of the provided transit service. Highly frequent service will imply lower average wait times for customers. Service frequency also affects the perception of the system's reliability and car competitiveness.

As noted earlier, metros and LRT systems are often preferred in developed-nation cities due to the reduced labour costs associated with a single driver operating multiple vehicles. However, the other side of this equation is that larger capacity vehicles tend to result in lower frequency of service, especially in North American cities with relatively low passenger numbers. The lower frequency is due to the need to adequately fill transit vehicles in order to operate efficiently. Table 12 gives peak and non-peak service frequencies for some rail-based systems in the United States.

**Table 12 Service frequency for rail-based systems**

| System | Peak frequency (minutes) | Non-peak frequency (minutes) |
|---|---|---|
| Denver Light Rail | 3-6 | 9-26 |
| Miami MetroRail | 6 | 10-60 |
| Portland MAX | 5-13 | 13-33 |
| St. Louis MetroLink | 10 | 10-30 |
| San Diego Trolley | 9-15 | 15-30 |

While a frequency of five to ten minutes may not seem long in relative terms, from the perspective of the passenger, wait times can have much longer perceived values. Customers may perceive waiting time to actually be two to three times greater than the actual duration. Thus, a wait of five to ten minutes may actually seem like as much as 30 minutes to the waiting passenger. Long waits can contribute to increased passenger stress and overall dissatisfaction with the service. Long waits can imply greater risks in terms of exposure to theft and violent crime.

The proper sizing of BRT vehicles can help keep service frequency in the range of two to five minutes throughout the day. The higher frequencies are particularly feasible in developing cities where customer flows are relatively large.

2.2.3.4 Reliability

Reliability is related to the level of confidence one has in the transit system's ability to perform as expected. The concept of reliability is related to the previous discussions of travel time and service frequency, but can also refer to other system characteristics such as comfort and safety.

An unreliable service can create a high degree of personal stress if a customer does not know when and/or if a vehicle is going to arrive at a station. Unreliable services ultimately lead to non-captive users seeking more robust travel options, such as private vehicles.

Each type of transit system has different characteristics with regard to reliability. 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, LRT, and BRT all have excellent records of reliability, particularly when compared to more conventional transit services. Segregated right-of-ways help to better control service frequencies and headways between vehicles. Systems with complete grade separation, such as underground metros, have a

particular advantage in terms of avoiding unforeseen incidents at mixed traffic intersections.

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 removal are taking place. The breakdown of a metro or LRT vehicle is another matter. Until the disabled vehicle is cleared from the system, there can be considerable disruption to service. Further, BRT vehicles can be removed utilising standard tow vehicles. In the case of rail vehicles, more specialised removal equipment is required.

Another consideration is the impact of extreme weather considerations on the system. Systems that are completely underground are immune to such affects, although a weather-related failure of the electricity supply can obviously have an impact. Ice on rails and busways can act to slow or even halt services.

#### 2.2.3.5 Comfort

The level of comfort within a system depends upon many design characteristics that are somewhat independent of mass transit type. Station seating and protection from the elements are dependent on system design. Of course, underground systems have the advantage of a better natural barrier from outside weather conditions. The interior design of the vehicles is again dependent upon design specifications, and can be of equal quality for either rail or BRT services. However, some types of trams may have a more narrow width which may limit design options and in some cases create a more squeezed environment for the customer.

Ride comfort is one potential area of 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 performance better permits value-added activities, such as reading, for the customer. 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 and improved suspension. With this type of BRT vehicle set-up in cities such as Bogotá, Curitiba, and Quito, on-board activities such as reading are quite feasible. However, in general, the ride smoothness of rail vehicles is superior to that of BRT vehicles.

#### 2.2.3.6 Safety

Segregated lanes for rail and BRT vehicles help to reduce the potential for accidents, and thus make such mass transit options relatively safer over more standard services. Grade separated services, such as underground metros, particularly benefit from avoiding such conflicts. Both BRT and LRT systems face potential risks when crossing intersections. The opening of the Houston (USA) LRT system has been met with a higher than expected accident rate between private vehicles and LRT vehicles. Private vehicle owners are often unaccustomed to the presence and operation of segregated transit vehicles and may be unprepared for the implications.

Fully grade separated systems do incur other types of risks that may affect safety. The higher maximum speeds reached on underground and elevated systems implies that in the event of a mishap, there is a greater chance for serious injury and fatalities. Further, underground and elevated systems have added difficulty in evacuating customers during a system emergency.

2.2.3.7 Customer service

Customer service features are equally possible for both BRT and rail-based systems. Intelligent Transport Systems (ITS) that inform passengers of expected arrival times, clear maps and payment instructions, and friendly and helpful staff are not dependent on the type of transit system.

However, the higher capital cost associated with rail-based solutions does imply that financial pressures can reduce the ability to implement customer amenities. The lower costs associated with BRT may allow transit developers more financial manoeuvrability to include service amenities that can be quite influential in affecting customer satisfaction and ultimately in attracting ridership.

2.2.3.8 Integration

As noted earlier, bus services tend to be the backbone of most developing-city transit systems, even when a rail-based system is operating on major corridors. The ability to transfer comfortably and easily between neighbourhood feeder services and trunk-line services is a major determinant in attractiveness of the overall system. Poorly executed transfer services often share some of the following characteristics:

- Long physical distances separate the two services involved in a transfer; for example, customers may have to cross a street to make the transfer;
- Transfer is conducted in an area unprotected from extreme weather conditions;
- Transfers are poorly timed so that long waiting periods are required; and,
- Customers must effectively pay twice for transferring between lines.

Transfers with such characteristics do little to foster customer good will. Conversely, a fare-free transfer conducted in a pleasant, safe, and controlled environment with a brief wait will minimise the undesirability of transferring.

While it is possible for either BRT or rail-based transit to achieve effective transfers, the nature of BRT may make such transfers more feasible. First, there is less economic discontinuity between feeder bus services and an exclusive busway. Both systems are based on bus vehicles and operate within relatively similar cost structures. In developing cities, both feeder services and busway services typically operate without subsidies. Thus, finding a business model that allows smooth integration and shared infrastructure between feeder and trunk-line services is more easily facilitated. By contrast, LRT and metro systems operate with significantly different cost structures. Since these rail-based systems typically require subsidised operation, developing an integrated business model is more complex.

Second, some BRT systems are able to cleverly eliminate the distinction between feeder and trunk-line services. In cities such as Porto Alegre (Brazil), transit vehicles from multiple routes utilise the same trunk-line corridor, but these vehicles then leave the busway to directly serve different feeder areas. In this arrangement, virtually all customers receive a direct trip into the city centre.

Operating rail-based systems into lower-density neighbourhoods is not economically viable. Thus, it is typical for LRT and metro systems to require integration with standard bus services in order to connect at the neighbourhood level. Allport (2000, p. S-6) notes that:

> "Integration with the bus system is particularly necessary to metro viability, and often difficult to achieve."

The integration difficulty arises from the different cost structures, managerial and administrative requirements, and physical discontinuities between systems at different grades (surface and underground). Few examples of seamless travel between bus and rail systems are found, although systems in Hong Kong, Miami, and Sao Paulo have achieved some success in this area.

Accommodating other types of feeder services is equally important. Arriving at the transit station by taxi, by bicycle, or by walking, should also be considered in the system's design. Designing for these modes is relatively independent of transit type. However, in some cases, underground systems may be able to provide more space for bicycle parking than median LRT and BRT systems. Typically, in all cases, terminal areas should provide sufficient space to include bicycle facilities. Permitting bicycles on-board the vehicle is a significant advantage for the customer who can then use the bicycle to arrive at the final destination. In narrow transit vehicles, such as some tram systems, the ability to enter with a bicycle may not be physically feasible.

#### 2.2.3.9 Image / status

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

Rail-based systems traditionally have maintained an edge with regard to creating a modern and sophisticated image. Such an advantage becomes particularly important when attempting to attract ridership from private vehicle users. At the same time, the traditional image of the bus is relatively poor. Attracting middle-income 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 evoke images that are inferior to bus systems (Figures 25 and 26).

The image problem is most closely associated with bus technology. However, as has been noted, traditional bus services and BRT are two distinct types of service. BRT systems have done much to create a modern and unique identity (Figure 27). The modern tubed boarding stations in Curitiba helped to make a dramatic new impression for the service. Modern vehicles that cover their wheels and emulate the rounded shape of LRT vehicles also help to create a new image.


To date, the success of BRT systems in cities such as Bogotá, Curitiba, and Quito has dispelled much of the image concerns. It has been noted that users in Bogotá do not say 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 effective in creating a metro-like image.

Nevertheless, in developed cities of North America and Western Europe, the perception of BRT versus rail-based transit is still a major decision-making consideration.

### 2.2.4 Impacts

The characteristics of different transit technologies can result in different impacts as measured by urban, economic, environmental, and social 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.

#### 2.2.4.1 Economic impacts

Economic impacts can include the transit system's ability to foment economic growth, stimulate jobs, and encourage investment. A prized objective with transit systems is to encourage transit-oriented development (TOD), which refers to the densification of development along transit corridors. If a transit project is implemented successfully, the creation of densified transit corridors can help to increase property values as well as shop sales levels. However, the research to date relating transit to property values and sales is still of a limited nature.

During a three-month period after the construction of the Brisbane (Australia) busway, land values along the corridor increased by 20 per cent (Hazel and Parry, 2003). Apartment rental values in Bogotá have shown to increase by 6.8 per cent to 9.3 per cent for every five minutes closer the location is to a TransMilenio BRT station (Rodriquez and Targa, 2004). Likewise, research from the San Francisco-Bay Area metro system (BART) indicates a US$ 1,578 premium for every 0.03 km closer a home is to a BART station. Similarly, results from the Washington Metro system show a 2.4% to 2.6% premium in apartment rental prices for every 0.16 km closer to a station. Evidence also exists for the same effect with LRT systems. For example, one study indicates a 2 to 6 per cent premium on home selling prices for properties near the San Diego Trolley system.

It should be noted that there also exists studies that do not show property value increases from transit development. Thus, the quality and local context of the development plays a key role in determining the level of benefit. Some authors have also asserted that the local development benefit from BRT may be less than that from rail options. This assertion is based upon the idea that BRT may be perceived as less permanent than rail infrastructure. The perception of permanence is quite important to property developers who would be at risk if a transit project was later removed. To date, there is no actual data indicating that BRT is perceived as being less permanent. As noted above, the results from Brisbane and Bogotá indicate that like rail transit, BRT can produce development gains.

Employment generation is another economic measure of a project's impact. Transit projects generate employment through the planning and construction phase, equipment provision (e.g., vehicles), and operation. In developing cities, employment creation tends to be a fairly important factor. Projects that ultimately reduce employment levels, in comparison to previous transport services, are more politically difficult to pursue. By contrast, in the developed city context, labour costs represent a much larger component of operating costs, and thus are typically a target for reduction to the extent possible.

BRT construction can provide a high level of employment per input of investment. Metro construction also provides employment but much of the project expenditures go towards the expensive machinery required for the tunnelling activities. In Bogotá, the first phase of TransMilenio produced 4,000 direct jobs during construction. The operation of the first 40 kilometres of the system also provides 2,000 persons with long-term employment.

BRT can also be instrumental in attracting local investment from equipment providers such as vehicle manufacturers. Unlike rail-car production, bus fabrication can be economically scaled at the local level. Major international bus manufactures have established production facilities in BRT cities such as Curitiba, Sao Paulo, Pereira (Colombia), and Bogotá. 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, and Japan. 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.

#### 2.2.4.2 Environmental impacts

All transit options produce environmental impacts when displacing journeys that would be otherwise taken by individual motorised transport. Thus, the amount of expected ridership and the number of persons switching from private vehicles to public transit is a significant determinant in calculating environmental benefits. The ability of mass transit systems to encourage private vehicle users to switch to transit depends on many factors, most notably cost and service performance. The convenience of private vehicle use gives a difficult competitive environment for transit. However, research in Bogotá indicates that approximately 10 per cent of former vehicle users have now switched to the TransMilenio BRT system (Steer Davies Gleave, 2003).

The type of fuel utilised with the transit vehicles also contributes to the overall environmental impacts. LRT and metro vehicles almost always electrified. Trolley buses, as utilised on the Quito BRT system, are also propelled by electric motors. Electricity produces no local emissions, but do contribute to regional and global emissions through the process of generation. Thus, electrified transit systems can be quite instrumental in improving ambient air quality at the local level.

The degree of environmental impact from electricity generation depends upon the fuel source. Renewable sources such as biomass, hydro, solar, and wind are relatively clean, but these sources typically only constitute a small percentage of total electric generation. Natural gas is also a relatively clean energy source but the combustion process does produce emissions such as nitrogen oxides and carbon dioxide. Nuclear energy is not typically utilised in developing nations, but in any case, carries with it other types of serious waste issues. Finally, coal remains a major energy source for electricity generation, particularly in developing nations such as China, India, and Indonesia. Coal combustion produces significant quantities of nitrogen oxides and sulphur oxide, which are precursors to acid rain, as well as significant emissions of greenhouse gases. If coal is a major constituent of

the electricity supply, total emissions from electrified transit can easily exceed the emissions of vehicles powered by natural gas and clean diesel technology.

As noted above, BRT vehicles can be propelled by electricity, but more commonly utilise natural gas or clean diesel fuels. The amount of emissions from natural gas or clean diesel vehicles depends upon many factors including local geographic and topological features, fuel quality, and driving behaviour. BRT systems, even in developing nations, require fairly stringent emission levels, and typically are a dramatic improvement over the previous standard bus services. For example, the Bogotá and Quito systems require Euro II emissions compliance, and are mandating a schedule to eventually move to Euro III levels. Nevertheless, natural gas vehicles and clean diesel vehicles do emit nitrogen oxides, carbon monoxide, particulate matter, and sulphur oxides at the local level. Additionally, these vehicles also contribute to greenhouse gas emissions.

Mass transit vehicles of all types also reduce emissions through smoother operations. With fewer station stops and fewer conflicts with mixed traffic vehicles, mass transit in dedicated corridors is less prone to operational inefficiencies.

Besides air emissions, public transit is also a contributing factor to the overall level of ambient noise in a city. Since one transit vehicle is equal to 100 or more individual vehicles, the reduction in noise, like the reduction in air emissions, can be considerable if ridership is increased. Thus, public transit in general contributes to lower decibel levels in a city. Electrified systems, such as LRT, metros, and electric trolleys, are particularly quiet while in operation. However, rail and trolley systems can also produce excessive noise, especially during braking. The noise generated from braking can be particularly amplified inside tunnels, such as with metro systems. Noise from the BART metro system in the San Francisco Bay area regularly exceeds 100 decibels. The maximum standard for BRT systems such as Bogotá is 90 decibels.

#### 2.2.4.3 Social impacts

Social impacts refer to the ability of a new transit system to help create more social equity within a city. Thus, this factor is related to previous discussions on affordability and employment creation, as well as social changes due to the new urban environment. Social impacts can also refer to changes in the safety and sociability of the streets.

Public transit's potential social impacts can thus include:

- Affordability of fares, especially for low-income groups
- Creation of a social environment encouraging personal interactions
- Attractiveness to all income segments of society and thus offering a meeting point of all income groups
- Reduction in crime and insecurity in both the transit system and its surrounding environment.

The lower unsubsidised fare levels of BRT in developing cities can help make the transit system accessible to a wider social audience. Of course, with subsidisation,

fares on LRT and metro systems can likewise be made affordable to the majority of the population. The metro systems in Mexico City and Delhi, for example, employ significant fare subsidies in order to ensure accessibility. However, this subsidy implies that public funds must be taken away from other potential public services.

Transit systems can also provide one of the few places in a city where all social groups are able to meet and interact. An affordable and high-quality system can attract customers from low-income, middle-income, and high-income sectors. This role as a common public good can be quite healthy in creating understanding and easing tensions between social groups.

The regeneration of an urban area due to public transit improvements can have multiple social benefits. As noted, the upliftment of an area creates employment and economic growth. Additionally, evidence suggests that public transit improvements can also reduce crime. There is no evidence to suggest that BRT or rail-based systems hold an advantage over one another with regard to crime reduction. In general, the more professional the transit environment, the less likelihood there is of crime. Further, higher levels of surveillance also can act as a deterrent. Security cameras and emergency all buttons are utilised in both BRT and rail-based systems. However, the longer train sets used in rail-based systems will tend to create greater separation between the driver and most passengers. Also, the driver of a rail system is generally separated from the passengers by an enclosed wall. By contrast, the open nature of a bus allows greater awareness by the driver of any security problems arising in the vehicle.

#### 2.2.4.4 Urban impacts

Transit and transport systems have a major impact on the shape and quality of urban life. A new transit system will wield a considerable influence over the physical form of a city. This impact occurs both directly through the transit infrastructure as well as indirectly through the development that occurs around the transit corridor as a result. In the long term the system will even influence where people decide to live.

The Curitiba BRT system has helped to focus considerable development along the busway corridors. A planning ordinance that restricted high-rises to the corridors also helped to achieve the transit-based development. The transit-development linkage is so pronounced that one can see exactly where the give busways are located even when flying over the city in a jet airplane, due to the density of commercial and residential buildings. In turn, this density helps the municipality in several ways. First, more development near the BRT stations means that more people will be to access and utilise the system. Second, the higher urban density also implies that municipal costs associated with electricity and water connections are reduced. Connecting municipal services to more suburban locations can be several times more costly.

In comparison to individual motorised transport, public transit consumes far less of the public domain. Figures 28 and 29 illustrate the difference in space requirements between 60 private vehicles and 60 public transit customers.

As surface modes, BRT and LRT require use of public road space. With its fixed guideways LRT typically requires less road width than BRT. This space savings is especially true of the smaller tram vehicles. Metros, of course, consume the least amount of surface space with only the entrance and exit points protruding into the public space. Elevated systems still consume space due to the need for support columns. Typically, systems such as the Bangkok SkyTrain require one lane of surface space to provide this infrastructure. Additionally, sidewalk space is typically also taken near stations in order to provide stairways and other access means to reach the elevated platforms.

The conversion of traffic lanes to public transit lanes can become highly politicised with arguments both in favour and against the exclusive lanes. Given the higher number of passenger-trips served in a more space efficient manner, it can be argued that public transit deserves a prioritisation. Nevertheless, automobile users will likely complain that the exclusive transit lanes will create congestion. However, an alternative view suggests that private vehicles can also gain from the loss of a lane. In many developing cities, public transit and mixed traffic share the same road space. Conflicts arise because public transit and private vehicles have very different mobility patterns. Transit vehicles, especially informal mini-bus operations, will stop on a fairly random basis. Private vehicles, though, tend to travel directly between destinations. Thus, the random nature of the transit vehicles will negatively impact the free flow preferences of the private vehicles. The separation of public transit from private vehicles can thus lead to greater order and flow rates for all vehicles.

The use of exclusive lanes by BRT and LRT also may result in an overall reduction in private vehicle use. The concept of "induced traffic" has been used to explain how roadway expansions seem to attract new traffic and ultimately do relatively to deter congestion. Evidence from bridge and street closings in Great Britain and the United States indicates that a reduction in road capacity actually reduces overall traffic levels, even accounting for potential traffic transfers to other areas (Goodwin et al., 1998). Thus, the empirical evidence suggests that giving exclusive road space to LRT and BRT will lead to reduced private vehicle use and little to no overall change in congestion levels. The fact that underground metro systems do not consume road space may thus result in a reduced incentive for motorists to switch to public transit. Since the existing road will continue to be available, any motorists switching will create more space, which can in turn encourage more private vehicle use.

### 2.3 The myths of BRT

A new mass transit system represents many opportunities and risks for governmental entities, private firms, civic groups, and the general population. With so much at stake, it is not surprising that the decision on the type of system can be fiercely competitive. This competition, though, can be quite healthy as cities can use the process to identify the most appropriate technology.

As noted earlier, BRT can be a highly effective option for cities seeking a high-quality mass transit option at a reduced cost. However, in the competitive environment of mass transit systems, BRT has also been subjected to various negative claims and myths. While BRT is certainly not the answer to every mass transit situation, table 13 compares the myths of BRT to the reality experienced in actual projects.

**Table 13 The myths of BRT**

| Myth | Reality |
|---|---|
| BRT cannot compete with the **capacity** of rail systems | Bogotá's TransMilenio system moves 36,000 passengers per hour per direction while BRT corridors in Sao Paulo can also provide capacities over 30,000 passengers per hour per direction. Such capacity numbers are in fact larger than many rail-based systems including all LRT systems and many metro systems, such as systems in cities like London, Santiago, and Bangkok. |
| BRT is only appropriate for **small cities** with low population densities. | Bogotá is a megacity of 7 million inhabitants with a population density of 230 inhabitants per hectare. In comparison, the population densities of selected Asian cities with rail-based systems are: Manila, 198 inhabitants per hectare; Bangkok, 149 inhabitants per hectare; Kuala Lumpur, 58.7 inhabitants |

| | |
|---|---|
| | per hectare (Newman and Kenworthy, 1999). |
| BRT requires a great deal of **road space** and cannot be built in narrow roadways | Design solutions exist for virtually every road space circumstance. Quito runs a BRT system through three metre wide streets in its historical centre. It should not be forgotten that even rail takes space; the support pillars for the Bangkok SkyTrain in fact takes away a lane of traffic. |
| BRT cannot compete with rail options in terms of **speed and travel time** | A US GAO study found that a comparison of BRT and LRT systems actually showed that BRT systems produced faster average speeds (US GAO, 2001). |
| BRT uses vehicles with rubber tyres which is an **inferior technology**; customers will never accept BRT | It is doubtful that anyone in Bogotá, Curitiba, or Quito feels that they have an "inferior technology". The appearance of BRT stations, terminals and vehicles can all be made to appear as sophisticated and inviting as any rail option. |
| BRT cannot deliver the **transit-oriented development** and land use advantages of rail | One only needs to see the rows and rows of high-rise development that has occurred along Curitiba's BRT corridors to realise that BRT can lead to as much or more urban regeneration as rail. |
| BRT is fine as a **feeder service**, but it cannot serve main corridors | Yes, BRT can work economically as a feeder service or system extension service, and it can do so without requiring subsidies or prohibitively expensive fares. But the Latin American BRT systems have also proven that it functions perfectly well in high-density mainline corridors. |

BRT is not always the best solution for a given city, as much depends on local conditions and local preferences. However, recent experiences indicate that BRT is apt at delivering effective mass transit for developing cities at economical price. The successful realities of Bogotá, Curitiba, and Quito demonstrate that the myths on BRT are really just myths.

# 3. Planning for BRT

This BRT Planning Guide seeks to help build the institutional and technical capacity of developing city municipalities that are interested in achieving improved transit services. This module provides an overview of the structure and contents of a BRT plan. While these planning elements have been extracted from some existing BRT plans, it must be recognised that planning practices vary greatly by location and circumstances. Thus, actual BRT plans in a particular developing city may necessitate other elements which are beyond the scope of this *Sourcebook* .

The sharing of BRT planning documents from other cities, though, does present an opportunity to greatly reduce planning costs. It is also hoped that a planning template will help reduce the amount of time required to move from the conceptual phase through to implementation. A focused BRT planning process can be reasonably completed in a period of 12 to 18 months. An overview of the entire BRT planning process is provided in Figure 30.

**Figure 30 Overview of the BRT planning process**

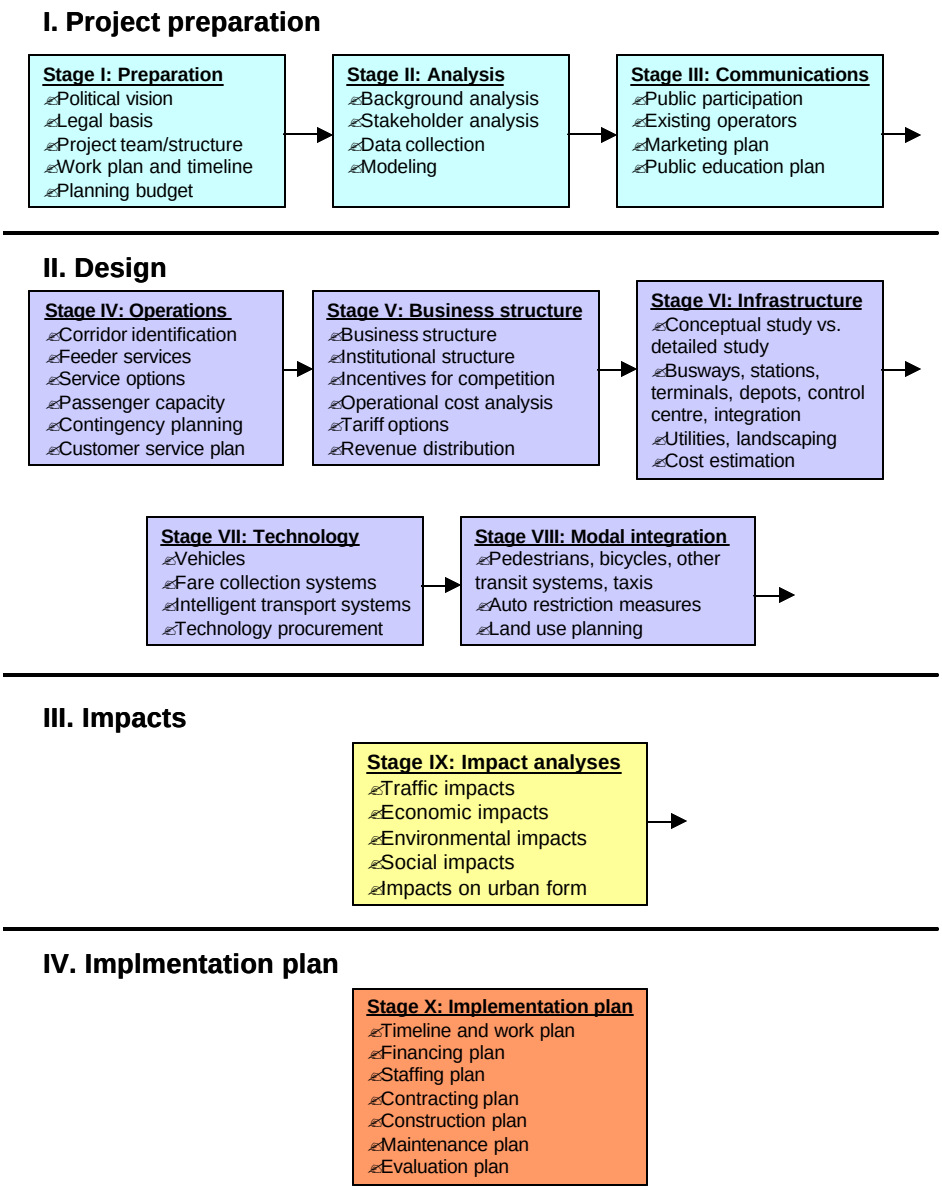



Figure 30 identifies four major activities in the realisation of a BRT plan:

1. Project preparation;
2. Design;
3. Impact analysis; and,
4. Implementation plan.

This guidebook will detail the content of each of these planning activities.

The planning stages outlined in this guide are presented in roughly chronological order. However, it should be noted that there is significant interaction between the different stages, and that many activities are actually undertaken simultaneously. For instance, cost data from technology decisions will impact financial analyses and routing decisions will impact busway design options. Additionally, it may be useful for a city to initially address each of the planning elements at a general level before

proceeding with a more detailed analysis. Further, many of the steps are inter-dependent with data from one area (e.g., engineering design) affecting decisions in another areas (e.g., business structure).

Additionally, the project team may wish to conduct an overview study of each planning stage prior to engaging in detailed analyses. Thus, the project team may elect to cover the all the planning stages process over the course of a few months. This analysis will not be in the detail ultimately required, but it will provide an important broad perspective on the final project.

The general idea of the overview study is to develop a sufficient outline of the project to give political officials, planning staff, and the public a perspective on the project's direction. An overview study will then allow the planning team to move forward with having to wait for the long amount of time to complete detailed engineering drawings of road works. If the planning team was to only proceed sequentially, then it is possible a great deal of detailed work may have to later be re-done when it is determined the situation dictates a different approach.

An overview study can provide sufficient detail to allow political and technical decision-makers the ability to make big picture decisions on system size, costs, business structure, and features. Some of the initial estimates that may be determined within the overview study are:

- Estimated length of project's first phase (trunk and feeder services)
- Potential business and administrative structure for system
- Estimates of expected capital costs
- Estimates of expected operating costs
- Estimates of expected fare levels
- Understanding of potential financing sources
- Level of cooperation expected from private sector operators
- Listing of all major stakeholder groups, organisations, and individuals
- Initial marketing concepts (system name, logo, etc.)
- Design characteristics (potential fare collection systems, security systems, station and terminal concepts, vehicle specifications, etc.)

The issues raised in the overview study should be seen as initial concepts and not immovable decisions that all must accept. Explaining the preliminary nature of the findings can help dispel fears that all major decisions have been finalised. These initial findings can actually help the participatory process by giving stakeholder groups a tangible example to build upon. It is sometimes difficult to offer practical suggestions and comments without some initial focus to the project, especially with a topic as relatively new as BRT.

## 3.1 Planning Stage I: Project Preparation

The first stage of the process involves galvanising the political and institutional support for the project. Additionally, this stage is also a time to organise and plan the entire BRT development process. Work plans, timelines, budgets, and the formation of a planning team are essential pre-requisites before proceeding further. Investments made early in properly structuring and organising the planning process can pay significant dividends later in terms of both the efficiency and effectiveness of the overall effort.

The topics to be presented in Planning Stage I, "Project Preparation", are:

**3.1.1 Project creation and commitment**

**3.1.2 Legal basis**

**3.1.3 Project team and management structure**

**3.1.4 Project scope and timing**

**3.1.5 Planning budget and financing**

### 3.1.1 Project creation and commitment

*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 (1901-1978)

#### 3.1.1.1 Political commitment

Before a smart card is used, or before a clean vehicle is purchased, or before a busway is built, a person or a group of persons must decide that action is required to improve a city's transit system. The inspiration may come from a civic group, a bus operator, a civil servant, or a political official. Nevertheless, without someone acting as a catalyst, good ideas will unlikely become reality.

The creation of an environment suitable to introducing a new mass transit system can depend upon 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. In such instances, the progression towards system planning happens almost immediately.

In other instances, a long period of persuasion and information gathering will precede the commitment. Site visits to cities with high-quality systems can help officials and the press visualise the possibilities. The development of videos and graphics illustrating how the system would look within a particular city can also help

the visualisation process. Testimonials from one political official to another may sometimes be appropriate. Showing how mayors and governors that deliver high-quality systems tend to win elections can also be helpful. The techniques to achieving project commitment are varied, and can depend greatly upon the local context, but the principal aim is to stimulate a demand for dramatically raising a city's transit quality.

In recent years, visits to the systems in cities like Bogotá, Curitiba, and Quito have persuaded officials to other cities to proceed with projects of their own. By speaking with technical staff and political officials in cities with existing systems, perspective system developers can understand the possibilities in their own cities (Figure 31). Experiencing a high-quality system in a relatively low-income city such as Quito also shows city officials that a system is possible regardless of local economic conditions. In many instances, the process to develop a BRT 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.

3.1.1.2 Statement of vision

Political leadership is probably the single most important factor in realising a successful BRT project. Without such leadership, the project will not likely have sufficient momentum to survive the inevitable challenges from opposition groups and special interests. Further, without leadership, it is significantly more difficult to galvanise public opinion towards supporting a new outlook on public transit.

An initial vision statement from the political leadership marks an important first step in making the case for improved transit to the public. 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 mass transit 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 transit system for the twenty-first century, the city will become increasing competitive, attract more investment and tourism, and ultimately stimulate the economy and job creation."

- ✍ "Place over 80 per cent of the city's population within 500 metres of a mass transit corridor."

- ✍ "Provide a one-ticket service that will allow a person to travel to any point of the city in less than 30 minutes with no delays from congestion."

The announcement should be placed within an overall press and media strategy for the project. The press and media organisations should be thoroughly briefed about the vision being put forward. These organisations should also be given a basic overview of BRT and its potential for the city. In some cases, press visits to cities with existing BRT systems can help reinforce the positive attributes of the project. Graphical and even video depictions of what the system will look like in the major corridors of the city can also help the media and the public visualise the potential. Section 3.3.2 provides more information on public outreach strategies and techniques.

3.1.1.3 Relationship to master transport plan

The vision for the new transit system should also be consistent with the vision and objectives set forth in any previous master transport plans. While BRT itself may not be explicitly noted in an existing 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.

### 3.1.2 Legal basis

In most cases, a statutory or legal mandate needs to be created prior to the project being officially recognised. This process then allows public funds to be disbursed towards the planning process as well as permits planning staff to be employed on the project. The actual authorisation process will vary depending upon local, provincial, and national laws and regulations. In some cases, city councils or provincial parliaments will need to give formal approvals before project expenditures can be realised. In other cases, the mayor or governor may have greater legal authority to approve project activities independently.

Of greatest importance is to maintain an open and transparent process throughout. 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 authorisation mechanisms are not followed, opposition groups may later use such improprieties as a means to stop the project. The proper legal mandate will also establish the BRT project as a city-wide priority.

### 3.1.3 Development team

A new mass transit system for a city is not a small undertaking. It is unlikely to be achieved without staff dedicated full-time to the effort. Attempting to plan a BRT system while simultaneously juggling other planning duties will most likely not produce a high-quality or timely result. Thus, the organisation and selection of a dedicated BRT planning team is a fundamental step towards planning the system.

#### 3.1.3.1 Planning staff

Depending on the intended timeline for planning and implementing the system, the initial number of full-time team members will likely vary from three to ten. As the project progresses, the size and specialties of the team will likely grow. Some of the initial posts to be filled may include:

- Project coordinator
- Administrative support
- Project accountant
- Public education and outreach
- Negotiator for discussions with existing operators
- Liaison officer for international organisations
- Finance specialist / economist
- Transport engineer
- Transport modeller
- Design specialist

In some cases, it may be possible to outsource some of these activities to consultancies. However, it is important to retain a certain degree of in-house technical competence in order to maintain a perspective that will allow for informed decision-making.

The composition of the team may include both existing municipal employees as well as new staff with specialised skills. Since BRT is a relatively new concept, it is

sometimes difficult to find staff with extensive implementation experience. For this reason, some training and even study tours may be appropriate mechanisms to develop local technical capacity (Figure 32).

3.1.3.2 Consultants

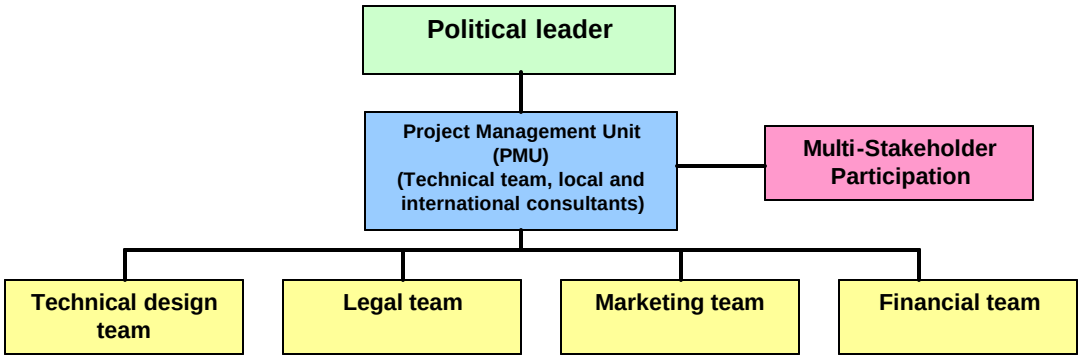
Utilising consultants within a BRT project can be a cost-effective means to gain individuals with key specialties and direct BRT experience. The use of consultants allows skills to be brought on board without the cost and overhead of a full-time hire. Further, in many instances the particular skills may be only needed for one component of the project, and thus do not justify a full-time position.

Perhaps, more importantly, consultants help avoid the situation where cities are needlessly reinventing lessons already learned elsewhere. International consultants with significant BRT experience can help smooth the path from planning through to implementation. In all likelihood, such consultants have experienced many of the problems that will be faced by the local team and thus can propose effective solutions. A local team working in conjunction with experienced international professionals can ideally result in a combination of world best practice and local context.

Of course, a city should not become over-dependent upon consultants. The local context is still best realised by local staff. The key decision-making points ultimately must be made by local officials. Consultants are one of several resources that lead to knowledge sharing. Section 4 of this guidebook lists many of the texts and web sites with information on BRT topics.

3.1.3.3 Project management structure

Initially, the team will be involved in basic fact-finding and analysis work, such as estimating both existing and projected transport demand. However, as the project begins to coalesce towards a more formalised and structured effort, then a specific organisational structure may be appropriate. Figure 33 gives an example of an organisational structure for a BRT development project. In this case, the mayor (or other leading political official) serves as the chairperson overseeing the project. This type of direct leadership involvement helps ensure that the project remains a top priority throughout the development process.



The organisational structure in Figure 33 also shows a steering committee consisting of key outside stakeholders such as non-governmental organisations, other government agencies, and private sector associations. Formal inclusion of all key stakeholders in the process can help ensure the necessary buy-in to make the project a reality. Giving a voice and ownership role to these groups will ideally create a spirit of shared commitment that will drive the project towards implementation.

### 3.1.4 Project scope and timing

#### 3.1.4.1 Work plan and timeline

Once a vision is set for the BRT system and an initial team is formed, a detailed work plan and timeline on how to achieve the vision will be necessary. By walking through each step of the process, municipal officials and the public will have a better idea of the scope of the project and the necessary activities to make it happen.

Invariably, cities underestimate the amount of time needed to complete a full BRT plan. A BRT plan can be reasonably completed in 12 to 18 months, but can take longer in cases of very large and complicated cities. The actual duration of the planning process will depend greatly upon the complexity of the project and upon other local conditions.

Completing the work plan and timeline will help ensure that important elements such as public communication and education are not in- advertently left out. Sharing the work plan and timeline with politicians, press and the public will also help ensure that all parties have realistic expectations of progress with the project.

No matter how well one plans, though, unexpected events will also act to necessitate modifications. Thus, the work plan and timeline should be revisited and revised from time to time during the planning process. Figure 34 provides an example of a basic BRT timeline.

**Figure 34 BRT Planning Process: Workplan and Timeline**

| Activity | Pre-project | Months 1-3 | Months 4-6 | Months 7-9 | Months 10-12 | Months 13-15 | Months 16-18 |
|---|---|---|---|---|---|---|---|
| **1. Project preparation** | | | | | | | |
| 1.1 Project creation and commitment | | | | | | | |
| 1.2 Legal basis | | | | | | | |
| 1.3 Project team and management structure | | | | | | | |
| 1.4 Project scope and timing | | | | | | | |
| 1.5 Planning budget and financing | | | | | | | |
| **2. Analysis** | | | | | | | |
| 2.1 Background and situational analysis | | | | | | | |
| 2.2 Stakeholder analysis | | | | | | | |
| 2.3 Transport data collection | | | | | | | |
| 2.4 Transportation demand modelling | | | | | | | |

| Activity | Pre-project | Months 1-3 | Months 4-6 | Months 7-9 | Months 10-12 | Months 13-15 | Months 16-18 |
|---|---|---|---|---|---|---|---|
| **3. Communications** | | | | | | | |
| 3.1 Public participation processes | | | | | | | |
| 3.2 Communications with existing operators | | | | | | | |
| 3.3 Marketing plan<br><br>3.4 Public education plan | | | | | | | |
| **4. Operations** | | | | | | | |
| 4.1 Corridor identification | | | | | | | |
| 4.2 Feeder services | | | | | | | |
| 4.3 Service options | | | | | | | |
| 4.4 Passenger capacity | | | | | | | |
| 4.5 Operational control and contingency planning | | | | | | | |
| 4.6 Customer service plan | | | | | | | |

| Activity | Pre-project | Months 1-3 | Months 4-6 | Months 7-9 | Months 10-12 | Months 13-15 | Months 16-18 |
|---|---|---|---|---|---|---|---|
| **5. Business and regulatory structure** | | | | | | | |
| 5.1 Business structure | | | | | | | |
| 5.2 Institutional structure | | | | | | | |
| 5.3 Incentives for competition | | | | | | | |
| 5.4 Operational cost analysis | | | | | | | |
| 5.5 Tariff options | | | | | | | |
| 5.6 Revenue distribution | | | | | | | |
| **6. Infrastructure** | | | | | | | |
| 6.1 Conceptual study on busways, stations, terminals, and depots | | | | | | | |
| 6.2 Control centre and traffic control signal conceptual design | | | | | | | |
| 6.3 Public utilities, landscaping, commercial space | | | | | | | |
| 6.4 Infrastructure cost analysis | | | | | | | |
| 6.5 Detailed engineering design | | | | | | | |

| Activity | Pre-project | Months 1-3 | Months 4-6 | Months 7-9 | Months 10-12 | Months 13-15 | Months 16-18 |
|---|---|---|---|---|---|---|---|
| **7. Technology** | | | | | | | |
| 7.1 Vehicle technology | | | | | | | |
| 7.2 Fare collection system | | | | | | | |
| 7.3 Intelligent transportation systems | | | | | | | |
| 7.4 Technology procurement process | | | | | | | |
| **8. Modal Integration** | | | | | | | |
| 8.1 Modal integration plan (bicycles, pedestrians, transit, taxis, etc.) | | | | | | | |
| 8.2 Auto-restriction measures | | | | | | | |
| 8.3 Integration with land-use planning | | | | | | | |

| Activity | Pre-project | Months 1-3 | Months 4-6 | Months 7-9 | Months 10-12 | Months 13-15 | Months 16-18 |
|---|---|---|---|---|---|---|---|
| **9. Impacts** | | | | | | | |
| 9.1 Traffic impacts | | | | | | | |
| 9.2 Economic impacts | | | | | | | |
| 9.3 Environmental impacts | | | | | | | |
| 9.4 Social impacts | | | | | | | |
| 9.5 Urban impacts | | | | | | | |
| **10. Implementation plan** | | | | | | | |
| 10.1 Timeline and workplan | | | | | | | |
| 10.2 Financing plan | | | | | | | |
| 10.3 Staffing plan | | | | | | | |
| 10.4 Contracting plan | | | | | | | |
| 10.5 Construction plan | | | | | | | |
| 10.6 Maintenance plan | | | | | | | |
| 10.7 Monitoring and evaluation | | | | | | | |

### 3.1.4.2 Project phases

#### *a. 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. The phased approach is necessitated for several reasons:

- 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 city traffic flows

The initial vision of the overall system will likely evolve as circumstances change. However, the evolving nature of the urban landscape means that corridors and concepts may be altered, but in general, the overall concept will still be valid. The types of factors that may change over the development horizon of the project include:

- Demographic changes in population and population density
- New property developments that significantly alter travel frequency around major origins and destinations
- Cost factors for both infrastructure and operations.

Additionally, the lessons learned during the first phases of the system will undoubtedly affect future designs. The BRT development process should be one of constant improvement in order to best serve customer needs.

#### *b. A whole-system vision*

However, even if a system is to be built over a series of phases, it is still worthwhile to put forward a vision for the entire system. Such a vision may consist simply of a route map showing where all planned corridors are intended to be placed. Thus, even residents and stakeholders who will not immediately benefit from the initial phases of the system will see the long-term value for themselves.

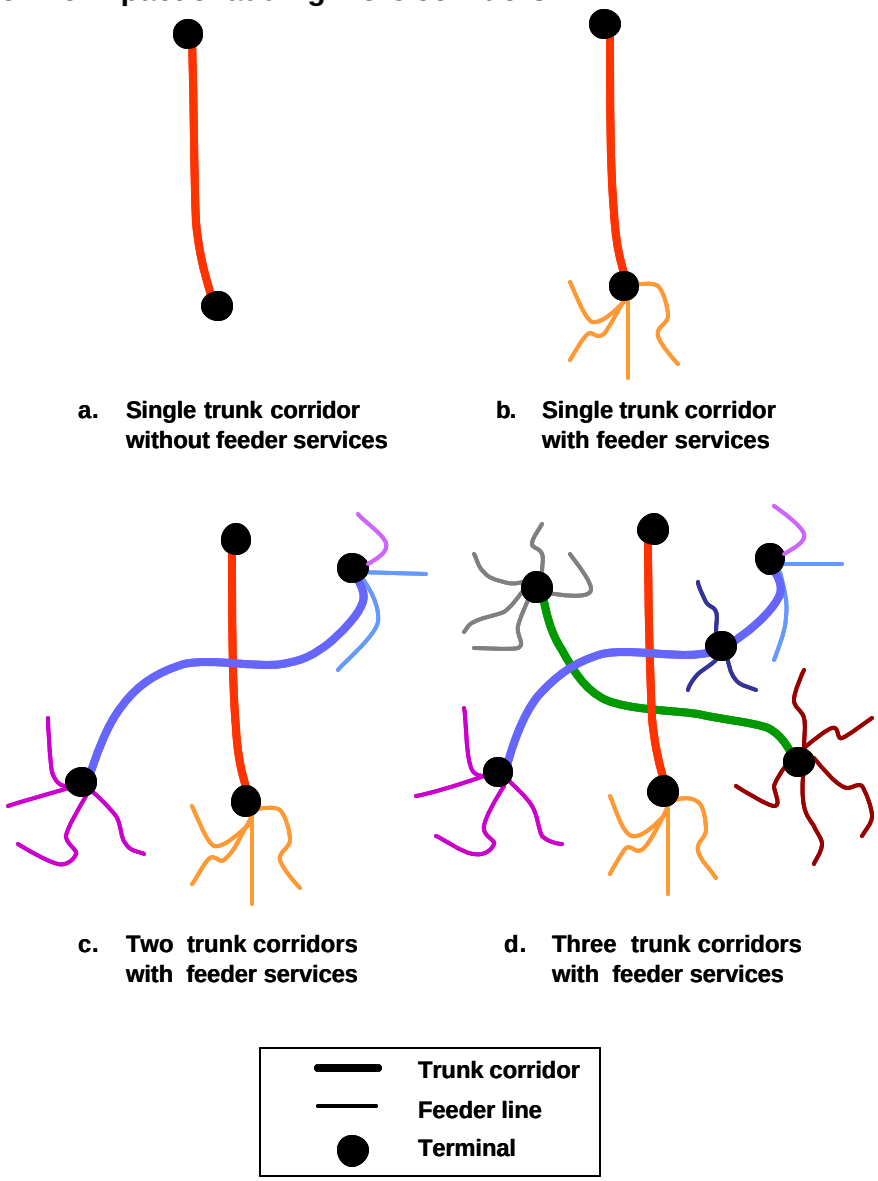
Further, the establishment of an overall vision for a network will be seen as a legacy from the existing political administration to future administrations. If the concept of an entire network is firmly set, then there is less likelihood that future administrations will forgo implementation of the full system. The loss of political will is always a risk when moving from one political administration 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 just a single corridor may not attract sufficient passenger

numbers to become financially sustainable. If the financial model fails in the first phase, there may never be a second phase. A single corridor strategy depends on people working, shopping, and living on the same corridor. This highly limited set of circumstances typically means that a single corridor simply cannot achieve sufficient customer flows. The limited usefulness of a one-corridor system will also dampen public support for the future system.

A second corridor in the initial plan does not simply translate into a doubling of the possible destinations. Rather the math of public transport corridors tends to behave in an exponential manner. The math of transport corridors means that one plus one does not equal two but is instead equal to four. This result is due to the added permutations of trips possible with each leg of the corridor. Figure 35 illustrates the progression of increasingly greater destination possibilities that are achieved by adding each new corridor.

**Figure 35 The impact of adding more corridors**



Clearly, scenarios (a) and (b) in Figure 35 provide the customer with relatively few destination options. In these instances, many customers will continue to use their existing transport options, even if they spend some of their travel time on the new transit system's single corridor. However, scenarios (c) and (d) begin to provide a service that will compete quite well with other modal options. In these scenarios, many customers will be able to fulfil all their travel needs within the new BRT system. If only scenarios (a) or (b) are followed in the project's first phase, then there will be a high degree of risk regarding the system's future.

*c. Evolution versus revolution*

The issue here is whether to approach BRT by a strategy of "revolution" or "evolution". A revolutionary approach implies that the city commits to a bold plan for an entirely new city-wide transport system. An evolutionary approach implies that the city begins developing its new system slowly, by implementing relatively small projects one by one. The revolutionary approach depends upon a highly motivated and charismatic political leader who can push through a wider vision. The evolutionary approach is more characteristic of municipal leaders with only a moderate amount of political interest towards public transport.

Bogotá and Curitiba were successful with highly charismatic leaders who developed a revolutionary vision. The initial corridors of these systems were built in just a few years, and these corridors were of sufficient size to achieve financial sustainability even at the outset. Both Bogotá and Curitiba have continued with an evolutionary expansion of additional corridors. Thus, even within a relatively revolutionary approach, there will likely be a continued evolutionary expansion of the system. The key to the success of Bogotá and Curitiba, though, was the expansive vision and commitment put forward by its political leaders.

By contrast, Jakarta (Indonesia) initiated its BRT project with a limited single corridor of just 12.9 kilometres. The limited nature of the Jakarta system was further exacerbated by the lack of integrated feeder services. Unsurprisingly, ridership on the initial corridor has been under expectations. While expansion is still expected to occur with a second route, the city is also moving ahead with a monorail project in other corridors. The limited success of the initial BRT corridor has perhaps lessened the future viability of BRT as a city-wide transit solution. Thus, a relatively weak initial vision coupled with weak political will becomes a self-fulfilling prophesy in which self-imposed limitations create a ceiling as to the ultimate size and quality of the system.

Based on the observed examples of BRT to date, the scope and force of the initial vision will likely set the tone for the ultimate quality of the product.

### 3.1.5 Planning budget and financing

#### 3.1.5.1 Budgeting fundamentals

The realistic scope and depth of the BRT planning process is largely determined by the available funding. However, the first step should be to determine the required

amount based upon the projected activities. An estimated budget for the plan can be developed from the activities outlined in the work plan. The budget will include staff salaries, consultant fees, travel and study tours, resource materials, telecommunications, and administrative support. Some of these costs may be covered by existing budgets and overheads while other line items will need newly dedicated funding. Since the planning horizon is likely to encompass 12 to 24 months of time, any cost escalations such as projected salary increases or inflationary trends should also be considered.

Budgets should be made as realistic as possible. Overly-optimistic projections will ultimately be compared unfavourably to actual results, which will be used by project opponents to undermine the project's image. Unfortunately, projecting budgets is never an exact science. Unexpected and unforeseen events will undoubtedly arise which will create the need for budgetary adjustments. Thus, it is always wise to include a contingency amount that will help cover such unexpected costs. The contingency is often represented as a percentage of the projected total (e.g., 10% of the projected budget).

BRT planning costs have historically varied considerably, depending upon the scope and complexity of the project, as well as the degree to which in-house expertise is utilised in comparison to consultants. To plan the extensive TransMilenio system of Bogotá, a total of nearly US$ 3 million was spent in the planning process. By comparison, using principally in-house professionals, the municipality of Quito spent only approximately US$ 500,000 to plan its smaller system. In general, though, planning costs will likely range from US$ 400,000 to US$ 5 million. It is hoped that this BRT planning guide will help cities plan a BRT system at a lower cost and within a shorter time frame.

#### 3.1.5.2 Local funding sources

In comparison to other transport projects, such as road networks and rail systems, the planning costs of BRT are typically much less. For this reason, the costs are often financed within existing municipal or provincial revenues without the need for alternative financing sources such as loans or bonds. This situation can even be true of low-income, developing cities. Local, provincial, and national resources should all be quite sufficient to readily complete the BRT planning process.

In some cases, the local private sector may actually take the lead in financing and conducting the BRT planning process. Private sector bus associations sometimes find it in their own interest to help encourage BRT development. Private sector interests have help to lead BRT efforts in such cities as San Salvador (El Salvador) and Dhaka (Bangladesh).

#### 3.1.5.3 International funding sources

However, at the same time, several international sources stand ready to assist cities interested in BRT. The international resources often also bring the additional advantage of allowing greater access to consultants with international BRT experience. The disadvantage of many international funding sources is the amount

of effort required in the application process and the sometimes lengthy delay in receiving project acceptance.

*a. Multi-lateral organisations*

Multi-lateral organisations such as the World Bank, regional development banks, and agencies of the United Nations may be able to provide grants to support planning activities and initial demonstrations. Unlike loans, grant-type funding mechanisms do not require repayment. One such grant mechanism is the Global Environment Facility (GEF). The GEF was created in 1991 to assist governments and international organisations in their goals of overcoming global environmental threats. Thus, GEF funds are utilised to address such issues as the degradation of international waters, biodiversity, global climate change, ozone depletion, and persistent organic pollutants (POPS). Through the global climate change programme and the GEF's Operational Programme number 11, transport is an eligible sector for funding. BRT projects qualify under article 11.10(a) of Operational Programme 11: "Modal shifts to more efficient and less polluting forms of public and freight transport through measures such as traffic management and avoidance and increased use of cleaner fuels."

To qualify for a GEF project, a municipality will need the support of its national GEF focal point, which is typically housed at either a national ministry of the environment or a national ministry of foreign relations. Additionally, the project will need one of the GEF's implementing agencies to champion and support the project through the application process. Eligible implementing agencies include the World Bank, the United Nations Development Programme (UNDP), the United Nations Environment Programme (UNEP), and regional development banks (e.g., African Development Bank, Asian Development Bank, Inter-American Development Bank). To date the GEF, with World Bank support, has approved three projects that include BRT related elements. These project sites are Santiago, Chile; Lima, Peru; and Mexico City, Mexico.

The size of a GEF grant depends on the type of application and the nature of the project. GEF funding mechanisms include:

1. Small Grants Programme (funds of less than US$ 50,000)
2. Small and Medium Sized Enterprise Programme
3. Project Preparation and Development Facility (PDF)
    - PDF Block A (up to US$ 25,000 for project preparation)
    - PDF Block B (up to US$ 350,000 for project preparation)
    - PDF Block C (up to US$ 1 million for project preparation)
4. Medium-Sized Projects (up to US$ 1 million for project)
5. Full-Sized Projects (large grants of sometimes over US$ 10 million)

The GEF transport projects in Chile, Peru and Mexico are full-sized projects. GEF resources are unlikely to directly finance infrastructure, but are useful in assisting with the planning process. Additionally, GEF funding can also be an effective means to attract complementary financing from other sources.

Other international organisations may also support BRT planning activities. For example, the United Nations Development Programme (UNDP) has played a role in developing BRT projects in Pereira (Colombia) and Cartagena (Colombia) through technical assistance activities.

*b. Bi-lateral agencies*

Additionally, bi-lateral agencies such the German Overseas Technical Cooperation Agency (GTZ), the Swedish International Development Agency (Sida), and the United States Agency for International Development (USAID) may be approached to assist on the provision of support and technical resources. GTZ has played a role supporting BRT development in such cities as Bangkok (Thailand), Buenos Aires (Argentina), Cartagena (Colombia), and Surabaya (Indonesia). Sida has assisted BRT awareness in Bangalore (India) and Dhaka (Bangladesh). USAID has been active with BRT support in Accra (Ghana), Dar es Salaam (Tanzania), Dakar (Senegal), Cape Town (South Africa), Delhi (India), Hyderabad (India), and Jakarta (Indonesia).

*c. Private foundations*

Private foundations such as the Hewlett Foundation, the Shell Foundation and the former W. Alton Jones Foundation have also been supporters of BRT activities. The Hewlett Foundation is supporting BRT support activities in Beijing (China), Rio de Janeiro (Brazil), São Paulo (Brazil), and Mexico City (Mexico). The Shell Foundation, through the World Resources Institute, is assisting BRT development in Mexico City and Shanghai (China).

## 3.2 Planning Stage II: Analysis

The demand for transit services will be one of the principal determining factors in designing the system. Virtually all major decisions such as the choosing the busway corridors, the size of the vehicles, the size of stations and terminals, and the type of fare collection systems will emanate from the likely passenger demand. Transport modelling tools can be useful in projecting future system demand, and thus help in determining the system's capacity needs over a longer time horizon.

A starting point for this type of analysis is to fully understand the current matrix of journeys taken in the city as well as the current supply of transport services. This section outlines both a traditional transport modelling approach as well as noting the minimum analytical requirements for determining the projected demand.

The topics to be presented in Planning Stage II, "Analysis", are:

**3.2.1 Background and situational description**

**3.2.2 Stakeholder analysis**

**3.2.3 Transport data collection**

**3.2.4 Transportation demand modelling**

### 3.2.1 Background and situational description

A city's public transit system is intimately woven into the existing demographic, economic, environmental, social, and political conditions. Understanding these conditions enables the BRT planner to better align the prospective public transit system with the local realities. Some of these data items will later be inputted into transportation models to project future needs. Other portions of this background information will help the planner view the proposed public transit system in its wider socio-economic context.

For instance, by understanding the major employment areas of the city, one can better project the location and times of the day when transit will be required. Further, the relative economic purchasing power of the city's inhabitants will later assist in developing a realistic tariff schedule. Demographic figures on population, population densities, and future population projections will be key inputs into the transportation modelling process. Trends in environmental conditions will help determine the sorts of air quality and noise objectives that the BRT system can help to achieve. Quantifying the social equity levels throughout the city may assist in recognising the districts that will most benefit from improved public transit services. Finally, mapping out the various political actors and the dates of upcoming elections can help establish realistic project timeframes. It is often difficult to gain political support for BRT initiatives if elections are relatively soon. However, if a political administration feels that there is sufficient time to demonstrate a tangible outcome, then the prospects for political commitment tend to be greater.

The type of background information to be collected can thus include:

- Population, population density
- Overall economic activity (Gross Regional Product)
- Economic activity by social groupings
- Employment levels (unemployment and underemployment)
- Environmental conditions
- Social equity levels
- Schedule of local, regional, and national elections.

### 3.2.2 Stakeholder analysis

The pre-planning period is also the time to begin identifying key groups and organisations that should be included in the planning and development of improved transit services. Specific agencies, departments and political officials will all have varying opinions and interests with regard to developing a new transit system. Non-governmental and community-based organizations will be important resources to draw upon during later public participation processes. The types of organisations to be sought during the stakeholder identification process include:

- Existing transport operators, and operators' and drivers' associations (formal and informal)
- Customers (including current transit users, car owners, non-motorised transport users, student travel, low-income communities, physically disabled, elderly)
- Municipal transit departments
- Municipal environmental departments
- Municipal urban development departments
- Traffic and transit police
- Relevant national agencies
- Non-governmental organisations
- Community-based organisations.

Agencies or civil society groups that are excluded from the planning and development process may react in ways that will be detrimental to eventual implementation. Some groups may interpret their exclusion as evidence that the new transit project is counter to their interests. Excluded agencies may also feel threatened that their domain of responsibility and influence is being eroded. In such instances, the excluded organisations may oppose and even obstruct the project development process.

The inclusion and active participation of all interested parties is a simple way of avoiding much of the potential opposition to project development. However, such participation should not be conducted in a token manner. If agencies or groups feel that their inputs are not being considered seriously, then again the same counter-productive reactions may occur. More importantly, stakeholder groups can significantly help to improve the quality of the project. Each stakeholder has a unique view on public transit issues and holds the potential to contribute to an improved final product. This pre-planning activity is aimed at initially just identifying

all the relevant stakeholders. Section 3.3.1 of this guidebook includes suggestions on how to conduct an effective participatory process.

### 3.2.3 Transportation data collection

A solid understanding of existing transport choices will help serve to define the present and future requirements of a BRT system. The data collected on current transport supply and demand will serve as a major input into determining the design characteristics of the system. This data may also be used within a transport software model to project various different scenarios.

The accuracy and precision of the data collected depends in part on the funding that is available for the analysis. Traffic counts and surveys encompassing large sample sizes will help provide an accurate basis but may prove to be too costly for many developing cities. Fortunately, in many cases, mode share and travel data have already been collected to a certain degree. For example, the Japanese International Co-operation Agency (JICA) has assisted many cities in defining baseline travel demand information. In some cases, this existing data can be updated to reflect current conditions at a lower cost than starting a data collection process from its very beginning.

This section discusses the following data collection topics:

- Minimum data collection requirements
- Current transport demand (traffic counts and surveys)
- Current transport supply
- Survey of attitudes and elasticity of demand
- Land-use data

#### 3.2.3.1 Minimum data collection requirements

Not all developing cities will be able to afford a full data collection process that results in identifying origin-destination pairings to any degree of great detail. However, these cities will still need to quantify existing passenger volumes on major corridors. Thus, as a minimum, cities will wish to conduct basic traffic counts on principal transit corridors. The most important focus of the traffic count will be the existing public transport passenger numbers. However, since a percentage of passengers from other modal options (e.g., private autos, motorcycles, etc.) will likely switch to the new BRT system, basic counts of these vehicles and passengers should also be undertaken.

The number of persons boarding and alighting at major points along the corridors should also be documented. The numbers will help in determining the size of stations and the resulting dwell times for transit vehicles at stations.

This basic data collection process should also include an inventory of all existing public transport vehicles (e.g., standard buses, mini-buses, vans, etc.). This inventory of transit supply can then be correlated with the corridor passenger counts. If cooperation with existing transit operators is possible, then interviews to

record current routings, travel times, and passenger numbers of each operator will be quite useful.

3.2.3.2 Detailed data collection on current transport demand

Establishing the nature of existing travel patterns is fundamental to projecting the requirements for a proposed mass transit system. However, demand studies can be the most costly component of the data collection process. Finding the right balance between the need for accuracy and the level of costs is a key consideration. Funds expended on demand studies translate directly into fewer funds for other aspects of the planning process. Common elements of a demand analysis include an origin-destination survey (O-D survey), behavioural determinants for travel, and activity data (e.g., opening times of shops). The most crucial element from the perspective of developing a mass transit system is the O-D survey. Thus, the following description focuses upon techniques for delivering an effective O-D survey. Figure 36 provides a graphical representation of the data collected through an O-D analysis.


Trip origins Trip destinations

*a. Survey techniques*

The origin-destination (O-D) survey can be built upon several different survey techniques. These techniques include:

- Household and work place surveys
- Intercept surveys (external cordon)
- Intercept surveys (internal cordons and screen lines)

- Traffic and person counts

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 trip generation. Likewise, work place surveys can also be an effective mechanism. Unfortunately, household and work place surveys are probably the most costly of the O-D techniques. The other techniques, such as intercept surveys and traffic counts, are typically done in conjunction with the household and work place surveys in order to confirm results.

The type of data collected in household and work place surveys generally falls into two categories (Ortúzar and Willumsen, 2002):

- *Personal and household characteristics and identification* (number of household members, sex, age, number of motorised vehicles, number of persons holding a driving license, educational levels, and occupations);
- *Trip data* (origin and destination of each trip, multi-stage trips, purpose of trip, mode utilised, time of travel including start and end times, and amount spent on travel)

The format and design of the survey can affect the ultimate accuracy of the data collected. Whether the survey is performed as self-completion or as an interview (or mixed) can determine the reliability of the information. Misinterpretation of questions can be a significant source of error. For this reason, the questions should be simple and direct. The number of open questions should be kept to a minimum. It is also vital to include all modes (including bicycle trips and walking trips) and all household members (even children) in the survey.

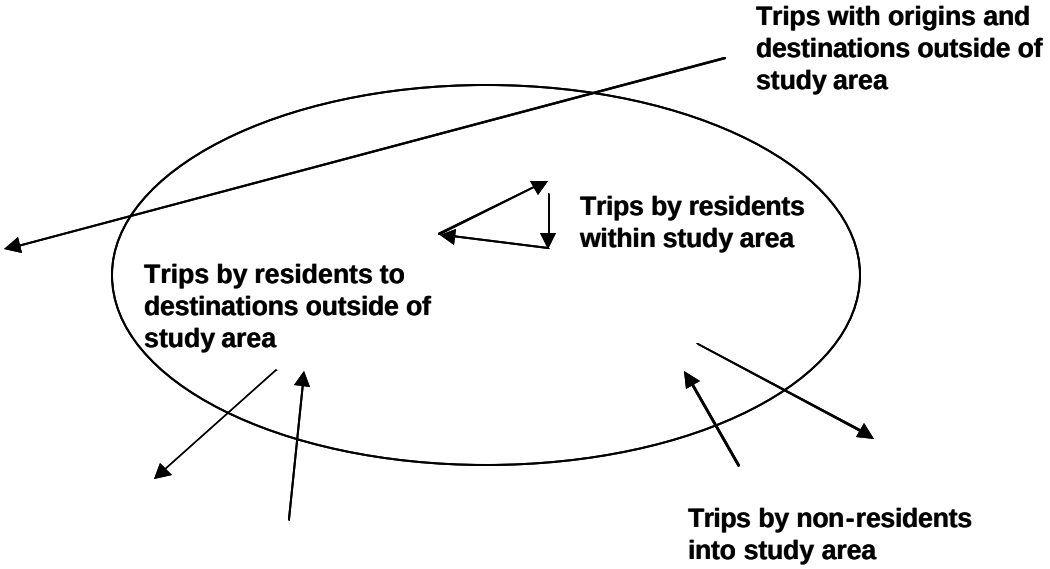
A more detailed type of household survey is known as a travel diary. In this type of survey, sampled subjects carry a diary with them for a set period of time (e.g., one week) and record all trips. The travel diary provides a level of detail that can be missed in a simple one-off interview session. However, since a travel diary survey requires at least two visits to the household (before and after), it will be more costly than simple interview sessions.

*b. Study area*

Intercept surveys and traffic counts are physical counts conducted on selected points in the transport network. As noted earlier, these physical counts can be integrated with the survey data in order to provide a greater degree certainty in the overall results. The scope of the intercepts and traffic counts depend upon the design of the study area. Figure 37 is a standard graphical representation of a study area. As noted in the figure, screen lines and cordon points typically capture four types of trips:

- Trips with origins and destinations outside the study area
- Non-residents moving in, out and around the study area
- Residents moving within the study area
- Residents moving in and out of the study area.

**Figure 37 Representation of study area for analysis**




Source: *Adapted from Ortúzar and Willumsen, 2002*

*c. Zoning systems*

The data collected is typically assigned a particular location or "zone" within the city. The development of zones allows the aggregation of data from households with similar travel and socio-economic characteristics. This aggregation becomes important in making the data useable within standard transportation models.

The size of the zones and the number of zones is again a trade-off between accuracy and cost. Further, the size and number of zones depends in part on how the data is to be utilised. For large-scale strategic studies, fewer zones are required. For detailed traffic management studies, though, a finer definition of the zones will likely be necessary. Table 14 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 14 Typical zone numbers for studies**

| Location | Population | Number of zones | Comments |
|---|---|---|---|
| London (1972) | 7.2 million | 2252<br>~1000<br>~230<br>52 | Fine level subzones<br>Normal zones at GLTS<br>GLTS districts<br>Traffic boroughs |
| Montreal Island (1980) | 2.0 million | 1260 | Fine zones |
| Ottawa (1978)<br>Santiago (1986) | 0.5 million<br>4.5 million | ~120<br>~260 | Normal zones<br>Zones, strategic study |
| Washington (1973) | 2.5 million | 1075<br>134 | Normal zones<br>District level |
| Bogotá (2000) | 6.1 million | 637 | Normal zones |

| | | | |
|---|---|---|---|
| Marseille (2001) | 1.5 million | 562 | Normal zones |

Source: Ortúzar and Willumsen, 2002

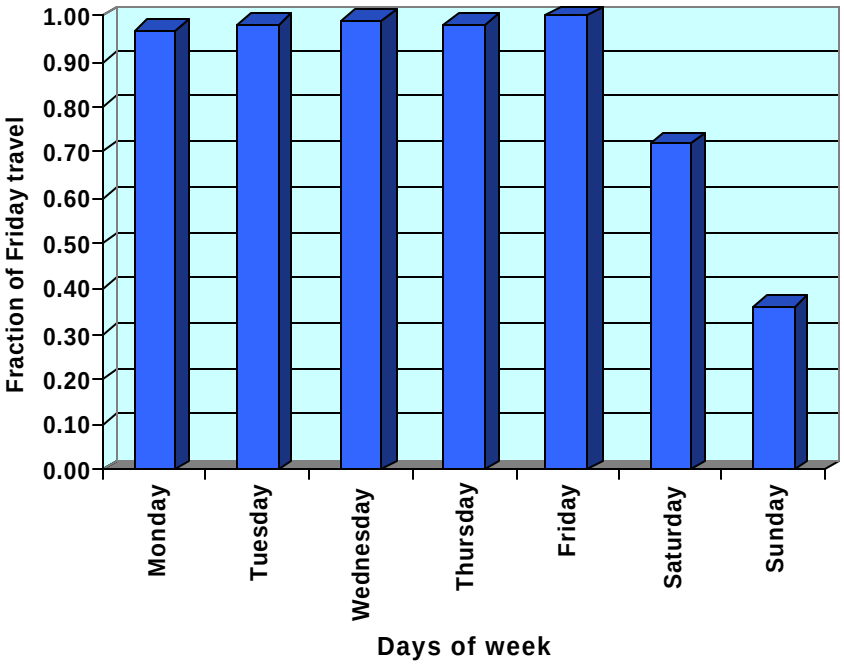
It is recommended that zone boundaries are consistent with census and other administrative zones that already exist in the city. This compatibility will facilitate the overlaying of different data types. Once the data is entered into a model, the zone is actually represented by a "zone centroid", which is a singular point that is used to signify the average characteristics of the particular zone.

*d. Study period*

The travel surveys should be conducted over the widest possible time period in order to fully capture daily, weekly, and even seasonal variations. The difference in travel demands during the peak and non-peak periods will be important in terms of determining the optimum number vehicles required for the mass transit system as well as the sizing of stations. Again, the desire to capture a full set of data points must be offset by the cost of the study.

Typically, demand profiles during weekdays are quite different than during weekends. Further, even days during the work week can vary. For example, schools may release students at different times during the week. Likewise, employers may permit flexibility on departure times for employees during a particular day such as Fridays. These sorts of nuances in demand flows are highly dependent on local customs and circumstances. Figure 38 gives a day-by-day demand profile from Bogotá.

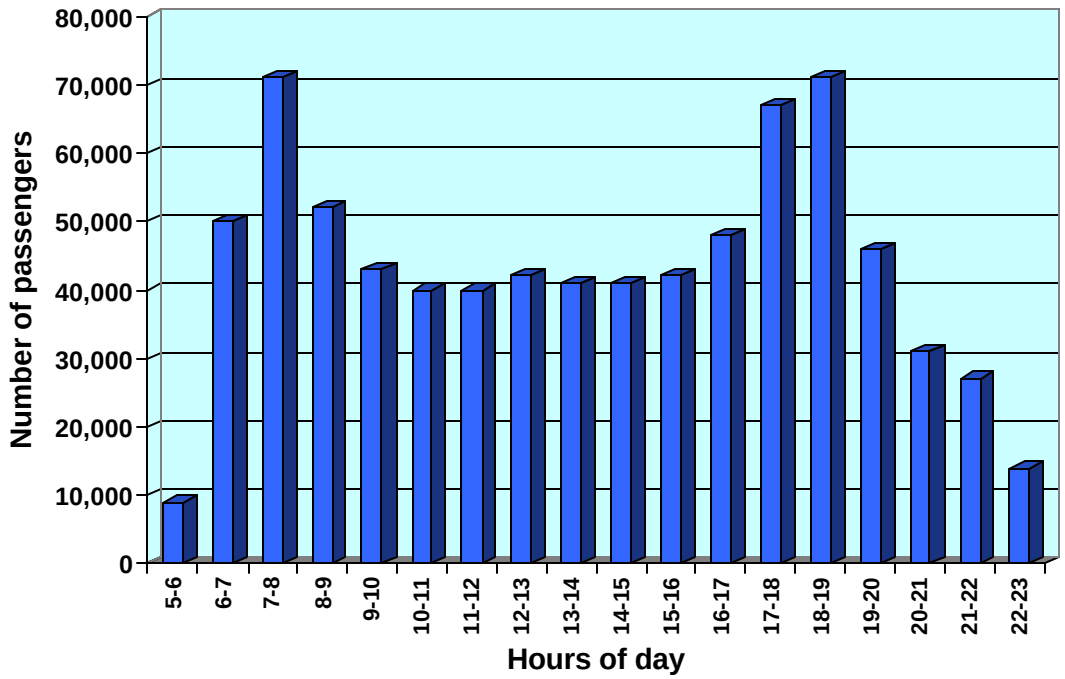
**Figure 38 Variation of demand during week**




Source: TransMilenio SA; Bogotá, Colombia

One of the most significant factors in designing a transit service is the relative demand profiles for peak and non-peak hours. Peak travel times typically occur during 1 to 2 hour periods in the morning and late afternoon when people are commuting between their homes and their employment. Accommodating peak capacities while simultaneously maintaining cost-effective operations during non-peak times can be a planning challenge. The system will need to be sufficiently sized in terms of vehicle and lane capacities to handle the peak periods but sufficiently nimble to still operate within cost restraints during non-peak periods. Figure 39 gives an hourly demand profile from Bogotá.

**Figure 39 Hourly demand profile**




Source: TransMilenio SA; Bogotá, Colombia

This type of demand data will later serve as the basis for determining the operational characteristics of transit service along each corridor. Section 3.4 (Operations) of this document relates the modelling results to the operational design of the system.

*e. Types of errors*

Due to the nature of the data collection and modelling process, errors will always be present to a certain degree. The very fact that it is a sample being analysed rather than an entire population means that the data is not 100 per cent representative. However, a well-designed data collection process can help minimise the errors involved. Further, awareness of the different types of errors can help project designers to maintain a healthy perspective on the process. There are at least two types of errors that are commonly experienced during data collection:

1. Measurement errors
   These 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. Further, there will also be a degree of bias in which respondents answer questions in a manner that represents a desired state rather than reality.

2. Sampling errors
   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) (Ortúzar and Willumsen, 2002).

To offset these errors, project designers must balance the cost of the activity against the desired accuracy and precision. However, by understanding the potential errors and the ultimate objectives of the survey work, a cost-effective data collection regime can be developed.

*f. Sample size*

As noted previously, the number of observations is constrained by financial and human resources. While the statistically desirable sample size may be that represented in table 15 (Bruton, 1985), the reality of what is possible is often quite different. The number of trips undertaken in each zone is also a determinant that can dictate sample sizes. However, quite often a realistic compromise can be found in which the goals of the study are achieved at reasonable sampling levels.

**Table 15 Sample sizes recommended in traditional surveys**

| | Sample size (dwelling units) | |
|---|---|---|
| **Population of area** | **Recommended** | **Minimum** |
| Under 50,000 | 1 in 5 | 1 in 10 |
| 50,000 – 150,000 | 1 in 8 | 1 in 20 |
| 150,000 – 300,000 | 1 in 10 | 1 in 35 |
| 300,000 – 500,000 | 1 in 15 | 1 in 50 |
| 500,000 – 1,000,000 | 1 in 20 | 1 in 70 |
| Over 1,000,000 | 1 in 25 | 1 in 100 |

Source: Bruton (1985) in Ortúzar and Willumsen (2002)

*g. Survey correction and validation*

As data is collected and compiled, in some circumstances, it may be necessary to undertake corrective actions. These corrections become necessary if key sub-groupings, such as by household size or socio-economic, are not represented in the appropriate proportion. Corrections may also become necessary if certain questions have a high percentage of non-responses. In such cases, an expansion of the original sample size can help to correct the deficiencies in the collected data.

A validation process is typically undertaken at the conclusion of the data collection process in order to provide a degree of quality control. Validation will often include checks on the completeness and internal consistency of the data. These checks can be accomplished electronically by coding and digitising the data. Validation may also imply quality control checks with a sample of interviewed households. These checks are principally to confirm that the interview did indeed take place and that all questions were presented.

3.2.3.3 Current transport supply

The demand for transport services is only part of a city's transit equation. An inventory of the existing supply of services is also an essential part of characterising the current situation. The data collected on the supply side include:

- Size and capacity of road network
- Inventory of parking facilities
- Identification of public transport networks
- Quality and coverage of pedestrian infrastructure
- Quality and length of bicycle infrastructure
- Number of public transport companies (including private operators)
- Number and age of public transport vehicles by type
- Costs of travel (both individual and mass transit modes)
- Schedules and frequency of public transport services

Typically, the road network will ultimately be represented by a series of "links" and "nodes" within the transportation model. The links are homogenous stretches of road between junctions while the nodes represent the junctions. All roads do not need to be represented in the analysis. Major arterials and key connector roads may be sufficient for purposes of a mass transit study. The road network will become important when evaluating the impact of the new mass transit system upon private vehicle traffic. However, some authors suggest that the network should also include one additional level of road hierarchy (e.g., secondary roads as well) in order to account for aggregate errors.

The current public transport network likewise consists of links, representing corridors of service, as well as nodes, representing stops where passengers can enter the system. One would also denote nodes where connections are possible between corridor services. Data on any additional fare costs associated with such transfers would also be noted. Additionally, a distinction would be made between different public transit services (e.g. between rail and bus services).

Recording the number of companies with collective transit operations, including both privately- and publicly-owned entities, will provide insight into the viability of achieving competitive balances within the industry. Typically, public transit in developing cities has gravitated towards one of two structural extremes: 1.) A single, state-owned monopoly; or 2.) Hundreds (or more) of individually owned vehicles. Neither of these two predominate designs necessarily leads to an optimal result in terms of customer service or economic efficiency.

The number and average age of the public transit vehicles also provides vital information that will have ramifications on the economic and environmental impacts of a transformation in services. The existing fleets in many developing cities have average ages over 15 years. Any modernisation programme must consider how such vehicles are to be retired.

Finally, basic information on transit tariffs and the costs of other modal options (private automobiles, motorcycles, taxis, etc.), service frequency, and average velocities all help determine the underlying competitive nature of existing travel options.

#### 3.2.3.4 Historical trends

Basic historical data on such information as mode shares, travel times, and travel costs provide key perspectives on trends that will affect the degree of difficulty in implementing a mass transit solution. As noted previously in table 3, public transit ridership is falling relatively rapidly in most parts of the world. At the same time, private vehicle ownership is experiencing unprecedented increases in much of the developing world. In such a scenario of falling public transit ridership and rapidly increasing private vehicle ownership, the challenge of successfully reversing the trend cannot be underestimated. Further, once the levels of private vehicle ownership exceed a certain point, the political will to address public transit can be lost.

The historical trends will also be fundamental to establishing a baseline by which the effectiveness of the mass transit system can later be measured against. The trends will help determine the impacts of the system in terms of economic, environmental, and social indicators. For instance, if public transit ridership is falling at a known rate prior to the implementation of the new system, a reversal of this trend can be a strong endorsement of the project's success.

Unfortunately, time series data is often not available, as historical records may simply not exist. However, for major indicators such as mode share and/or vehicle ownership, some data points are likely to be evident. Alternatively, historical trends can also be gained from interviews that probe for past practices.

#### 3.2.3.5 Surveys of attitudes and elasticity of demand

Information on the existing travel practices of citizens can largely be gained through the physical counts and the surveys noted previously. Questionnaires and surveys that ask persons about their actual travel patterns are generally known as "revealed preference" surveys. However, there may be data information that seeks to ask persons questions about hypothetical situations. For instance, one may wish to know if a person would switch to public transit if the cost, quality, and frequency of service reached a certain point. Such hypothetical surveys are known as "stated preference" surveys.

Of course, posing hypothetical possibilities to interviewed parties can present several methodological challenges. As noted previously, there are errors associated with just asking about actual practices. Persons can misinterpret questions or may provide answers that do not match actual practices. Such errors can quickly multiply when presenting scenarios that do not represent reality.

Nevertheless, understanding how commuters value certain qualities such as cost, comfort, convenience, and security is quite useful for designing a new public transit service. The elasticity of demand for a transport mode as measured by its perceived and real costs is a vital point in determining the viability of a proposed mass transit option. Further, the elasticity of demand will ultimately help in determining the most effective tariff levels for the service.

The list of hypothetical scenarios presented will often include an existing option in order to provide a comparative base. Responses to the hypothetical scenarios can involve ranking different options or grading the options. In order to avoid the various pitfalls inherent to stated preference surveys, some best practice standards are recommended for consideration:

- Provide respondents with a realistic set of specific and tangible options
- Limit the number of different variables to no more than three or four (cost, service frequency, walking time, number vehicle changes, etc.) in order to avoid confusion
- Permit the person to reply "none of the above" in case none of the presented options meet a minimum level of quality for the respondent

3.2.3.6 Land-use data

Compiling an inventory of land-use information will be helpful as input data to trip generation models. The land-use data will include noting major areas of residential, commercial, and industrial activities. The land-use inventory will denote if certain areas have designated uses due to mandatory zoning laws. Land-use data may also include locations of parking provision (e.g., areas of on-street parking, car parks, etc.).

### 3.2.4 Transportation demand modelling

Modelling is a simplified representation of real world systems that allows projections of future conditions. Transportation modelling is quite commonly utilised to determine expected demand and supply conditions that will help shape decisions on future infrastructure needs and supporting policy measures. Modelling helps project future transport growth as well as allows 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 gage the impacts 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.

While complex mathematical relationships underpin transportation models, the basic premise behind the modelling analysis can be presented in an understandable form to a wide audience. Figure 40 outlines the classic four-stage transport model. This model still serves as the basis for the various software products that today enable effective transport modelling.

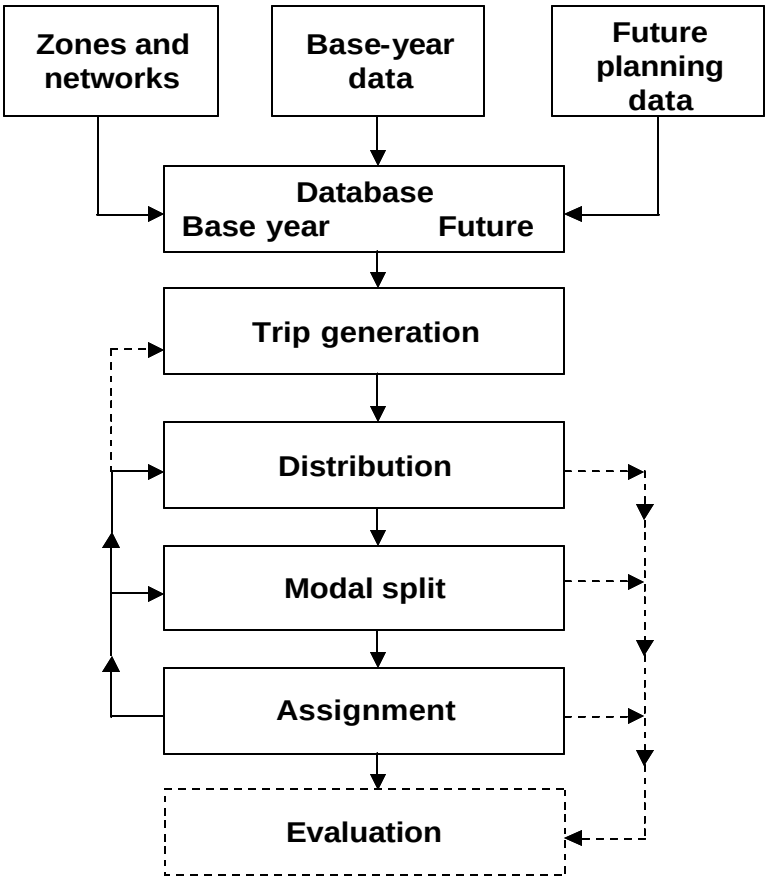
In some circumstances, full formal modelling may not be required at all. Instead, simplified scenario building utilising spreadsheet analysis can provide the basic information required to proceed with the BRT planning process. Of course, a full modelling process will provide a higher degree of certainty for decision-makers and planners. The decision on the degree of modelling undertaken is in part a question of the resources available (financial and temporal) and in part a question of the complexity of the city's transport sector. A highly fragmented and complex urban

landscape may require more analytic effort than a city with relatively clear and consistent transport patterns.

This section will discuss the following topics related to BRT modelling:

- Minimum requirements for BRT modelling
- Inputting of existing transportation data and future projections
- Scenario building (trip generation, trip distribution, mode share, assignment)
- Modelling software

**Figure 40 Representation of standard transport model**




Source: Ortuzar and Willumsen, 2002

3.2.4.1 Minimum requirements of transportation modelling

The modelling process outlined in this section may prove to be unrealistically lengthy and costly for some developing cities. However, even cities with limited resources can gather basic informational inputs and conduct a useful analysis. The modelling activity is the basis for much of the subsequent design decisions in the BRT system. Thus, an investment in time and financial resources, even at relatively low levels, can markedly improve the quality of the BRT project.

As noted above, collecting basic data on the current public transport demand and supply is relatively achievable at a low cost. Even if full household surveys are not feasible, basic traffic counts and transit operator interviews can provide a solid base of information. Plotting approximations of transit demand along the major corridors and determining the major points of trip origins and destinations is likewise an activity that can be estimated to some degree of certainty.

To project future transport trends, assumptions relating transport to expected economic growth can provide basic expectations of the percentage of annual growth. The other significant set of assumptions will relate to the amount of mode shifting to take place. If current informal operators are allowed to continue in conjunction with the BRT system, what percentage of the ridership will remain with the existing operators? If the new BRT system implies an increase in fare levels, what percentage of public transport users will switch to lower-cost options such as walking or cycling? What percentage of private vehicle users (two-wheel and four-wheel private vehicles) will switch to the BRT system? How will each of the shifts change over the course of the life of the BRT project?

In Bogotá, an estimated 10 percent of private vehicle users switched to the BRT system during the first phase of the project (Steer Davies Gleave, 2003). Most public transport users moved to BRT since many directly competing routes by existing operators were eliminated. However, the slightly lower price of existing operators has meant that a number of customers have continued using these services in cases where they still operate. Further, the simultaneous development of high-quality cycle ways in Bogotá has meant that cycling's mode share has increased from 0.4 percent of all trips to over 4 percent.

This minimal type of analysis can be achieved within a reasonable timeframe with modest resources. While such analysis does not provide the same degree of certainty as a full modelling process, it does provide a minimum degree of informed decision making. Thus, it is quite worthwhile to make this effort. Proceeding directly to system design without a solid basis of transit demand will be far more costly in the long term.

#### 3.2.4.2 Detailed modelling for BRT

##### *a. Trip generation*

The data collected in the previous section will serve as the key inputs into the modelling process. The first stage of the process consists of utilising demand models to define trip generation characteristics. Specifically, the model attempts to match the total number of origins for a given area to specific destinations. Quite often trips are categorised by classifications such as trip purpose, time of day, and person type. Trip purpose may include the following:

- Work
- Education
- Shopping
- Social and recreational
- Personal business

- Accompanying others
- Other

Classification by time of day may differentiate between morning peak, evening peak, and off-peak periods. Classification by person type typically focuses upon personal characteristics such as income level, car ownership levels, household size, and household structure. These personal characteristics along with other factors such as residential density play a role in determining the number of trips produced per household. The selected transport model will utilise these factors to calculate an estimated number of trips.

*b. Trip distribution*

The next stage of the modelling process involves distributing the generated trips amongst different destinations. Typically, this distribution occurs in the form of a matrix formed by rows of origins and columns of destinations (Table 16). The values in each of cells of table 16 represent the number of person-trips undertaken between the particular origin-destination pair.

**Table 16 A general form for a two-dimensional trip matrix**

| | **Destinations** | | | | | |
|---|---|---|---|---|---|---|
| **Origins** | 1 | 2 | 3 | …j | …z | $?_j T_{ij}$ |
| 1 | $T_{11}$ | $T_{12}$ | $T_{13}$ | …$T_{1j}$ | …$T_{1z}$ | $O_1$ |
| 2 | $T_{21}$ | $T_{22}$ | $T_{23}$ | $T_{2j}$ | $T_{2z}$ | $O_2$ |
| 3 | $T_{ij}$ | $T_{ij}$ | $T_{ij}$ | $T_{ij}$ | $T_{ij}$ | $O_3$ |
| I | $T_{i1}$ | $T_{i2}$ | $T_{i3}$ | $T_{ij}$ | $T_{iz}$ | $O_i$ |
| | | | | | | |
| Z | $T_{z1}$ | $T_{z2}$ | $T_{z3}$ | $T_{zj}$ | $T_{zz}$ | $O_z$ |
| $?_i T_{ij}$ | $D_1$ | $D_2$ | $D_3$ | …$D_j$ | …$D_z$ | $?_{ij} T_{ij} = T$ |

Source: Ortúzar and Willumsen, 2002

Since models are used to project the impacts of future scenarios, one also must consider how to represent expected changes in the number of trips. For example, models can account for growth in trips by relating the number of trips to expected changes in such factors as population, income, and accessibility. Many different types of trip distribution modelling techniques exist. One of the most common forms of trip distribution modelling is known as the “gravity model”. The right modelling approach depends on many factors, including desired level of complexity and the cost of the analysis.

Ultimately, the trip distribution model will need to be calibrated and validated for accuracy. For example, the model will need to be able to reasonably replicate the base year distributions in order to show that it is relevant to the area being studied.

*c. Modal split*

Perhaps the most important stage in the transport modelling process is the selection of mode choice for the different trips. Determining the number of trips to be made by public transport, non-motorised options, and private motorised options will have a

profound impact on future municipal investments. The factors that affect mode choice can be summarised into three groupings (Ortúzar and Willumsen, 2002):

1. Characteristics of the trip maker
   - Car availability and car ownership
   - Possession of driving license
   - Household structure (young couple, couple with children, retired, singles, 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, security

The modal split model will typically include these factors in assigning levels of usage between different modes.

*d. Assignment*

The previous stages in the modelling process focussed primarily on the demand side of transit services. The "assignment" stage is where the supply of transit services are matched with these demand conditions. Within a BRT system, the assignment stage also helps to identify usage levels amongst different routing and service options. For instance, it is quite useful in planning terms to know the number of passengers who will be utilising express routes versus local routes. Equilibrium conditions within assignment are achieved when each passenger has been assigned the most efficient routing based upon inputs factors such as monetary costs and time of travel.

*e. Evaluation*

The previous modelling stages have combined supply and demand factors to develop an overall simulation of a city's transit services. The final stage of the process is to evaluate the robustness of the particular solution being proposed by the model. Hopefully, the model will produce equilibrium conditions that lead to a single identifiable solution for the given input factors. In evaluating the model, several iterations are run in order to determine if the model results converge to an equilibrium point. If several iterations produce such a convergence, then the

proposed solution is considered to be sufficiently robust. The lack of a convergence implies that changes in the model structure may be necessary before proceeding.

#### 3.2.4.3 Modelling software

The development of transportation modelling software has greatly aided the process of transport supply and demand projections. Software models today can greatly ease the modelling process and increase accuracy and precision. However, with an 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 modelling task. Table 17 lists a few of the commonly used software packages that are on the market today.

**Table 17 Modelling software packages**

| Software name | Vendor |
|---|---|
| EMME / 2 | INRO Consultants Inc. |
| CUBE | Citilabs |
| QRS II | AJH Associates |
| TMODEL | TModel Corporation |
| TransCAD | Caliper Corporation |
| VISUM | ITC |
| SATURN | Atkins-ITS |
| TRIPS | Citilabs |

## 3.3 Planning Stage III: Communications

Effective transport planning is not conducted in isolation. In many instances, insights from the public, civic organisations, existing operators, private sector firms, and other governmental entities are more relevant than merely relying upon planning staff and consultants. Systems should be designed around the needs and wants of the customer. All subsequent details with regard to technology and structure can follow from this simple focus upon the customer. As noted previously, bus systems today are often losing mode share because customer concerns about convenience, safety, and comfort are not being addressed. In developing cities, existing transport operators represent another key group that can provide insights into the design process, especially with regard to costs and the final business structure of the system.

This planning stage discusses methods for engaging these key stakeholders in the design process as well as the key attributes in providing a customer-friendly service. The topics to be presented in Planning Stage III, "Communications", are:

**3.3.1 Public participation processes**

**3.3.2. Communications with existing transit operators**

**3.3.3. Marketing plan**

**3.3.4. Public education plan**

### 3.3.1 Public participation processes

Typically, a significant barrier to the actual implementation of a BRT system is neither technical nor financial in nature. More often, it is a lack of political will and a lack of communication and participation from key actors that ultimately undermines a project's progress. Communications are not only important in terms of obtaining public approval of the project but also provide the design insights of the people who will be using the system. Public inputs on likely corridors and feeder services can be invaluable. Incorporating public views on design and customer service features will also help ensure that the system will be more fully accepted and utilised by the public. Professional planners and engineers obviously do play a key role in system design, but often such "professionals" do not frequently use public transport systems, and thus do not possess some of the design insights of the general public. Some cities are now requiring public officials to use public transport each day so as to retain a better understanding of the daily realities.

Managing and fostering wide public involvement can be a challenge to agencies and departments unaccustomed to public processes. Non-governmental organisations sometimes are better equipped to manage such processes. Alternatively, consultants are also a possibility. Third party management of the public

participation process can also be an effective mechanism to achieve an independent and objective viewpoint on design issues. In some cases, community members may be more comfortable expressing opinions to local organisations rather than exclusively to public officials.

### 3.3.2 Communications with existing transport operators

*"And it should be realised that taking the initiative in introducing a new form...is very difficult and dangerous, and unlikely to succeed. The reason is that all those who profit from the old order will be opposed to the innovator, whereas all those who might benefit from the new order are, at best, tepid supporters of him."*

- Niccolo Machiavelli

As Machiavelli noted in the 16th Century, change is never easy and likely will be resisted regardless of the benefits of the intended change. BRT can improve profits and working conditions for existing operators and drivers. However, in many countries, the sector is unaccustomed to any official involvement and oversight, and operators often carry a distinct distrust of public agencies. In cities such as Belo Horizonte (Brazil) and Quito (Ecuador) proposed formalisation of the transport sector has sparked violence and civil unrest.

Ideally, the existing operators can come to view BRT as a positive business opportunity and not as a threat to their future. How this key sector comes to view the concept, though, largely depends on the circumstances and manner in which BRT is introduced to them. The municipality will wish to carefully plan an outreach strategy that will build a relationship of openness and trust with the existing operators. At least one planning staff member should be dedicated permanently to liaison activities with the existing operators. In some instances, this position may best be filled by a former transit operator or another person who holds personal credibility with the operators.

Visits to cities with existing BRT systems can be quite appropriate for private transit operators. Many of the fears that the operators may hold about BRT can be successfully dispelled with a first-hand view of a system. Further, private operators are probably most convinced by speaking directly with operators in other cities which have already experienced a conversion from conventional services to BRT. Discussions between different private operators are thus a very effective mechanism to create an atmosphere of support and trust.

### 3.3.3 Marketing plan

Bus Rapid Transit is not just another bus service. However, communicating this effectively to the public is not an easy task. The negative stigma of existing bus systems is a formidable barrier to overcome in selling the BRT concept. In most parts of the world, the words “public transport” have the same connotation as some other public goods such as “public restrooms”. Thus, public transport is something that is not clean and not particularly nice, and should only be endured when truly necessary.


The right marketing campaign can help put BRT in a new light for the customer. The civic pride exuded from the TransMilenio system in Bogotá has manifested itself through several unusual outcomes. Some couples have decided to hold their weddings in the system (Figure 41). Additionally, some unrelated establishments have decided to co-opt the TransMilenio name into their own business (Figures 42 and 43). In general, the borrowing of the system's name and image should be avoided since their unauthorised use can ultimately damage the system's public esteem. Further, intellectual property rights should be closely guarded. However, the borrowing of the TransMilenio image by others is in many respects a compliment to the system's high quality. The image would not be expropriated in this manner if it was not highly valued by the public.

An effective marketing plan begins with the identification and segmentation of potential user groups. The use of focal groups is a standard market research technique to gain insights into customer impressions. By understanding the needs and constraints of each market segment, tailored marketing strategies can then be designed and employed.


3.3.3.1 System logo

The name and logo of the system is another key starting point to impart the sense of a new type of transit service. Creating the right marketing identity helps create the right image in the customer's mind. Cities that have successfully implemented BRT have developed marketing identities that set their product apart and excite the public's imagination (Figure 44). In many instances, avoiding the term "bus" can be part of a strategic plan to re-position the new transit service in the market. Since the word "bus" can sometimes have a negative connotation, the use of other terms such as "metro" or "rapid transit" will instil the preferred sort of image with the customer. For example, the developers of the proposed BRT system in Barranquilla (Colombia) have chosen the name "TransMetro", which helps to invoke an image of modernity, quality, and sophistication (Figure 45). Likewise, the new system in Guayaquil (Ecuador) is known as "Metrovía".

**Figure 44 Examples of mass transit logos**


The colours utilised within the logo and the physical system should also be carefully considered. Colours can both influence public receptiveness to the system as well as reinforce the system's meaning to the city. For example, Bogotá chose red as the colour for both the buses and the logo. The idea was to equate the

TransMilenio system to the life-blood of the city with the BRT corridors representing the life-giving arteries. Other cities select colours that relate to a local flag or other identifiable attribute of the local environment.

Creating a public recognition of the system can also be bolstered by a slogan or tag line 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 (Figure 46). For example, the message may stress the time saving aspects, the level of convenience and comfort, or the modernity of the system.


The logo should also be integrated into the system's infrastructure. A recognisable motif adorning stations and buses will help gain customer familiarity with the system. Further, archways or poles with system signage at stations will help alert potential customers that there is a station in this location.

3.3.3.2 Marketing campaign strategy

Transit agencies should consider the use of a range of outreach media for their message. The promotional campaign can be communicated in billboards, print ads, radio, television, and special events. The choice of communication medium depends upon the cost and expected number of persons to be reached. While television can be most effective in reaching a large audience, it is by far the most costly option. However, in many cases, media organisations may donate the cost of the advertising as a public service announcement.

Integrating celebrities into the marketing campaign can be quite beneficial. Entertainers, political officials, and other well-known persons can help draw attention to the system. Convincing leading political officials to utilise the system for their daily travel is of particular value. If a Mayor, Governor, or other official makes regular use of the system, this practice sends an important message that the system is of high quality and that all members of society can be proud to use it.

### 3.3.4 Public education plan

BRT will hopefully introduce a range of customer service innovations that will provide a dramatically improved transit experience for the public. To prepare the public for BRT, an educational campaign will be necessary. This plan is in part designed to secure support and approval for BRT but also to better prepare the public on how the system will be used. Thus, a public education campaign is similar

to the overall marketing effort, but the focus is less on selling the system and more on providing a baseline of information to the public.


The public education process starts well before the system goes into operation. Information kiosks such as those shown in Figures 47 and 48 are effective means of reaching out to potential customers. Ottawa's TransitWay system maintains a permanent information outreach office located at a highly-accessible shopping mall in the city centre. Public outreach workers such as those utilised in Honolulu and Bogotá (Figures 49 and 50) are a very personal and thus effective means of reaching consumers. In each case, the system developers do not merely assume that "if one builds it, the customers will come."

Generating excitement over the look and utility of the new public transit system can help to ensure that the project is fully implemented. A high level of public support will make it more difficult for small groups of special interests to undermine the project. Further, the degree of public support can also bolster political officials who may otherwise be swayed by detractors.


Public education campaigns can also prepare citizens for how the new system will function. Public transit users may be unaccustomed to the proposed siting of routes, the functioning of feeder services, and the operation of fare collection systems. Communicating how the system will function can be accomplished using similar techniques as developed for the overall marketing campaign. Outreach programmes through direct community discussions with residents as well as information kiosks can be effective.

An actual small-scale demonstration of the system may in fact be one of the most effective types of public education mechanisms. Cities such as Lima (Peru) have introduced the BRT concept to residents through such a demonstration (Figures 51 and 52). In the case of Lima, a demonstration station and vehicle was placed in a central park of the city. While this demonstration did not actually provide any transport services, it did give residents a tangible example of the proposed system. Allowing residents to practice using the fare collection system reduces future uncertainty that can act as a barrier to ridership. Further, the demonstration also is one of the best means for achieving public excitement over the possibilities of a new system. Citizens can actually see and feel how the new system will change their city and their lives.

## 3.4 Planning Stage IV: Operations

With the identification of travel demand characteristics (Planning Stage II) and inputs from interested groups and individuals (Planning Stage III), it is now possible to prepare a conceptual framework for the operational aspects of the new transit system. By knowing where key origins and destinations are located, the planning team can identify the most appropriate initial corridors. Further, the team can also consider the various type of routing and service options that are possible, such as feeder, express, and local services. Decisions are also possible on the level of customer service quality that will be provided within the system. Attributes such as service frequency, hours of operation, comfort levels, cleanliness, security, and safety will all eventually affect overall ridership levels.

The topics discussed in Planning Stage IV, Operations, are:

**3.4.1 Corridor identification**

**3.4.2 Feeder services**

**3.4.3 Service options**

**3.4.4 Passenger capacity**

**3.4.5 System management and control**

**3.4.6 Customer service plan**

### 3.4.1 Corridor identification

3.4.1.1 Basis for corridor selection

The choice of corridor location will not only impact the usability of the BRT system for large segments of the population but will also have profound impacts on the future development of the city. The starting point for corridor decisions is the demand profiles generated during the modelling process, which will help identify the daily commuting patterns in both spatial and temporal terms. Clearly a key consideration is to minimise travel distances and travel times for the largest segment of the population. This objective will typically result in corridor siting near major destinations such as work places, universities and schools, and shopping areas. The demand profiles generated in Planning Stage II ("Section 3.2 Analysis") of this document provides the basis for determining likely corridors.

Thus, the areas serving the highest customer demand may be selected as the initial system corridors. However, in some instances, lower demand corridors may be selected if the degree of complexity in the high-demand corridors creates implementation difficulties. System developers may first choose to address a less complex corridor in order to first gain experience. If a lower demand corridor is

selected, though, it must still possess a sufficient quantity of useful origins and destinations so that the initial system will be financially viable.

Access for special groups, particularly disadvantaged communities, may also be a determining factor. Some systems prefer to develop initial lines around low-income areas so as to demonstrate that BRT has strong developmental linkages. Bogotá, for instance, focused its initial corridor in the lower-income south of the city. The initial corridors, though, will typically include key employment destinations such as central business districts. While road space in such areas may be more limited, the concentration of employment and services in central areas makes it imperative to provide direct access. A system will only be financially viable if the destinations served meet the public's principal mobility requirements.

#### 3.4.1.2 Roadway options

Trunk corridors are typically selected to operate upon major arterial roads. These roads often offer several advantages:

- Population densities are often higher near major arterials;
- Wider road space to accommodate both dedicated busways and mixed traffic lanes;
- Clear and logical connections with other major arterials in order to form an integrated network; and,
- A concentration of major destinations such as businesses and shopping areas.

The wider space available on such roadways permit lower construction costs, as less re-engineering of the road structure is typically necessary. The choice of arterial roads may also provoke less concern about noise and traffic impacts since these roadways already have a significant presence of motorised vehicles.

However, major arterials are not the only option to consider as trunk corridors. In some instances, another viable alternative is the selection of secondary streets that are parallel to and near a major arterial. The necessity of using a secondary road may occur for several reasons. First, existing traffic levels on major arterials may be such that political officials are uncomfortable with expropriating space from private vehicles. Second, major arterials may not provide easy or safe access for pedestrians to reach the BRT stations.

Secondary roads often hold the advantage that they are more "traffic calmed" for effective busway conversion. In some cases, a secondary road may be entirely converted to BRT use, and thus prohibit access to private vehicles. The feasibility of such an approach depends upon existing use patterns in the area. If the area is largely commercial, then the busway may co-exist quite well, especially since it will provide a concentration of customers for the businesses. However, if the area is largely residential, then there may be conflicts with individuals seeking private vehicle access to their properties. Such conflicts can sometimes be resolved with the establishment of access hours during non-peak periods, but this approach is not always possible. A remaining solution is to legally expropriate such properties for

public purchase, but such purchases can be quite costly as well as sometimes politically disruptive.

In general, though, secondary roads are considered more commonly as feeder routes. Since extensive residential sites are located along secondary roads, providing services to these areas becomes essential to operating a viable system.

### 3.4.2 Feeder services

#### 3.4.2.1 Trunk-feeder services versus direct services

Providing a transit service to all major residential and commercial sectors of a city can be challenging from a standpoint of system efficiency and cost effectiveness. The densest portions of the city necessitate high-volume vehicles to achieve the required capacity while lower-density residential areas may be most effectively served with smaller vehicles. However, at the same time, customers generally prefer not to transfer between vehicles when given the choice. The question for BRT system planners is how to balance these varying needs and preferences. Smaller residential areas do not have to be sacrificed from the system. A well-designed system can accommodate a range of population densities in order to achieve a true "city-wide" service.

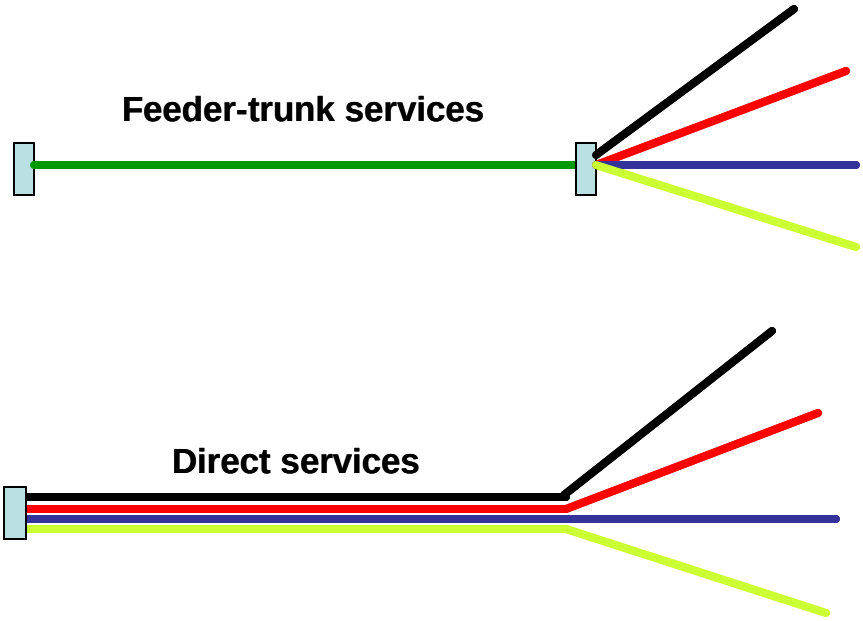
In general, there are two service options for addressing the presence of both high-density and lower-density areas within a city. These options are:

1. Trunk-feeder services; and,
2. Direct services.

Trunk-feeder services utilise smaller vehicles in lower-density areas and then necessitate passengers to transfer to higher-capacity vehicles at terminals. A trunk-feeder service thus operates relatively efficiently by closely matching vehicle operating characteristics to the actual demand. However, such services do imply that some passengers will need to transfer vehicles in order to reach their destination. The process of transferring can be seen as an undesirable burden for some passengers.

Direct services avoid the need for customers to transfer since the same vehicle serves both the feeder area and the trunk-line corridor. However, direct services incur a substantial cost penalty for operating vehicles that do not closely match the actual demand. Thus, direct services may imply that a large vehicle must enter into lower-density areas where relatively few passengers will be in the bus. Alternatively, direct services may imply that small vehicles operate efficiently in feeder areas but are undersized for the economics of trunk corridors. Direct services may still necessitate a transfer if the passenger's destination is a different corridor than the closest trunk corridor. Figure 53 provides a graphical comparison of trunk-feeder services and direct services.

**Figure 53 Illustrative comparison between trunk-feeder services and direct services**




In general, the most successful BRT systems (e.g., Bogotá, Curitiba, and Quito) operate with trunk-feeder services. However, there are also examples of systems, such as Porto Alegre (Brazil) and Kunming (China), which operate with direct services. The decision to choose a trunk-feeder service or a direct service can depend on many factors, including the structure of the city, the variation of population densities and service demand across different sectors of the city, distances to be travelled, and the business structure of the system. Table 18 lists the factors affecting the decision on the type of service.

**Table 18 Comparison of trunk-feeder services and direct services**

| Factor | Trunk-feeder service | Direct service |
|---|---|---|
| Population densities | Trunk-feeder services are most efficient when their exists significant differences in population density between major corridors and residential areas | Direct services can be the most efficient when there is little difference in population density across the entire route |
| Business structure | Permits a “closed” type system in which only concessioned operators are allowed into the system | Favours an “open” type system in which all public transport vehicles are permitted into the system |
| Busway configuration | Permits median busways, which have the advantage of avoiding turning conflicts with other vehicles and permitting transfers between corridors | Typically limits the design to side-aligned busways since the doorways must accommodate boarding along smaller roadways; this makes transferring to other corridors more difficult |
| Vehicle types | Trunk line routes can | Difficult to permit articulated |

| | | |
|---|---|---|
| | typically accommodate articulated or bi-articulated vehicles; feeder routes would typically employ standard sized buses or smaller | or bi-articulated vehicles since the turning radius of these vehicles is too large for smaller roadways |
| Travel time | Time penalty incurred for requiring transfer, but speed along the main busways is maximised | Time saved in avoiding transfers, but "bunching" of vehicles along busway can frequently reduce speeds and increase travel time |
| Capacity | High passenger flow rates can be handled efficiently with trunk-feeder services | The bunching of vehicles along with busway can inhibit the passenger flows handled by direct services |
| Distance travelled | Impact of a transfer is less if the overall travel distance is relatively long (10 km or more) | Avoiding transfers can be particularly desirable across short travel distances |

There is no right or wrong answer with regard to routing options since so much depends on local circumstances such as population density changes within a city. A trunk-feeder service might be more appropriate in the following conditions:

- Population densities vary significantly between main-line corridors and residential areas
- High-capacity corridors (greater than 8,000 passengers per hour per direction)
- Closed system with concessioned operators
- Buses over 12 metres in length
- Median busway and median stations
- Corridors over 10 kilometres in length

By contrast, a direct service might be more appropriate in the following circumstances:

- Urban areas with highly uniform population densities
- Lower-capacity corridors (less than 8,000 passengers per hour per direction)
- Open systems permitting unrestricted use of busway by all transit companies
- Smaller vehicles such as medium-sized buses and mini-buses
- Staggered stations (separate stations for each direction)
- Short corridors lengths

3.4.2.2 Lack of feeder services

Can a BRT system operate only on major corridors without any supporting feeder services? Some cities have attempted to implement a busway system without providing either feeder services or direct services into residential areas. Typically, this arrangement occurs when a city wishes to implement a limited experiment on a major corridor during a BRT project's first phase. By doing so, the municipality can

avoid addressing many of the complicated issues related to existing informal operators who service residential areas. The municipality can also avoid the complications related to the integration of services. However, the results to date on such an approach have not been entirely positive.

Jakarta (Indonesia) inaugurated its TransJakarta BRT system in January 2004 with an initial Phase I corridor of 12.9 kilometres. The system in this corridor consists of a single-lane median busway (Figure 54). The corridor is largely composed of business and shopping oriented destinations with few residential origins. The municipality elected not to provide any feeder services during the opening phase. The city also elected to allow the existing bus operators to continue operating in the mixed traffic lanes. Unsurprisingly, the results have not been favourable either to the BRT system or the general traffic. The limited BRT system has carried just 60,000 passengers per day and 6,000 passengers per hour per direction at peak times. The continued operation of the existing operators in the reduced confines of the mixed traffic lanes has also exacerbated overall traffic congestion levels. Retroactively Jakarta is attempting to arrange feeder services with existing operators but the arrangements have failed to work properly.

Jakarta's experience with the first phase of the TransJakarta system provides several lessons regarding the importance of feeder services and coordination with existing services. The lack of feeder services has created three troubling outcomes in Jakarta:

- Negative first impression of BRT
- Insufficient demand for a financially-viable BRT system
- Increase in overall congestion levels

A combination of negative articles in the press and consternation from private vehicles users has given the BRT system a difficult start from a public relations standpoint. In turn, this negative first impression will make it politically difficult to implement additional corridors. Already, the city is turning to a costly monorail option for other corridors in the city. The fact that the existing buses remain in operation (but with one less lane of mixed traffic) has increased congestion levels, which was one of the areas supposedly to be targeted by the new BRT system. Thus, in conclusion, the lack of feeder services or direct services into residential areas creates extremely difficult operating conditions for a new BRT system.

### 3.4.3 Service options

#### 3.4.3.1 Local services and station spacing

The most basic type of transit service along a corridor is typically known as "local service". This term refers to stops being made at each of the major origins and destinations along a route. However, in comparison to conventional bus services, the distance between stops on BRT corridors is greater. A typical range of distances is between 300 metres and 700 metres.

By avoiding short stopping distances, the overall travel time is reduced due to higher average vehicle velocities. "Hail and ride" services provided by private bus operators in many developing cities implies that the bus will stop whenever a customer indicates that he or she wishes to board or alight. While this practice will reduce subsequent walking distances to destinations, the net effect of all passengers controlling stopping location greatly increases overall travel time for everyone.

The location of BRT stations will again follow from the origin and destination modelling conducted earlier. Major destinations such as commercial centres, educational institutions, and large employers will all influence the location. Additionally, an array of other factors, such as road configuration, will also play a determinant role in choosing a cost-effective location that best serves the customer.

#### 3.4.3.2 Limited-stop services

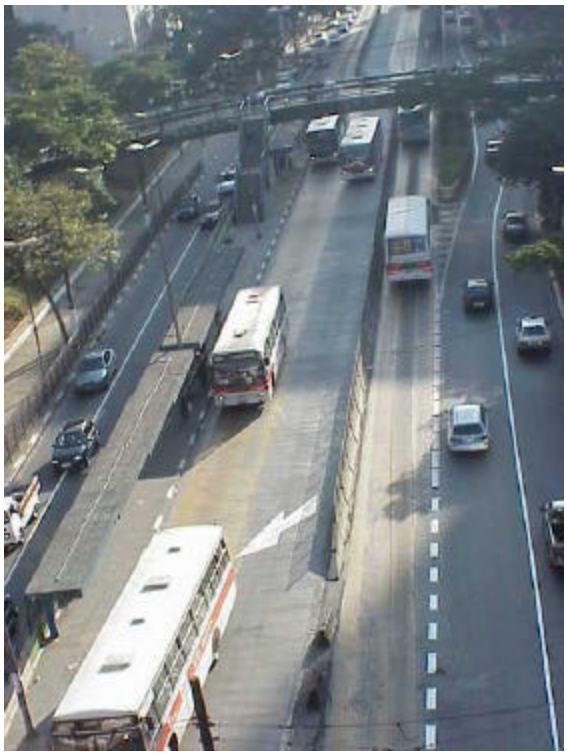
Typically, a few major stations will predominate as the intended destination of customers. For many passengers, stopping at each intermediate station adds significantly to the overall travel time with relatively little commercial benefit to the system operators. Thus, both passengers and operators can benefit from the provision of services that skip intermediate stops.

BRT's relative flexibility means that "limited-stop services" or "skipped-stop services" can be accommodated. The number of station stops to be skipped depends on the demand profile. Major station areas with the largest customer flows may be the most logical stops retained in a limited-stop service. However, the system can employ multiple limited-stop routes in order to ensure travel times are minimised for the largest number of customers. Thus, limited-stop routes can differ by the stations served as well as by the number of stations skipped by the service. Some routes may skip 3 or 4 stations while other routes may skip double that number.

Well-designed stations can permit customers to transfer from local services to the limited-stop service. Thus, even if a customer does not reside near a limited-stop station, he or she can transfer to a more rapid service after just a few stops in a local-service vehicle. In some instances, customers may find it advantageous to go beyond their desired stop in a limited-stop vehicle and then return a few stations by way of a local service. The principal idea is to give the maximum flexibility to the customer in order to reach the destination in the most convenient manner.

While limited-stop services do provide much amenity value to customers, these services do introduce greater complexity to the management of the system. The coordination of vehicles on the same corridor with different travel characteristics can be a challenge. Limited-stop services are thus best implemented in conjunction with

vehicle tracking technology that permits a central control team to oversee and direct vehicle movements. The provision of limited-stop services also implies particular infrastructure requirements. In order to skip stops, the limited-stop vehicles must be able to pass intermediate stations. Thus, sufficient road space must be available for either a second set of exclusive busway lanes or the provision of a passing lane at by-passed stations (Figures 55 and 56). These requirements mean that cities employing limited-stop services will incur greater system complexity and higher infrastructure costs.



3.4.3.3 Express services

Another type of limited-stop service is known as an "express service". Express services skip all stations between a peripheral area and a central core area. Thus, express services are an extreme form of limited-stop service.

Express services function quite well when a large residential area is a considerable distance from the city centre. If population densities are such that vehicles reach capacity at peripheral areas, then it can be efficient to transport these passengers directly to central locations. The reduced travel time of express services can be a major enticement to curb the growth of private motorised vehicles in the city's periphery. In many developing cities, low-income communities are often located at such peripheral locations, and thus, the provision of express services can be way of achieving greater equity within a system.

However, express services can also induce sprawl if not planned in a coordinated fashion. If the provision of an express service leads to additional development of greenfield sites at the city's periphery, then the long-term impacts may actually be to increase motorised travel. Such sprawl type development can also increase

municipal costs in providing basic services such as electricity, water, and sanitation. Thus, the identification of express service corridors needs to be carefully considered against the city's overall land-use plan.

3.4.3.4 Segmentation of services

No two customers are exactly alike. Each person has their own transportation patterns and habits as well personal preferences for comfort, convenience, and affordability. In some cities of the world, services are segmented to offer different transit characteristics to more closely match specific customer preferences. Thus, in Hong Kong and Bangkok, premium air conditioned bus services are offered to persons who are willing to pay more. In the Kolkata metro, women are afforded the option of entering carriages that are women only. In Buenos Aires, Rio de Janeiro, and Sao Paulo, executive mini-buses provide express services from the city centres to affluent communities. These executive vehicles also tend to offer air conditioning, increased leg space, and more comfortable seating.

The opportunity also exists for BRT systems to offer various types of services to cater to particular groups. The advantage of such segmentation is that it is possible to target groups who may not otherwise travel by public transportation. However, there are also disadvantages. Each layer of segmentation increases system management complexity. Ensuring the correct spacing of vehicles becomes all the more difficult when one is not only managing different routes but also routes plus special features, such as air conditioning. Further, purchasing vehicles with different characteristics can increase overall costs due to the loss of bulk purchasing possibilities. Each permutation of different features (air-conditioning, seat types, interior spacing, vehicle size, etc.) reduces standardisation.

Perhaps more importantly, though, specialised services perpetuate some of the very social divisions that well-designed transit systems try to overcome. As Enrique Peñalosa, the former Mayor of Bogotá, has noted, "the TransMilenio system is one of the few places in Bogotá where the wealthy and poor meet on an equal basis." This sort of social familiarity helps achieve an important goal of community cohesion and unity in a city. Public transport is a place where all the citizenry (the young, the elderly, and the physically disabled) can experience the city's complete diversity. Instead of providing a high-quality service to the wealthy and a different type of service to the poor, systems like TransMilenio have proven that it is possible to provide affordable excellence in public transport for everyone.

### 3.4.4 Passenger capacity

Once the initial BRT corridors are selected, the demand forecasts for these corridors can be used to determine optimum values for factors such as vehicle capacity, vehicle load factors, service frequency, and dwell times. These attributes in conjunction with the desired preferences for service types (trunk-feeder, direct, local, limited-stop, etc.) and the configuration of stopping bays will allow system developers to model different options for meeting the expected passenger capacities.

3.4.4.1 Vehicle capacity

Vehicle passenger capacity, load factors, and required service frequency are all mutually dependent. The maximum passenger capacity for a given vehicle is in part dependent on assumptions about culturally acceptable levels of customer comfort at peak times. A trade-off exists between the number of seats provided versus the amount of standing space provided. In some cases, a seated passenger consumes as much as twice the space as that required by a standing passenger. However, for long journey times passengers may have a strong preference for seating. The amount of personal space each passenger requires can vary between different cultures. Knowledge of local preferences in conjunction with stated preference surveys can help evaluate the best spatial arrangement.

Some cities with extreme differences in peak and non-peak demand have considered the application of different sized vehicles for the two periods. In this scenario, high-capacity vehicles are operated only during crush peak periods while lower-capacity vehicles are utilised at other times. While this use of different vehicle types can help better match demand and supply, the additional costs and complexity of operating multiple vehicle types usually exceeds the benefits. These additional costs include:

- Higher vehicle costs due to loss of economies of scale in purchasing a single vehicle type
- Difficulty in providing station entry bays for different doorway configurations
- Greater complexity and managerial requirements for dispatching multiple vehicle types

A typical system will already have at least two vehicle types in operation (i.e., larger vehicles for trunk services and smaller vehicles for feeder services). Adding another layer of complexity in terms of vehicle types is usually not recommended. However, in cases of extreme demand variances between peak and non-peak periods, multiple vehicle types may be an option to consider.

#### 3.4.4.2 Load factors

The vehicle load factor refers actual capacity usage as a percentage of the maximum passenger capacity. For example, if a vehicle has a maximum capacity of 160 passengers and an average capacity of 128 passengers, then the load factor is 80 percent (128 divided by 160). Generally, it is not advisable to plan to operate at a load factor of 100 percent. At a 100 percent load factor there is no room for system delays or small inefficiencies, both of which are likely outcomes of over-crowded conditions. The desired load factor may vary between peak and non-peak periods. In the Bogotá TransMilenio system, typical load factors are 80 percent for peak periods and 70 percent for non-peak periods.

It is also worth noting that it is possible to operate at a load factor exceeding 100 percent. Such a level implies that passengers are more closely packed than the maximum recommended levels. 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.

#### 3.4.4.3 Service frequency

The service frequency refers to the wait time between arriving vehicles. The wait time is also known as the "headway" between vehicles. In general, it is desirable to provide frequent services in order to reduce customer wait times. Customers often perceive waiting times to be much longer than the actual duration. Thus, to provide a car-competitive public transit service, minimising customer waiting is fundamental. The targeted wait times are closely related to the expected load factors. Longer wait periods will tend to increase the load factor as more passengers will arrive at the station.

Service frequency varies between different cities with BRT, but in general, peak frequencies of one minute to three minutes are quite common. Non-peak frequencies are likely to be longer but usually in a range of four minutes to eight minutes. Service during weekends may also tend to follow non-peak frequencies. However, weekend services may also require peak and non-peak schedules, depending upon local circumstances. For example, weekend markets and sporting events may necessitate higher frequency services.

If the wait is too long, a passenger backlog can occur in which insufficient space is available in the arriving vehicle. As load factors approach 100 percent, significant customer dissatisfaction can be expected. Passengers will be quite frustrated if they are not able to board the vehicle. Such backlogs may imply that passengers will have to wait for many vehicles to pass before there is sufficient boarding space. Some passengers may force their way into the vehicle by pushing against the passengers standing near the doorway. This occurrence leads to both discomfort and the flaring of tempers. Further, the amount of time the vehicle sits at the station will likely increase in this scenario. The confusion at the door-to-station interface will likely prevent the closing of the doors in a timely manner. The catching of bags and even limbs within the closing door will not only slow the overall service but again will lead to significant customer dissatisfaction.

#### 3.4.4.4 Dwell time

Another factor impacting feasible operating conditions is the vehicle "dwell time". The dwell time is the amount of time vehicles are stopped at a station to allow passenger boarding and alighting. The amount of time required depends upon many variables including:

- Passenger flow volumes
- Number of vehicle doorways
- Width of vehicle doorways
- Entry characteristics (stepped or at-level entry)
- Open space near doorways (on both vehicle and station sides)

BRT systems operate with dwell times as low as 20 seconds. Conventional bus services can require over 60 seconds for boarding and alighting. In general, dwell times may be somewhat higher during peak periods than non-peak periods. The increase during peak periods is due to the additional time needed to board and alight the higher customer volumes.

In addition to dwell time, another key performance measure is the “saturation level” at a given stop. The saturation level measures the relative congestion of vehicles at a stop. The parameter is calculated as follows:

**Equation 2**

| | | | | |
|---|---|---|---|---|
| Saturation level at a stop | = | Dwell time (minutes) | x | Frequency (buses per hr) |

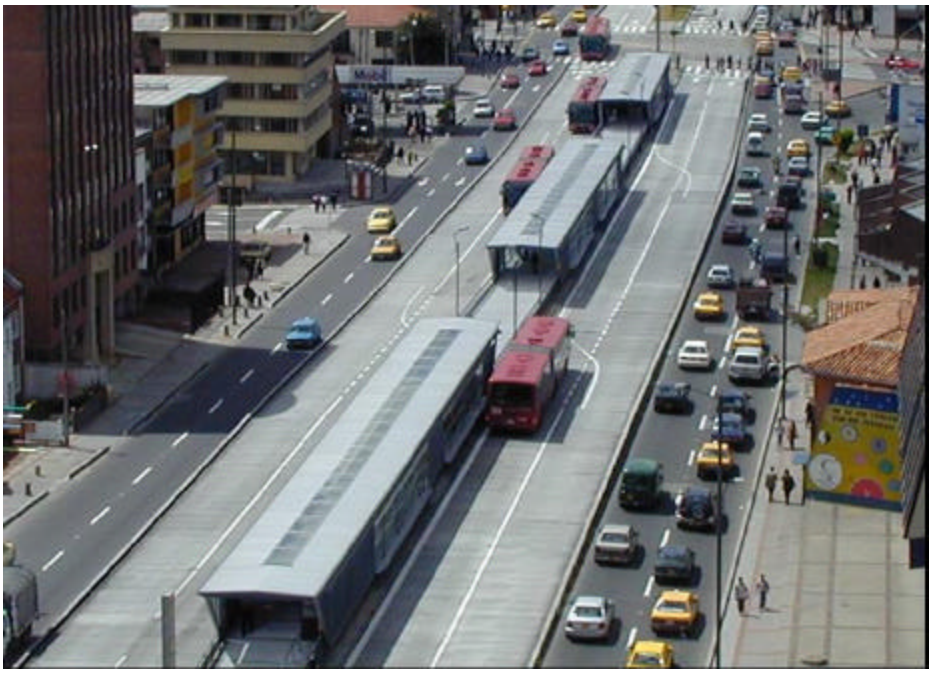
For example, if the dwell time is 20 seconds and there are 60 buses per hour, then the saturation level will be:

Saturation level at a stop = (20 seconds / bus) x (60 buses / hour) / (3600 seconds / hour) = 0.33

As the saturation level increases towards a value of 1.0, then the likelihood of bus queuing increases.

3.4.4.5 Stopping bay configurations

Passenger capacities along a corridor can be increased by providing multiple stopping bays at station. A stopping bay is the designated area where a vehicle will stop and align to the platform. In cities such as Curitiba, Kunming, and Taipei, only one stopping bay is provided per station. However, in other systems, allowing multiple vehicles to stop at the same time has proven to dramatically increase system capacity. Cities such as Bogotá and Porto Alegre employ multiple stopping bays within their BRT systems. Each stopping bay represents a different set of services or routes (e.g., local services versus limited-stop services or routes with a different final destination). In Bogotá, there are as many as five different stopping bays at an individual station (Figure 57).



In order for multiple stopping bays to function properly, the appropriate vehicle must have unencumbered access to its designated stopping bay. In Bogotá, the vehicles have this type of flexibility due to the provision of passing lanes at stations. The second set of busway lanes allows vehicles to pass others in accessing the correct bay.

In some instances, such as in Porto Alegre, roadway space may not permit a passing lane. However, Porto Alegre still manages to provide multiple stopping bays by ensuring the correct order of buses along the busway. This technique in which the order of vehicles is controlled is known as the "convoy" technique or the "platooning" of vehicles. In this scenario, two or more buses may run along the busway in a closely bunched pack. The order of the buses is set so that the first bus stops at the first stopping bay and the next bus stops at the subsequent stopping bay. Each stopping bay represents a different service or a different route. Unfortunately, the convoying or platooning of vehicles is quite difficult to manage and control. The buses must enter the busway in the appropriate order or there will be considerable delays and backing up of vehicles (Figure 58). Further, since passenger boardings will vary for different vehicles, the dwell times will also vary. Some vehicles may needlessly wait behind others while a longer boarding takes place. Thus, in a convoy system the slowest vehicle will likely set the speed for the entire fleet. For these reasons, multiple stopping bays are probably best implemented through the provision of passing lanes at stations.

3.4.4.6 Vehicle velocity

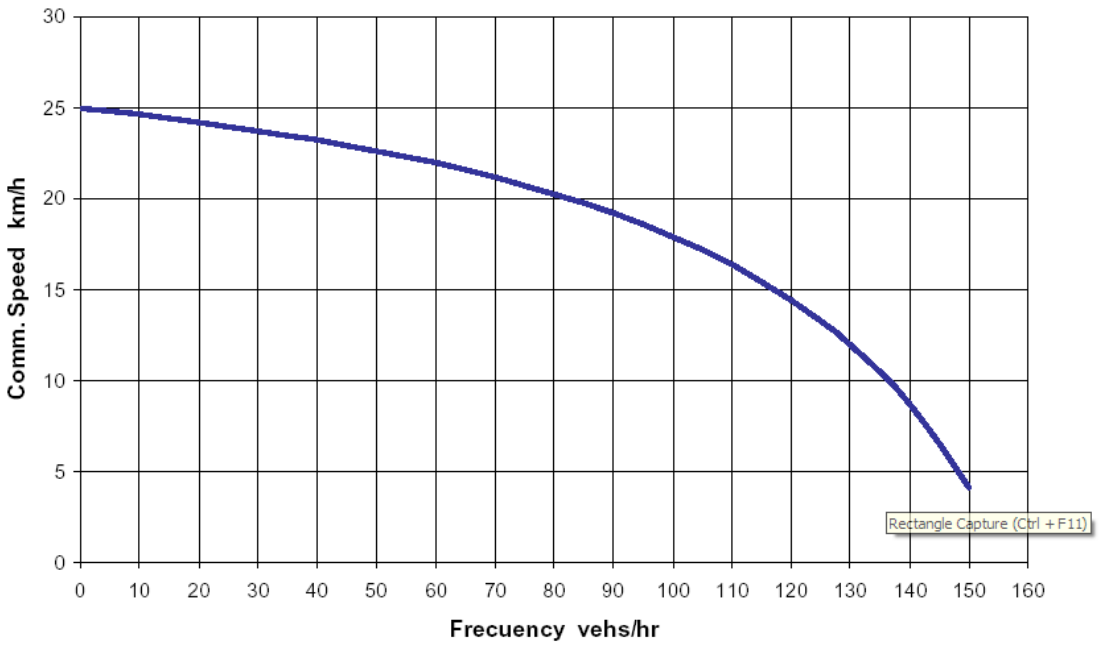
System capacity is actually not strictly dependent upon vehicle velocity. A system can move 20,000 passengers per hour at 20 kilometres per hour as well as at 10 kilometres per hour. Prior to the development of the Bogotá TransMilenio system, the city possessed a median busway that catered to all private bus operators. The uncontrolled system meant that there was considerable congestion on the corridor. The congestion was due to buses stopping at random locations as well as the over-supply of less efficient smaller vehicles. Nevertheless, the previous system moved approximately 30,000 passengers per hour per direction, but it did so at an average speed of less than 10 kilometres per hour. The TransMilenio system moves a similar number of passengers but at an average commercial speed of approximately 27 kilometres per hour. Figures 59 and 60 provide a visual comparison of Bogotá with the previous uncontrolled busway and with the TransMilenio BRT system along the same corridor.

Clearly, from the perspective of minimising travel time and fulfilling customer preferences, a rapid service is more desirable. While velocity and capacity may not be directly dependent, many factors that affect passenger capacity also affect average velocity. The factors that affect average velocity (i.e., "commercial" velocity) are:

- Number of busway lanes
- Dwell times
- Headways
- Vehicle acceleration and deceleration characteristics
- Number of controlled intersections

As the number of vehicles on the corridor increases, the level complexity and opportunity for conflicts also increases. In turn, these conflicts between vehicles lead to reduced velocities and increased travel times. Figure 61 shows the relationship between the frequency of vehicles and the average velocity on the Avenue Caracas Corridor in Bogotá.

**Figure 61 Relationship between average velocity and frequency of vehicles in Bogotá**




Source: Steer Davies Gleave

Thus, to maintain a system that both achieves high passenger capacities and high average velocities, the BRT system will necessitate the inclusion of design principles that promote unencumbered operation.

3.4.4.7 Capacity calculations

The passenger capacity of a given corridor is calculated based upon the discussed factors of vehicle capacity, load factors, service frequency, dwell times, and stopping bay configurations. Quite often a software model will assist in calculating the expected capacity and flow rates based on these factors. In general, though, the overall corridor capacity can be calculated from the following equation:

**Equation 3**

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Passenger capacity | = | Vehicle capacity | x | Load factor | x | Service frequency | x | Number of stopping bays |

Table 19 provides a sample of BRT capacity figures for several different combinations of the factors from the above equation. The values in this table are merely examples; the actual potential capacities for a given city will vary depending on a variety of local circumstances.

**Table 19 BRT passenger capacity scenarios**

| Vehicle capacity[1] (passengers) | Load factor | Headways (vehicle frequency in seconds) | Number of stopping bays | Capacity flow (passengers per hour per direction) |
|---|---|---|---|---|

[1] Standard-sized bus (12 metres): 70 maximum passengers. Articulated bus (18 metres): 160 maximum passengers. Bi-articulated bus (24 metres): 270 maximum p assengers.

| | | | | |
|---|---|---|---|---|
| 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 | 28,560 |
| 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 |

The values presented in table 19 assume that the vehicles operate on a segregated, median-aligned busway with at-level boarding. Values will be lower for side-aligned busways where there are significantly more turning conflicts with other vehicles. Further, if the vehicles have stepped passenger entry instead of at-level entry, longer headways will be necessary to handle the additional dwell times.

This section has provided sample values for a variety of factors affecting BRT passenger capacity. Table 20 summarises these values.

**Table 20 Sample values from existing BRT systems**

| Factor | Typical range |
|---|---|
| Vehicle capacity, standard-sized bus | 60 - 75 passengers |
| Vehicle capacity, articulated bus<br>Vehicle capacity, bi-articulated bus | 140 - 170 passengers<br>250 - 280 passengers |
| Load factor, peak period | 0.80 – 0.90 |
| Load factor, non-peak period | 0.65 – 0.80 |
| Headways, peak period | 1 – 3 minutes |
| Headways, non-peak period | 4 – 8 minutes |
| Dwell time, peak period | 20 – 40 seconds |
| Dwell time, non-peak period | 17 – 30 seconds |
| Number of stopping bays | 1 – 5 stopping bays |

The sample values represent the findings from a survey of existing BRT systems. However, they are presented for purely demonstrational purposes. The actual figures for a given set or circumstances are highly dependent upon local factors. Thus, care must be taken in attempting to utilise sample values in an urban environment that has its own unique set of characteristics.

### 3.4.5 System management and control

#### 3.4.5.1 Benefits of centralised control

Centralised control of the overall transit system affords many benefits for optimising efficiencies and minimising costs. Most conventional bus services lack a centralised control and management system; many do not even possess a basic radio dispatch

system. The lack of such controls means that each vehicle operates individually without the advantage of reacting collectively to service changes.

For example, a sudden change in demand, such as crowds leaving a sporting event, can be more readily addressed if additional transit supply is quickly dispatched from a central control facility to the site. A simple mechanical failure of one vehicle can stifle an entire system if a repair team or a tow truck is not immediately sent. Additionally, if a security problem arises, a control centre could provide an appropriate response, such as sending a security team to a station or bus. Without centralised control, these types of incidents will likely only be dealt with locally, which limits the effectiveness of any solution.

Further, when transporting large volumes of passengers through a corridor (over 10,000 passengers per hour per direction), a central control system becomes all the more indispensable to maintaining smooth operations. The "bunching" of vehicles within the system can easily occur without centralised monitoring and corrective actions. Further, if the bunching together of buses occurs, this situation also likely implies that there will be other points in the system where buses are too widely separated. Passengers are familiar with the situation in which two or three buses of the same route will arrive simultaneously, and then there will be no other buses for another 30 minutes. Ultimately, the price paid for failing to respond to these types of incidents will be customer dissatisfaction and lost ridership.

A centralised control centre can also serve as part of an evaluation tool to monitor and certify performance. In some instances, the control system can be linked with evaluating compliance with contractual terms. The control centre can monitor vehicle movements and verify odometer readings, and thus can play a role in the distribution of revenues based on kilometres travelled. The control system can also contribute to monitoring driver performance and identifying infractions, which again may be related to the amount of revenues given to operators.

A discussion on the technology options for efficiently managing and controlling the BRT system is found in section 3.6.7.

#### 3.4.5.2 Operational control and contingency planning

In a high-volume public transit system, there is very little margin for problems or errors. A vehicle breakdown, even for just a few minutes, can create havoc on the entire system. Likewise, a breakdown of a fare verification turnstile or non-functioning station door will create similar types of problems. Thus, preparing for any and all eventualities is a fundamental part of the operational plan. The development of backup and contingency plan will ensure that the system can continue to function even in difficult circumstances.

In some cases, driver repair training and/or instructions from a control centre can address very simple vehicle faults within a few minutes. However, when a breakdown occurs due to more serious problems, then contingency actions will be required. The first priority is to prevent a single breakdown from paralysing the entire system. Another high priority is to make a rapid disposition of the situation so that the affected passengers can be accommodated as quickly as possible.

While a second passing lane will alleviate some of the pressures from a vehicle failure, the additional lane is not an option for all systems. The immediate dispatch of a tow vehicle is likely to be the best course of action to avoid serious delays on the system. Tow vehicles should be on-call at all operational times. The strategic placing of tow vehicles throughout the system can help ensure a prompt response. Thus, tow vehicles should not only be based at terminal sites but also at intermediate points along the corridors.

For the passengers stuck in a non-functional vehicle, immediate solutions are also imperative. The perceived amount of time spent in a broken vehicle will likely be quite long from the customer's perspective. Passengers stuck waiting for ten minutes may perceive waiting time to be 30 minutes or higher, especially if persons are in a hurry to be at a particular destination. Thus, speed of response in moving passengers to another vehicle is quite important. If a vehicle failure occurs at a station, then passengers may simply be moved off the vehicle into the station area. If the failure occurs along the busway, then moving the passengers to a specially dispatched vehicle may be an option. Clearly, though, any movement of passengers on the busway will require special safety procedures. Since low-flow exits are likely to be on the street-side of the busway, exiting passengers will be exposed to traffic. A sufficient number of system staff and/or police must be on hand to make this transfer as safe as possible.

Failed station equipment, such as failed fare card readers or automatic doorways, also requires prompt action. In most cases, other fare card readers or doorways will be available to keep the system operating. However, the failures will lead to queuing and longer dwell times, which in turn will affect customer throughputs. Trained repair staff should thus be on-call during all operating hours. If the device cannot be immediately repaired, then a backup device should be installed. Thus, spare equipment for all major BRT systems should be kept on hand at all times.

### 3.4.6 Customer service plan

Unlike many existing bus services in developing-nation cities, BRT places the needs of the customer at the centre of the system's design criteria. The quality of customer service is directly related to customer satisfaction, which ultimately determines customer usage and long-term financial sustainability.

Unfortunately, unclear maps and schedules, unclean buses, and uncomfortable rides have been all too frequently the obligatory price to be paid for utilising public transport. Public transit and paratransit operators sometimes give scant attention to customer service, assuming instead that their market is predominated by captive customers who have few other options. Such a predilection, though, can lead to a downward spiral, in which poor services push more commuters toward two- and four-wheeled motorised alternatives. In turn, the reduced ridership curtails public transport revenues and further diminishes quality of services, which again leads to a further erosion of the passenger base. The impacts of poor customer service may not be immediately evident when the majority of the users are "captive" riders who have few other transport options. However, in the medium and long term these captive riders will become discretionary riders. The discretionary riders will then

likely switch to individual motorised transport the moment it becomes financially feasible to do so.

Customer service is fundamental at each level of operation. Are drivers courteous, professional and well presented? Are the stations and the buses clean, safe and secure? Is the morning commute a pleasant and relaxing experience or is it a hazardous and unfortunate trauma that must be endured? Individually, factors such as driver behaviour, signage, and seat comfort may appear to be insignificant measures, but their combined effect can be a significant determinant in the long-term viability of a transit service.

While these design and service features have helped to make dramatic improvements in system effectiveness and customer satisfaction, each is relatively low-cost to implement and relatively low-tech in nature. Thus, another lesson from BRT is that simple, ingenious, low-technology solutions are often of much greater value than more complex and costly alternatives. Customers probably do not care about the type of engine propulsion technology, but they do care greatly about the simple customer service features that directly affect their journey comfort, convenience and safety. Despite this rather obvious observation, too many public transport developers devote complete attention to vehicle and engineering aspects of system design and forget about the customer service aspects.

#### 3.4.6.1 Hours of operation

The opening and closing time of the system affects both customer utility and cost effectiveness. Ridership levels during early morning and late evening operations may be somewhat limited. However, the lack of service during non-peak hours undercuts the system's overall usability which will negatively affect ridership during other times. This need for comprehensive utility does not imply systems must operate 24 hours. In fact, many transit systems with 24 service experience significant security problems (e.g., robberies, assaults, graffiti, etc.) during late night and early morning hours.

The appropriate hours of operation will likely be based on the schedules of the major employment, educational, and leisure activities of the local citizenry. Thus, the hours will depend on key local indicators, including:

- Working hours of major employers
- Start and closing hours of educational institutions (including night classes)
- Closing times for restaurants, bars, cinemas, and theatres.

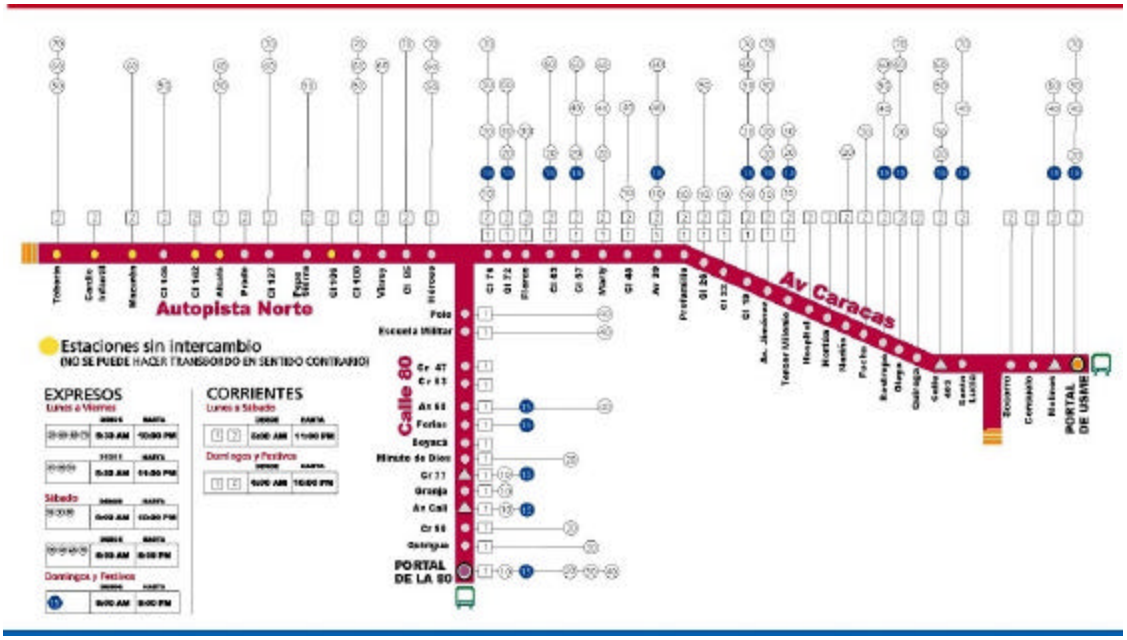
The appropriate operating hours will depend upon local cultural and social practices. In Bogotá, the TransMilenio system operates from 05:00 until 23:00, reflecting the relatively early start to the work day that is practiced there.

The hours may also be determined by labour laws and likely contractual arrangements with transit staff. If local labour laws allow flexibility with part-time employment, then the transit operators may have greater flexibility in matching the demand and supply of services.

The scheduling of late evening and early morning services may also necessitate different levels of non-peak service. For example, the frequency of non-peak services in the early evening (e.g., 19:00 to 21:00) may be greater than the frequency of non-peak services at later times (e.g.; 21:00 to 24:00). The frequency of service may also briefly increase during late periods, such as the period immediately following the closing of restaurants and bars. The principal aim is to maximise customer utility while simultaneously ensuring the cost-effectiveness of the system.

### 3.4.6.2 System maps

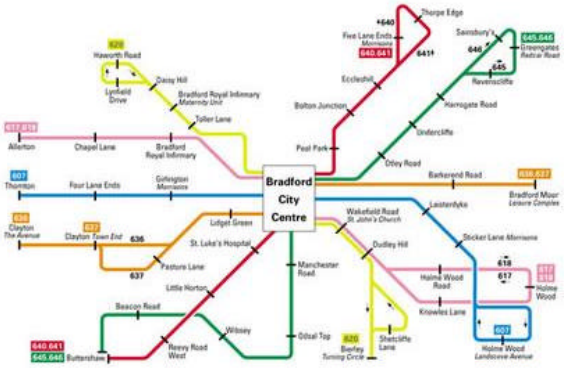
Historically, the ad hoc and paratransit systems in much of the developing world have followed informal and uncontrolled routings that required a seasoned system insider to fully understand and utilise. Many such systems are relatively incomprehensible and have formed a formidable barrier to potential new users, such as those with occasional transport needs and temporary visitors to the city. The TransMilenio BRT system in Bogotá emulates the better underground systems of the world by providing clear and colourful system maps (Figure 62).




A good test of a system's user-friendliness is to determine whether a person who does not speak the local language can understand the system within two minutes of looking at a map and information display. It is possible to achieve this level of simplicity in conveying the system's operation, but, unfortunately, most bus systems today do not even make the attempt.

Unlike the well-designed and colour-coded maps accompanying rail-based systems, maps for conventional bus systems are often quite confusing. While metros tend to use colourful "spider" maps to designate routes, most conventional bus systems use a complex web of mono-coloured lines and numbers (Figures 63). However, higher-quality bus systems are increasingly making use of spider maps to better convey information to customers (Figure 64). The idea behind a spider map is to give each

route its own colour-coded identity. The entire route is evident along with all major stations. The spider map from Bradford (UK) is part of a marketing strategy to re-brand the bus network as an “Overground” system. The word “Overground” is borrowed from the name of the London metro system which is known as the “Underground”. Thus, the spider map in Bradford helps impart the idea that the bus network is a mass transit system.




The differentiation of routes can be communicated through a variety of mechanisms including colours, numbers, and destination names. Colour-coding schemes are effective in allowing customers to readily differentiate between multiple routes. The colour-coding can be reflected both in the system route maps and on the vehicle itself. For instance, a coloured sign-board on the front of the vehicle can designate the routing direction. The sign-board can be easily removable in order to allow maximum flexibility in using the same vehicle on multiple corridors, depending on changes in customer demand. In general, customers can discern colours faster they can identify route numbers or worded destinations. However, in reality, route numbers, colour-coding, and destination labels can actually be used together to maximise customer recognition. Of course, care must be taken in not creating too much visual complexity. The best design is one that clearly communicates routes and destinations without undue complexity.

The completeness of a particular map can affect system usability. In some systems, such as Curitiba, only the map for one particular corridor is displayed at stations and within the vehicles. This limitation implies that persons only have a good working knowledge of their most frequently utilised corridors. Therefore, persons may not be able to use the system as adeptly for occasional trips. Further, the lack of an overall map means that customers cannot easily plot the most efficient routing for linked journeys with multiple destinations (e.g., work to shopping to school to doctor, etc.). The absence of a complete system map is also quite a disadvantage to visitors and occasional transit users. Thus, it is recommended that a complete system map be present at stations and inside vehicles. Of course, there are cost issues associated with providing quality maps, but in comparison to other aspects of system development (vehicles, busways, stations, etc.) the cost is relatively trivial.

The effective placement of maps in vehicles and stations is also a determining factor in the system’s user-friendliness. In Bogotá, maps are only available inside the station and within vehicles. However, some customers would like to visualise the system and route *before* paying and entering the system. Thus, it would be best to also have a system map outside the station entry point. The idea is to make the

system as simple and as inviting as possible to the customer. A major deterrent to public transport usage is the fact that many potential customers simply do not understand how the system works.

3.4.6.3 Signage

In addition to system maps, the various signage in and around stations as well as within the vehicles are key to customers readily understanding the system. Examples of the types of signage likely to be needed include:

- Instructions for using fare collection machines or vending booths
- Identification of station entry and exit points (Figure 65)
- Standing location within the station for particular routes (if multiple stopping bays)
- Directions for making transfers at terminals and intermediate transfer stations
- Actions required in the event of emergencies (instructions for call boxes, fire suppressing equipment, etc.) (Figure 66)
- Identification of locations within the vehicle for persons with special needs (physically disabled, elderly, parents with child, passengers with bicycles, etc.)
- Directions to amenity facilities (e.g., bicycle parking facilities, restrooms, etc.).


The fare collection process is another area of potential customer confusion that may inhibit the usability of the system. While regular users and captive users will make efforts to understand pricing and purchase options, other customer groups can view the fare system as another complication inhibiting usage. Clear and simple instructions are essential. Ideally, the design should be clear enough that a person who does not speak the local language can readily understand the amount of the fare and how it is to be paid.

Transfer points and bus stopping locations are potentially quite confusing to the customer. This confusion can be particularly acute during peak periods when crowds, noise, and distractions are at an extreme level. Such signage should be sufficiently sized and eye-catching to readily lead customers to the right location. System designers will wish to 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.

Certain areas of vehicles are typically designated for customers with special needs, such as those with physical disabilities, the elderly, and women with young children. These areas can be readily identified by the use of appropriate signage as well as colour-coding. The colour-coding may entail using different coloured seating in such areas.

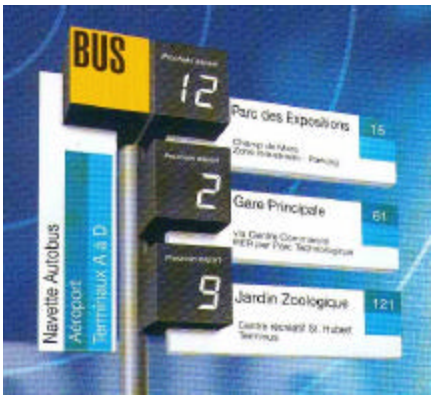
The variety of signage requirements within a BRT system should not imply that an over-abundance of visual cues is always desirable. If too much signage is present, a point of diminishing returns can occur. Too much signage can be visually distracting and prevent customers from absorbing vital information. "Visual clutter" is particularly problematic when systems utilise extensive advertisements. While advertisements can be an effective revenue source when used discretely, essential system signage can get lost if the commercial messages are too obtrusive.

3.4.6.4 Visual and voice information systems

Traditional signage is just one means to convey information to customers. Visual displays with real-time information are increasingly being used to relay a variety of message types. Such devices can display the following types of information:

- Next station stop (display inside bus)
- Estimated arrival time of next vehicle (display on station platform)
- Special advisories such as delays, construction work, new corridors, etc.
- Customer service announcements such as information on fare discounts

Real-time information displays that inform passengers when the next bus is due can be particularly effective at reducing "waiting anxiety", which often affects passengers who are not sure when or if a bus is coming (Figures 67 and 68). This feature allows customers to undertake other value adding activities to make best use of the time, rather than nervously waiting and standing at close attention to the horizon. Such displays can substantially reduce the customer's perceived waiting time.





Voice communications can also be a useful mechanism to convey essential information. The voice announcement of the next station permits the customer to focus on other activities (such as reading, talking with friends, etc.). Otherwise,

customers will tend to look up frequently either at a display or at the name of the station. Forcing the customer to know the local environment can add stress to the journey, especially for visitors and occasional transit users.

Voice messages can be done by way of the vehicle driver or by way of a recorded voice. Typically, it is recommended to use a recorded voice for reasons of clarity and consistency. Recorded messages also permit the use of digital technology rather than analogue technology. Digital voice messages are clearer and more readily understood than local analogue messages. Further, each driver will have his or her own accent that may not be understood by all. The use of a pre-recorded digital message that automatically activates itself at certain points in the journey will create a uniform and reliable information source. Additionally, the digital message will allow the driver to concentrate more on safety and other aspects of customer service. In some circumstances, it may be practical to deliver brief destination messages in more than one language.

3.4.6.5 Transit staff

In public transport as in life, sometimes a simple smile or kind word can make all the difference. The role of transit staff in making customers feel respected and welcome is one of the most powerful promotional tools that exist (Figure 69). While staff behaviour is probably one of the most economical means to creating good customer service, it is also sometimes one of the most ignored.


The training of transit staff in social interaction skills should be undertaken on a regular basis. Establishing a positive environment between staff and customers is not only healthy for attracting ridership but it can also improve employee morale. For fare collection agents, conductors, and drivers who handle thousands of passengers a day, each customer may just be another face in the crowd. However, for each customer, the brief interaction with staff can significantly affect the individual's opinion of the service. Thus, it is important that transit staff view each interaction with care. A customer service training programme should emphasise these points. Additionally, performance evaluations of transit staff should reflect the importance of excellence in customer interactions. Transit staff who excel in customer relations can be rewarded through salary incentives.

In many instances, transit staff will not be public employees. The growing trend towards the use of private sector concessions means that these employees will be responding to the demands of their private employers. However, this situation does not imply that the public agency cannot influence positive interactions between transit staff and customers. Financial incentives in concession contracts can encourage appropriate behaviour. Staff training on customer interactions can be a

mandatory requirement of the concessioned firm. The profit motive of the private firms can be a strong incentive to encourage a positive customer environment and a growing customer base.

Key customer interactions may occur at several points in the transit experience:

- Fare collection and fare verification process
- Customer information
- Interactions with on-board staff
- Security personnel

Fare collection is typically the point of the person's first interaction with staff. A combination of professionalism and friendliness can bolster the person's first impression of the system. A welcoming "hello" and a smile can be an effective personal touch that does little to slow the overall process. Responses to basic customer needs such as fare options, questions on routing, and the availability of change should be well prepared and rehearsed. Fare collection services should be well staffed to avoid long queues which may actually discourage persons from approaching a station.

The availability of staff dedicated only to customer information is a worthwhile investment. The presence of such staff in and around the station can be a significant public relations boost for a system. Such staff can approach customers who look confused or appear unsure of the system. In Bogotá, the "Mission Bogotá" programme is an example of a customer assistance programme that also doubles as a highly successful social upliftment initiative. Many of the participants in Mission Bogotá are individuals who were previously disenfranchised from society. Those who were formerly homeless, suffering from substance abuse, or workers in the sex industry are given an opportunity to contribute to society through social service. Through training and confidence building, the participants are dispatched to the streets with their blue and orange uniforms responding to public needs with a smile and professional manner (Figure 70). The programme provides the participants with a salary and many new skills. As part of their duties, the Mission Bogotá team provides customer service duties at TransMilenio stations.

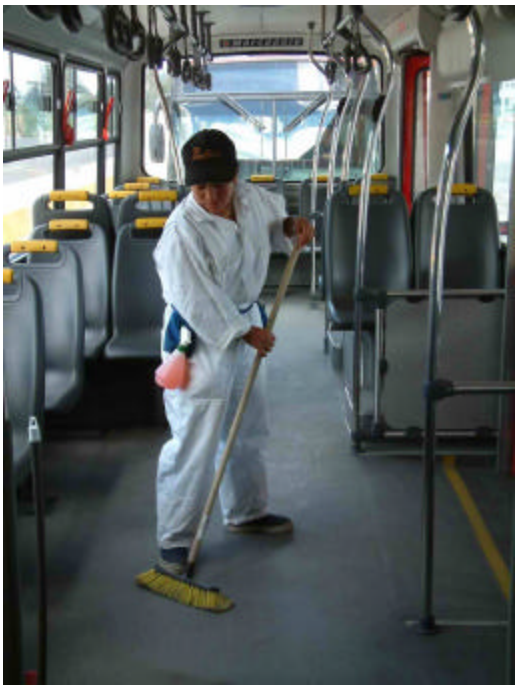
Security personnel also have a public relations function to fulfil in addition to the keeping of public order. However, in some instances, transit security staff report to the local police department or other entity. Thus, it is imperative that the transit organisation work with these other departments to ensure that transit security staff is appropriately trained. This training should include knowledge on the functioning of the system and inter-personal skills for interacting with the public. A customer is not likely to make a distinction between transit staff and security staff and thus will form an opinion on the system based on their interactions with all personnel.

Smartly-styled uniforms for all personnel also help to raise the public's perception of system quality and professionalism. Uniforms that are both comfortable to the user as well as project a stylish image can help change how the customers view public transport.

### 3.4.6.6 Cleanliness and system aesthetics

The cleanliness of the system is another seemingly trivial issue that has a major impact on customer perception and satisfaction. A transit system cluttered with litter and covered with graffiti tells the customer that this service is of poor quality. Such a scene reinforces the idea that public transport customers are somehow inferior to private vehicle owners. By contrast, an attractive and clean environment sends the message that the system is of the highest quality. Such a level of aesthetic quality can help convince all income groups that the transit system is an acceptable means of travel. Ideally, the transit system will come to be viewed as an oasis of calm and tranquillity in an otherwise chaotic world. To reach this state of aesthetic quality, it merely takes good planning and design.

An effective strategy against litter and graffiti is a combination of vigilance and maintenance. A strict policy with financial penalties for disobedience should be prominently employed. Additionally, any incidence of litter or graffiti should be cleaned up at the instance of identification. This sort of immediate response helps to overcome the so-called “broken window” theory of policing. The broken window theory says that if one window in a building is broken and goes unfixed, then in a short time all the windows will be broken. However, if the window is promptly repaired, then further incidences are greatly reduced. The idea is that small-scale problems can grow into large-scale lawlessness when the problems are left to fester. Litter left untouched sends a psychological message to customers that it is acceptable to leave rubbish about.



Strict cleaning schedules are a low-cost way of maintaining a positive transit environment and customer confidence in the system. In Quito, buses are cleaned after every pass along the corridor. Once a vehicle reaches the final terminal, a cleaning team goes through the vehicle leaving it spotless in about four minutes (Figure 71). This practice reduces the time night-time cleaning teams need to spend on the vehicles. Maintaining spotless operations also sends a message to everyone that littering is not to be done and thus tends to reduce the generation of trash. Likewise, a systematic cleaning schedule for stations and terminals can also keep a system in near pristine form. While one option is to clean only after system closing times, in highly frequented systems,

cleaning is likely to be needed during the day. Thus, scheduling cleaning activities in stations just after peak periods can be an option to address the accumulation of litter without interfering in the free flow of customers.

Policies regarding the consumption of food and drink in the system are also another effective strategy. On the one hand, permitting food and drink may seem like a nice service feature that allows the customer to undertake another value added activity while using the system. However, the price for permitting food and drink is an invariable deterioration in system cleanliness and in the long-term quality of the infrastructure. Typically, a policy against food and drink is necessary to maintain system quality.


The provision of trash receptacles is an option to help combat litter, but in some instances security concerns limit their availability. As public transport has unfortunately become a target of acts of terrorism, hidden compartments, such as trash bins, are often too dangerous in places with large numbers of persons. Alternatively, the provision of trash bins just outside of the stations is generally a safe and viable option. If the bins are placed in a consistent and well-demarcated space outside of the station, then customers will be able to have an option for disposing of trash. Public transport facilities also offer the opportunity to effectively market and implement a broader recycling programme. Since the public transport system is likely to be one of the most frequented places in the city, the synergies with other public campaigns, such as recycling, are a natural fit. The provision of multiple bins permitting the separate disposal of glass, paper, metals, plastics, organic materials, and other items is readily accomplished in conjunction with the transit system. For example, Singapore's metro system maintains this sort of recycling programme near entrances to the system (Figure 72).

Beyond policies and cleaning practices, the overall aesthetic design of the system infrastructure is a major factor in creating a positive environment for the customer. Design factors such as the use of light, materials, art, and interior design all contribute to an ambiance of calm, clarity, and comfort. Design issues are presented in more detail in the "Infrastructure" section of this guidebook (section 3.6).

#### 3.4.6.7 Comfort and convenience

The issues of comfort and convenience can greatly affect ridership levels, especially amongst discretionary riders. Comfort is affected by the quality of the waiting space at stations, the interior of the transit vehicles, and the overall environment of the system. Convenience refers to the proximity of the station to useful destinations as

well as the ease in reaching the station from points of origin. Convenience is closely related to the transport concept of “accessibility”.

Comfort in the general transit environment can depend upon the amount of the customer’s personal space. If peak hour services result in closely packed stations and vehicles, then the customer is subjected to discomfort and reduced security. Thus, the appropriate sizing of stations and vehicles and the provision of sufficiently frequent services are part of achieving a comfortable system.

Inside the vehicle, the amount of seating available and the type of seating plays a role in comfort. The trade-off between seated space and standing space depends upon system capacity requirements. However, even if standing space is predominant due to capacity demands, the quality of the standing space can also be enhanced. Adequate holding straps and sufficiently wide corridors in the vehicle interior can improve standing conditions. Padded seating materials, such as cloth, can add cost to vehicle purchases, but should at least be considered, especially if travel distances are relatively long.

The provision of station seating depends in part on the nature of the service. In high capacity, high frequency services, seating is unlikely to be required at stations and terminals since wait times are relatively short. The developers of the Bogotá system elected to forgo station seating in order to encourage passenger turnover. Seating can also consume valuable space in stations. In some instances the presence of seating can block boarding and alighting movements, and thus reduce throughputs in the stations. However, in instances when wait times are relatively long, some form of seating or support device can be warranted to avoid “standing fatigue”. One space saving solution is a leaning bar that permits waiting passengers to partially sit while leaning against a slanted bar. The bar can be padded to increase comfort. While a leaning bar is not as comfortable as a formal seat, it can be an effective alternative. The leaning bars can also avoid problems with individuals who elect to sleep on rows of seats.

Waiting time can also be a factor in designing fare collection and fare verification areas. The best solution is to provide adequate capacity in the fare collection system in order to avoid significant queuing. However, in some instances, such as fans departing a sporting event, entry queues are unavoidable. Queue guideways may be a useful mechanism to ensure orderliness, fairness, and clarity for waiting passengers. Video displays showing information or entertainment can be another option to reduce waiting stress for queuing passengers.

In many developing cities, the local climatic conditions can warrant climate control devices in the stations and vehicles. Air conditioning can make a significant difference for travel in tropical conditions. Likewise, heating can be important for colder climates. In order to compete for discretionary commuters who may have climate control devices in their private vehicles, such devices in the public transit system can be quite influential. However, there are both capital and operational cost considerations. For instance, air conditioning adds marginally to station and vehicle construction costs and can reduce fuel efficiency by 15 to 25 per cent in operation. Further, adapting stations to climate control devices implies design restrictions. The stations must be closed and relatively sealed, and thus likely

requiring a sliding door interface at the bus boarding zones. Again, this addition creates additional costs as well as additional maintenance and complexity issues within the system. There are also less costly climate interventions, such as passive solar design, that can be helpful. Section 3.6 ("Infrastructure") provides more discussion of such design options.

3.4.6.8 Security

Like any public place with large quantities of persons, buses can attract the wrong elements. The close confines of crowded conditions provide the perfect environment for pick-pocketing and other assaults on person and property. Fear of crime and assault is a highly motivating factor in the movement towards more private modes of transport, especially for women, the elderly and other vulnerable groups.

However, crime and insecurity can be overcome with the strategic use of policing and information technology. The presence of uniformed security personnel at stations and on buses can dramatically limit criminal activity and instil customer confidence. Further, security cameras and emergency call boxes (Figure 73) both permit more rapid response to potential threats as well as deter crimes from happening in the first place.

Even more worryingly is the rise of large-scale attacks on buses, such as the hijacking and murder that took place in front of television cameras in Rio de Janeiro, Brazil in 2000. This event has been made into a film called *Bus 174*. Crime and terrorism in cities such as Rio de Janeiro and Tel Aviv has had a chilling effect on ridership. Israel has lost approximately one-third of its public transport ridership in just a two-year period (Garb, 2003). While not every act of violence can be easily deterred, there are design features that can assist. Further, the highly visible presence of security staff and the watchfulness of passengers can reduce the possibilities of attacks (Figures 74 and 75).

3.4.6.9 Safety

Of the 1.2 million annual deaths from vehicle accidents in the world, the vast majority involve privately owned vehicles. Nevertheless, a single accident involving a public transit vehicle will make considerable news in comparison to the daily occurrence of car-related accidents. An accident involving public transit evokes emotions about governmental responsibility and public safety. The negative stigma from an accident can greatly diminish the public's trust and perception of the transit system. Thus, maintaining a high safety standard is fundamental.

Regular vehicle inspections, strict maintenance procedures, and required driver training are basic elements of a safety programme. Driver behaviour can also be positively reinforced through financial incentives and fines relating to speeding and other driving violations. The presence of clear evacuation instructions and fire protection equipment send a visible reminder to customers of safety preparedness and professionalism.

3.4.6.10 Amenity features

Transport is not just about transport. The time available during travel can be used effectively by the customer. A major advantage of public transport over private vehicles is that the time in transit can be used for other value-added activities such as reading, talking with friends, and relaxing. Amenity features can help to make the most efficient use of this value-added time.

It has been noted that entertainment systems such as video can be effective in stemming passenger impatience and anxiety during waiting periods. Video presentations at station areas may include news, weather, music videos, and customer information announcements. Audio systems are also an option. Music can be played within stations and buses.

While some customers will find video and audio entertaining and useful, this reaction is not always shared by all. For some these visual and aural displays contribute to an increased level of distraction and chaos in the public transit experience. One person's symphony is another's needless noise. In Quito, music

on BRT vehicles was suspended after students complained that it was difficult to study with the noise. Customer groups in Hong Kong formed in protest to the playing of music in vehicles (Figure 76). Thus, care must be taken in using certain entertainment features such as video and audio. The decision can be quite dependent on local customs and preferences. Further, like all such devices, video and audio systems involve a cost both in terms of the initial investment as well as in the long-term maintenance.



The advent of communications technologies such as the internet, email, and mobile telephones have revolutionised how people do business and how people interact with others at a distance. Public transport can offer services that take advantage of these communication technologies. Some transit systems are already beginning to offer free wireless internet services to their customers. The wireless feature can be supplied into vehicles and stations via transmitter technologies. While internet and email access may seem a needless extravagance in a developing-city public transport system, cities wishing to attract current private vehicle users may find the technology of great value. Further, as information technologies continue to fall in cost, the concept is not entirely out-of-reach for developing cities.

The use of mobile telephones within the transit system can also be of great utility to customers. Mobile technology is another easy means to stay in touch with the office or with friends while using public transport. In some circumstances, system developers may wish to provide special receivers to allow mobile connections in otherwise blocked areas such as tunnels. However, mobile technology may also create the same concerns over quiet that video and audio systems raise. The ringing of telephones and the loud ensuing conversations can be a serious distraction to those wishing to study, work, or simply relax. Thus, some discretion over the use of mobile technology may be advised. Again, any sort of restrictions would be highly dependent on local preferences and customs.

This section has discussed many activities that a transit system may wish to prohibit such as eating, drinking, making a mobile telephone call, etc. Clearly, there may be good reasons to impose such restrictions. However, system developers must walk a balance between preserving the quality of the system and giving maximum freedom to the customer. If the staff-customer interface is principally a list of things not to be done, then the system may appear in somewhat heavy-handed terms to

the public. Thus, it is quite important to focus on the most important restrictions (such as eating and drinking) and to do so in a clear and friendly manner.

Further, many of the amenity applications being discussed in this section, such as the enhancement of reading, studying, working, relaxing, and using information technologies, depend upon a smooth and level ride. Thus, vehicle and road quality will determine, to an extent, the viability of these activities. Smooth ride conditions are quite feasible with well-suspended high-floor vehicles and level roadways. However, ride comfort is definitely an area in which rail systems can have an edge over BRT.

Finally, there are some services that system developers may wish to provide customers as a courtesy. The provision of restrooms, lost and found offices, and emergency aid offices are examples. Opinions on whether to provide restrooms in a system can vary. If a system includes several hundred kilometres of runways and possible long commute times, then the provision of restrooms should be considered for patrons. Baby changing areas can also be quite appropriate in such circumstances. System developers in Bogotá elected to forgo restrooms based on a philosophy of wanting to keep passengers moving through the system without stopping. Restrooms and other facilities also involve capital and operating costs. Public restrooms are particularly susceptible to vandalism and physical deterioration which undermines the image of the overall system as well as the facility's functional utility. Nevertheless, a well maintained facility at major terminals may be a modest cost to provide adequate customer service.

Lost and found facilities are also an important service that can be reasonably expected to be provided in major transit systems. The location of a lost and found office should be well noted in system literature and at certain signage points.


Some systems use BRT stations and terminals as venues to publicise or implement other programmes of public interest, such as recycling facilities and air quality monitoring (Figure 77). Thus, the BRT system can be seen as a tool to achieve a variety of public outreach objectives and add even further value to the life of its customers.

## 3.5 Planning Stage V: Business and regulatory structure

The ultimate sustainability of the proposed BRT system is likely to depend less on the system's "hardware" (buses, stations, busways, and other infrastructure) and more on the system's "software" (the business and regulatory structure). If the BRT system can be made financially sustainable within an effective regulatory framework, then the remainder of the system design is largely a matter of technical details. The administrative and organisational structure of the system will have profound implications on the system's efficiency, operational nature, and costing.

However, effective regulatory and business structures are often quite difficult to achieve, especially when existing structures impose restraints over realising an optimum form. There is no one correct solution to structural issues, as local custom and circumstances play a determining role. Public operators may be unwilling to surrender their market and their administrative "turf". Private operators may be resistant of any changes, especially when they are unaccustomed to any governmental oversight. Ultimately, a mixed system with public and private sector roles may be the optimum approach to achieving a competitive and transparent system. Bogotá's TransMilenio provides an example of utilising the best qualities from both the public and private sectors.

The development of the system's business model will require some initial analysis of projected operating costs. This analysis will help identify the conditions in which operating companies can reach profitable (and thus sustainable) revenue levels. The calculation of operating costs will also allow initial estimates of expected customer tariff levels.



### 3.5.1 Business structure

#### 3.5.1.1 Existing business structures in developing cities

The existing public transport companies within a developing city will likely fall into one of three broad categories of market structures:

1. Public systems
2. Private sector systems
3. Mixed systems (public and private roles)

Publicly-operated transit systems are quite common in developed nations. In countries like the United States and some western European nations, the public transit agency acts as both the regulator and operator. However, in recent years, these systems have made greater use of private sector contracting for specialised functions. Publicly-operated systems in the developing world are relatively rare, but there are a few examples. In some instances, the public sector has taken over routes and areas that are not sufficiently profitable for the private sector. In most cases, publicly-operated systems are not very efficient. These systems are quite often heavily subsidised, over-staffed, and offering a service that is not highly responsive to customer demands.

Historically, a lack of financial resources and institutional control has meant that developing city transit has been have left largely to private operators. In many instances, these firms and individuals operate informally with very little public oversight. With fierce competition between many struggling small firms and little governmental control, the frequent result has been poor quality services that do little to meet the broader needs of the customer. Private operators will tend not to provide service to smaller neighbourhoods and will operate at particular hours. Small operators also tend to be run in a relatively inefficient manner. Small vehicles are utilised in places where high-capacity vehicles could be operated at a more efficient level. This inefficiency can lead to higher fare levels than would otherwise be required.

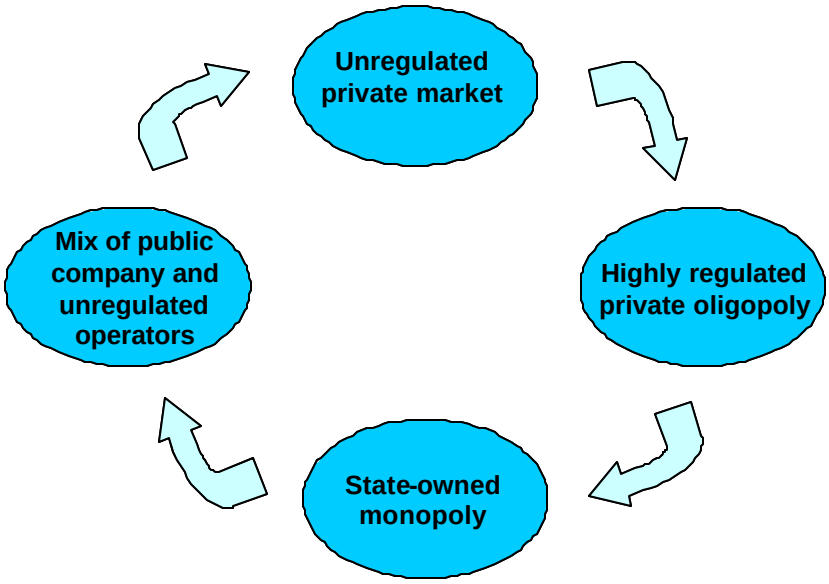
An uncontrolled transit environment can also lead to a serious over-supply of small vehicles. In Lagos (Nigeria) there are currently an estimated 70,000 mini-buses plying the streets. Until recently, over 50,000 mini-buses operated on the streets of Lima (Peru), and prior to TransMilenio, approximately 35,000 buses of various shapes and sizes ran along the streets of Bogotá (Figure 78). The large number of small transit vehicles contributes significantly to congestion and poor air quality. The unwieldy number of operators also represents a regulatory challenge to municipal agencies that lack sufficient resources.

In some instances, each vehicle is owned separately, often by the person who does the driving. In other instances, the transit vehicle is operated by a driver who leases the vehicle from a separate owner. Since 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 maximise fare revenues. Drivers will thus work as much as 16-hour days. The drivers will also have an incentive to drive as rapidly as possible to make as many roundtrips as they can. Further, drivers will even cut off other bus operators in

order to prevent competitors from capturing customers. In Bogotá, this behaviour was known as the "battle of the cent". 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 wait for the day that they can purchase their own private vehicle.

Thus, two extremes have predominated public transport regulatory structures: 1. Inefficient public monopoly; and 2. Poor quality private operators. Several cities have entered a vicious circle of moving between public and private systems along with intermediary steps of a highly-regulated private oligopoly and a mix of a publicly-operated entity competing with scores of unregulated operators (Figure 79). Cities such as Colombo (Sri Lanka) and Santiago (Chile) have moved around the entire spectrum of possibilities without ever finding a workable solution.

**Figure 79 The regulatory cycle**




Source: Meakin (2003)

The regulatory cycle becomes a vicious circle in which cities attempt to find quick fixes to ingrained structural and systemic deficiencies. The cycle's characteristics along with the reasons for inevitable collapse of each stage are given in table 21. As the spread of unregulated informal operators creates chaos on the street and poor quality services to the population, officials step in to regulate the industry. However, oligopolistic tendencies amongst the private firms mean that fare increases can be expected. Public pressure to reduce fares forces the firms to either curtail services or face bankruptcy. At this stage, the government decides to intercede in order to restore acceptable services. A public transit company is formed with monopolistic control over the entire market. Unfortunately, without the market incentives of profit and loss, the public company becomes quite inefficient. As public deficits mount, services and quality tend to diminish. Sensing an opportunity, illegal paratransit operators begin to fill the gaps in the public company's service. As the public company spirals into heavier and heavier losses, officials decide to turn the system entirely over to the private sector. Thus, the

regulatory cycle comes full circle with a return to the chaos of uncontrolled private operators.

**Table 21 The regulatory cycle**

| Industry composition | Characteristics | "Solution" |
|---|---|---|
| 1. Unregulated private operators | Chaotic, aggressive competition, dangerous driving, unstable services, no integration, variable fares. | Comprehensive regulation by Government. |
| 2. Highly regulated private oligopoly | Industry consolidates into large companies producing low levels of competition followed by fare increases; political pressures from increased fares result in lower-quality services or company bankruptcies. | Government nationalisation of firms (because 'only the state can assure adequate services'). |
| 3. State-owned monopoly | Low cost-effectiveness due to confused corporate objectives (service or profit?); low, sporadic or inappropriate investment; poor services. | Government tolerates 'illegal' private operators to meet unfulfilled market demands. |
| 4. Mix of public company and unregulated operators | Deficits from public company become politically unacceptable resulting in reduced services and increasing paratransit in the market. | Government gets out of business by privatisation or by withdrawal. |

Source: Meakin (2003)

3.5.1.2 Mixed systems

Fortunately, market structures are not limited to the options of an indebted public system or a chaotic private system. Mixed systems represent an alternative that allows cities to escape the vicious circle of the regulatory cycle. Mixed systems exploit the most appropriate role of both the public and private sectors in order to create a sustainable institutional and market structure. The use of extensive private sector contracting and concessions in conjunction with the judicious use of public oversight can produce the right set of conditions to minimise costs and ensure a high level of service quality. The challenge of achieving a well-functioning competitive structure lies in creating an appropriate set of incentives that ensures each actor is properly motivated to deliver a quality product.

The actual number of business structures is actually far greater than the simple categorisation of public, private, and mixed systems. Different types of contractual arrangements are possible within the framework of mixed systems. Table 22 outlines some of the options. Table 22 also distinguishes between situations where there is competition *for* the market and situations where there is competition *in* the market. Competition *for* the market implies that operators must compete to win the right to operate in a corridor or an area. By contrast, competition *in* the market implies that a firm will operate simultaneously with other operators in the same corridor or area and will be directly competing for market share.

**Table 22 Contractual options for different market structures**

| Type | Description | Competi-tion for market | Competi-tion in market |
|---|---|---|---|

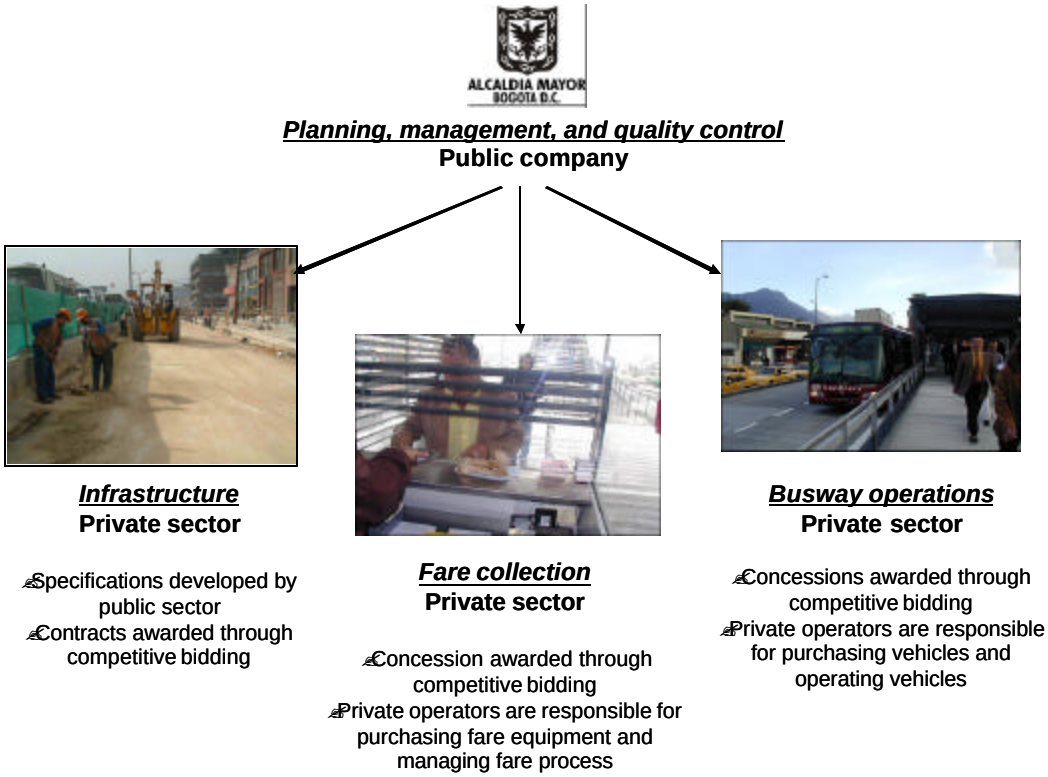
| | | | |
|---|---|---|---|
| Public monopoly | All system assets and operations are under the control of a public agency. | | |
| Management contracting | System assets remain in control of the public sector but certain operational and management functions are contracted to private firms. | X | |
| Gross cost service contracting | Private firms compete to operate routes but are paid on the basis of performance and not on the basis of passenger fare revenues. | X | |
| Net cost service contracting<br><br>Franchising (exclusive) | Private firms compete to operate routes and are paid on the basis of passenger fare revenues.<br>Operator wins contract for exclusive operation of route, and has the ability to innovate; public agency still sets fares and service parameters. | X<br><br>X | |
| Concessions (exclusive) | Operator wins contract for exclusive operation of route, and full financial, planning, and operational responsibility within parameters set by the public agency. | X | |
| Franchising (non-exclusive) | Franchising with multiple operators in the same market. | Possible | X |
| Concessions (non-exclusive) | Concessions with multiple operators in the same market. | Possible | X |
| Open market | Operators provide services without any restraints or control; routes, schedules, fares, number of operators and vehicles, and levels of quality are left to the private sector. | X | X |

Source: Adapted from Meakin (2002a)

Well-designed business structures for BRT systems have tended to seek considerable *competition for the market but limited competition in the market*. This strategic use of competitive motivations means that firms will have to compete aggressively within a bidding process in order to be allowed to operate. However, once the winning firms have been selected, there will not be competition on the streets to wrestle passengers away from other companies. Thus, firms will have an incentive to provide a high-level of service while simultaneously not generating the negative attributes of reckless driving, speeding, and cutting off other transit vehicles to gain an advantage. Some competition *in* the market can also be achieved by permitting multiple concession contracts along the same corridor. However, a transparent revenue distribution process along with an incentive system based on kilometres travelled rather than passenger numbers can avoid aggressive behaviour.

Bogotá's TransMilenio system has successfully developed a formula of private sector competition within a publicly-controlled system (Figure 80). The public company, TransMilenio SA, holds overall responsibility for system management and quality control. However, TransMilenio SA itself is only an organisation of approximately 70 persons, with oversight for a system in a city of seven million

inhabitants. Private sector concessions are used to deliver all other aspects of the system including fare collection and bus operations. The buses and even fare collection equipment are purchased by the private sectors firms.



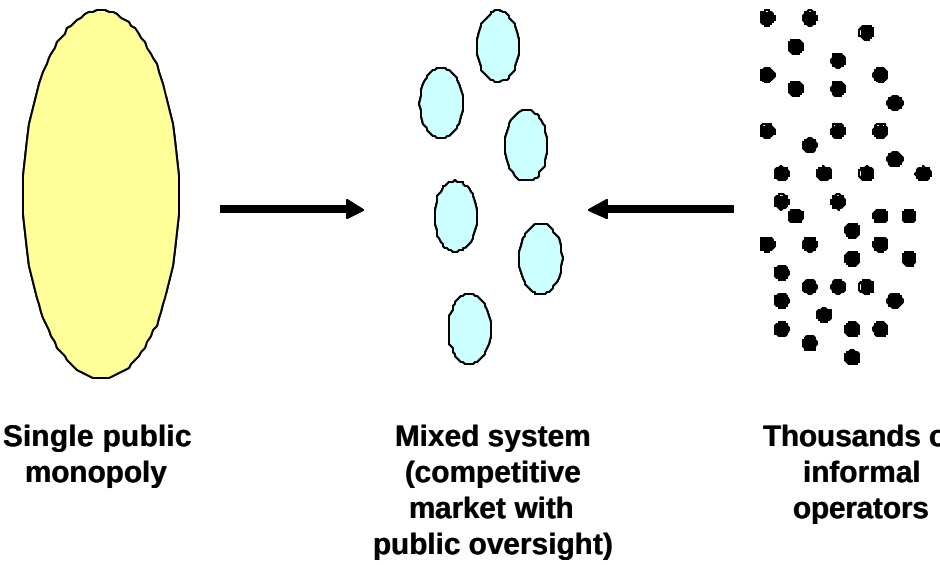

The director of TransMilenio reports to the Mayor's office via a board of directors. Thus, TransMilenio and the municipal government are able to leverage private sector investment and defer a large portion of the financial risks while retaining overall control on the shape of the system.

The infrastructure for TransMilenio is publicly financed, in the same manner that all other municipal road infrastructure is developed. 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. Thus, almost all possible aspects of TransMilenio are contracted or concessioned to private sector entities with public agency oversight.

### 3.5.1.3 Transforming existing systems to competitive, mixed systems

Of course, most cities do not begin from the point of having a well-structured system that balances the appropriate roles of the private and public sectors. Instead, most developing cities begin with one of the four conditions identified in the regulatory cycle. The challenge becomes how to transform an existing market structure into one delivering a cost-effective and high-quality service. Figure 81 shows a pictorial view of the challenge within the transformation process.

**Figure 81 The market transformation process**




Source: Adapted from Meakin (2003)

*a. Transforming a public monopoly*

In the case of a single public monopoly, the public firm cedes its exclusive control of the market by allowing private firms to compete. This process implies that the public transit company must somehow be altered to fit the new market conditions. Some of the options for such a transformation include:

- Public transit company is privatised through a transparent selling process, and the new firm subsequently competes for market access on equal terms with other private firms;
- Assets of the public company are sold and the company is formally dissolved to allow a new market structure to be shaped in a completely open manner;
- Public transit company relinquishes operations in the areas with the new BRT system and instead concentrates on other parts of the city.

Clearly, to undertake any of these options will necessitate a certain degree of political will on the part of political leaders. Public employees and union leaders will likely oppose such drastic changes. Since public companies frequently operate with inefficient levels of employees, the transformed organisation will likely need to reduce staffing numbers. To an extent, staff reductions can be mitigated by transfers to other agencies and by retraining programmes, but the process of change can be difficult for those involved.

*b. Transforming an open market*

Consolidating the thousands of registered and unregistered small operators into a more manageable structure also brings with it considerable challenges. Powerful interests will also likely resist any changes to the existing market structure. However, unlike the transformation of a single public entity, the thousands of private operators are both difficult to identify as well as difficult to organise.

Inclusion of existing operators in the concessions process is important for political, social, and functional reasons. Ideally, the operators will have had a participatory role in designing the concessions process in the first place. However, a major first step is the full identification of all existing operators. Unfortunately, not all the operators may be registered with the city's transport agency. In Bogotá prior to the BRT system, there were approximately 22,000 registered private bus operators, but it is likely that the actual number of buses was closer to 35,000. Since the unregistered operators are already working outside of the city's regulatory requirements, coaxing these individuals to join the BRT development process can be difficult. However, the BRT process can be a unique opportunity to bring unregistered operators back into the legal system. The lure of concession agreements in conjunction with operating restrictions on BRT corridors can be a strong incentive.

One option for bringing existing operators into the process is simply to let the incentive structure and the market forces guide the outcome. The design of the concessions process can give additional points to bid teams that include existing operators. The incentive process can thus create an environment of active engagement.

However, the municipality may also wish to give additional technical support to ensure that all existing operators are able to participate fairly in the concession competition. By building the business skills of the operators, the municipality will help to bolster individual competitiveness as well as improve the quality of the bidding process. In many instances, the operators may not even fully understand their own cost structure. Since the BRT system will represent a major professionalisation of their business, the operators will need new skills in accounting, negotiations, technological knowledge, and customer service.

Assistance can also be given in terms of helping individual operators form consortium groupings. An individual operator is unlikely to have the necessary resources and skills to bid as a single entity. Instead several small operators will likely form a consortium arrangement and bid jointly. Alternatively, a large company or an individual with sufficient financial resources will seek out smaller companies to join as partners. In either case, the smaller operators can be given stockholder status in the new venture. The operator's stake in the new enterprise will depend on the resources that are being contributed to the group. Small operators will likely be able to contribute the following types of assets:

- Points to the bid team as an existing operator
- Vehicles for use in the system
- Vehicles for scrapping (if required in bid conditions)
- Drivers and other staff
- Business knowledge

The value of the small operator's assets will determine their shareholder status. Operators will be able to "shop" their assets to many different consortiums in order to realise the best deal. Despite the inherently different business environment between BRT and informal operations, the existing operators may possess many valuable attributes. While their older vehicles will not likely be of use on trunk

corridors, it is quite possible that good quality standard vehicles can be of use on feeder lines. The older vehicles also offer value in terms of meeting any requirements for scrapping vehicles. Drivers will likely need some re-training in order to achieve new levels of safety and customer service, but their basic skill levels and knowledge of the city streets will assist in the transformation process.

At the end of the bidding process, it is possible that some existing operators will be left out of the new system. The losing bid teams and individuals who did not join a bid team may well take actions to thwart the new BRT system. These actions may include political pressure, legal challenges, and protest. Thus, the municipality may also wish to conduct a post-bid outreach effort with unsuccessful entities. The promise of future bidding opportunities and further skill training can help mitigate a negative backlash.

#### 3.5.1.4 Existing operators and continuance of service

A related issue is whether existing operators should be allowed to continue to operate along the same corridors as the BRT system. In order to assure that the BRT system is financially viable, mandating the phase out of competing informal services along the same routes may be a prudent action. Politically, it also may be an important gesture to private vehicle users in order to free up the remaining road space to mixed traffic.

However, a complicating factor is that the existing operators often will not operate along exactly the same route structure. These vehicles may only use a portion of the busway corridor for their routes. At different points along the corridor, the operators will enter and exit from various other routes and neighbourhoods. Curtailing their operations will imply that some areas may be cut-off from transit services altogether. Additionally, residents who will be accustomed to a certain type of routing service may be displeased with the removal of these services.

Thus, to avoid difficulties both to the transit operators and the serviced communities, the transit agency should consider a complete review of transit routes and licensing along the BRT corridors. Such a review of the entire city's transit route structure can lead to the following types of adjustments:

- Banning existing operators from servicing certain areas;
- Re-routing the existing operators to other areas;
- Permitting the existing operators to continue along certain segments of the corridor.

While banning the operators from certain areas of the city may seem difficult to achieve in political terms, incentives can be used to encourage acceptance. The withdrawal of existing services can be a pre-requisite for participation in the BRT bidding process. Intransigent operators can lose the opportunity to participate in the new system. Additionally, technical assistance and identification of alternative markets can help ease the process of consolidating existing services.

Another strategy sometimes employed is to simply permit the existing operators to continue operating in the BRT corridors. If the BRT service is of superior quality at a

similar price, then it is likely that the BRT service will dominate the market. The reduced travel times in busways along with a more secure and comfortable ride will likely attract the major share of the ridership. In this scenario, the existing operators will likely withdraw voluntarily due to the unprofitable market conditions. This strategy potentially avoids the conflicts that can arise from eliminating operators by mandate.

However, permitting the continued operation of the existing operators can also be a risk to the BRT system. Since many developing city residents are quite price sensitive, even small differences in fare levels may permit the existing operators to retain significant market share. In instances where existing operators provide direct services and the BRT system requires a transfer, the existing operators may retain an advantage. Thus, a strategy of permitting existing operators to continue along the BRT corridor should only be undertaken in situations where the BRT system will likely dominate the market due to its inherent advantages. Otherwise, the financial viability of the system will be undermined. Further, the continued operation of the existing operators may imply an overall increase in levels of traffic congestion.

The disposition of existing operators is a sensitive point in the development of any new transit service. Since drivers, conductors, and other staff of existing services tend to come from lower-income groups, concerns over fairness and social justice should be at the forefront of addressing this issue. If the process is managed properly, the market opportunities within the new BRT system can be a win for everyone, including the existing operators. Solutions are available that can address the needs of the operators. However, at the same time, a strong sense of political will is required to ensure that the goal of a high-quality transit system is the over-riding objective.

#### 3.5.1.5 Open versus closed systems

The business or market structure can also be closely related to the operational nature of the system. In some instances, a detailed bidding process will be utilised to determine which private firms will obtain concessions to operate on the busway. Firms that do not receive a concession are not permitted to operate on the busway, and many times, are also not permitted to operate on the mixed traffic lanes in the same corridor. This form of operational structure is known as a “closed system” in which the market is restricted only to firms that are successful in the bidding process.

Alternatively, the busway can be open to all existing operators without any significant restrictions based on vehicle numbers or routing. In this scenario, the operators continue in much the same business structure as before but with improved infrastructure. This option is known as an “open system” (Figure 82).

Cities such as Bogotá and Curitiba operate as closed systems by limiting entry to qualified private firms. Quito also operates closed systems on its Trolé and Ecovía corridors (Figure 83). Bogotá is perhaps the most complete example of a closed system utilising a full competitive structure.

A closed system does not imply that one cannot have multiple operators on the same corridor. Bogotá intentionally selects at least two operating firms on each corridor to ensure a degree of competitiveness within the market. In the case of strikes or operational problems with one of the operators, there is the leverage of the additional operating company to compensate.

Open systems require relatively few changes in the operating structure of the transport companies. In cities such as Kunming (China), Porto Alegre (Brazil), and Taipei (Taiwan), the use of an open system has avoided the need for any painful re-structuring of the industry. Bogotá also operated an open system prior to the development of the TransMilenio system. In an open system, buses operate in a similar manner to the situation before the busways. Fare collection is done on-board the vehicles with the revenues being retained by the operators. The only major improvement comes in terms of travel times and the smoothness of the ride due to the presence of the segregated busway.

In general, open systems tend not to be as coordinated and as efficient as closed systems precisely because no meaningful re-structuring of the industry has taken place. The relative lack of control over the movement of vehicles implies that congestion can occur along the busway. Aggressive behaviour amongst drivers is limited due to the physical design of the segregated lane, but nevertheless the lack of cooperation amongst drivers can result in some gaming tactics and dangerous driving (Figure 84).

Open system structures can be preferred when only a small portion of a BRT system is being developed in the initial stages. In such cases, the buses are only

on the busway for a relatively short distance prior to switching to more conventional roadways. Some new systems, such as Delhi (India), are opting for open systems due to both the incremental nature of the projects and the lack of sufficient political will to achieve a full closed system. Table 23 compares the relative advantages of both closed and open systems.

**Table 23 Comparison between closed and open BRT systems**

| Factor | Closed system | Open system |
|---|---|---|
| Access | Access limited to operators who were successful in bidding process. | Access given to a wider range of existing operators. |
| Control and management | Vehicle numbers, frequency, scheduling, and other factors are all coordinated centrally for optimum efficiency. | Individual companies tend to make own decisions regarding key control issues with relatively little central coordination. |
| Service quality | Service quality is strictly controlled to high standards by the contractual agreement through the bidding process. | Service quality is more dependent on the individual nature of each operator. |
| Service uniformity | Service is controlled to a high and uniform standard through the terms of the concession. | Service is more variable. |
| Competitive structure | Competition is *for* the market but with little competitive aggression *in* the market. | Little competition *for* the market but significant competition *in* the market. |
| Infrastructure | Works well in a full BRT network. | Works well in a busway system of limited size. |
| Fare collection | Pre-board fare collection by a separate concessioned firm; fare revenues distributed in a transparent process by an independent agent. | Fares collected on-board vehicle by each individual operator. |
| Business re-organisation | Typically accompanied by a full re-organisation of the bus industry. | Requires no large-scale re-organisation of routes or business practices. |
| Political will | Requires sufficient political will to install a new competitive structure. | Relatively little political will is required since no major changes are imposed on the business operations. |

### 3.5.2 Institutional and regulatory structure

The supporting institutional and regulatory structure can either create an environment of efficiency and transparency or lead to misplaced incentives and even corruption. The "public" side of an effective public-private partnership will play a pivotal role in developing and maintaining a competitive transit environment.

However, there is no one answer to an effective institutional structure since the existing agencies, historical precedents, geographical coverage of the system, and the local political dynamics will all shape the likely outcome. The options range from relatively focused specialised agencies to large transport departments that oversee all forms of public and private transport (Table 24). Further, these institutions can be either highly autonomous from the local government or closely controlled by elected officials and civil servants. The responsible level of government for a transit system is often local in nature, but the system can also be controlled in some instances by provincial governments or even national ministries. Finally, the institutional oversight of a BRT system can be implemented through an existing agency or through a newly created organisation.

**Table 24 Institutional options**

| Type of institution | Description |
|---|---|
| Transport department | Large entity with a wide range of regulatory and management responsibilities; typically reports directly to city political officials |
| Transport authority | Organisation with wide oversight on all public transport activities; frequently given autonomous status through a board of directors |
| Specialised transport agency | Smaller organisation with a focused mandate; typically reports directly to city political officials |

In general, transport institutions can have a range of responsibilities, including:

- Policy-making and setting standards
- Regulation
- Planning and design
- Project implementation
- Operational management
- Financial management
- Contracting and concessions
- Regulation
- Administration
- Marketing

At some level, each of these activities will need to be addressed by a governmental institution. However, whether the entity is organised as a single institution or several different institutions depends greatly upon local political circumstances.

A single transport institution avoids many of the inter-organisational conflicts that can otherwise occur. Rather than risking battles over each organisation's turf, a single institution removes much of this conflict. An organisation such as Transport for London (TfL) has a wide range of coordinating activities across the entire London metropolitan area. Prior to TfL's creation in 2002, transport was largely the responsibility of London's many local boroughs. Unfortunately, such an arrangement did little to foster coherent plans for systems that crossed borough boundaries. Although TfL contracts private firms for infrastructure development and operations, the public organisation maintains a wide range of responsibilities, including the following areas:

- London bus system
- Underground system
- Light rail lines
- Walking and cycling
- Congestion charging
- Taxi regulation
- Traffic management
- Maintaining major roadways
- River services

Internally, TfL organises around different divisions such as "street management" and "London buses", but overall, TfL is a single entity. In a similar fashion, the Land Transport Authority of Singapore holds a wide array of transport responsibilities all within a single organisation (Meakin, 2002b). London and Singapore also provide examples of the advantages of transport planning across an entire metropolitan area. In other urban conglomerations that consist of multiple municipalities it is often difficult to achieve a coordinated transit plan if each municipal government has its own planning processes. The single entity approach also enables London and Singapore to address car restraint measures, public transport, and traffic management activities in an integrated planning process and in a unified bureaucracy. However, a single transport institution does bring its own challenges. Large organisations can be more complex and more difficult to manage. With a range of priorities, a large institution may not have the same focus on BRT as a more specialised agency. In some instances, large organisations are also less responsive to market demands.

By contrast, in cities such as Bogotá and Curitiba, the BRT systems are overseen by smaller, fairly specialised organisations. In such instances, different aspects of BRT development and operation can reside in different organisations. In Curitiba, the planning and development of the transport master plan resides with the Institute of Urban Research and Planning of Curitiba (IPPUC). Another organisation, Urbanisation of Curitiba (URBS), is responsible for the actual implementation and management of the BRT system.

Bogotá created a new entity, TransMilenio SA, to oversee the development and operation of its BRT system. TransMilenio SA was formed as a "public company" which reports to the city's mayor through a board of directors. Other more traditional governmental departments also play a significant role in Bogotá's BRT system, but the new public company has taken a 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 non-governmental organisations and citizens groups who are able to better provide a customer perspective. The current TransMilenio board even includes an opera singer. Many of the related agencies, such as the transport regulator and the public works agency, also are represented on the board in order to assure coordination between all governmental organisations. In summary, the groups and individuals included in the TransMilenio board of directors are:

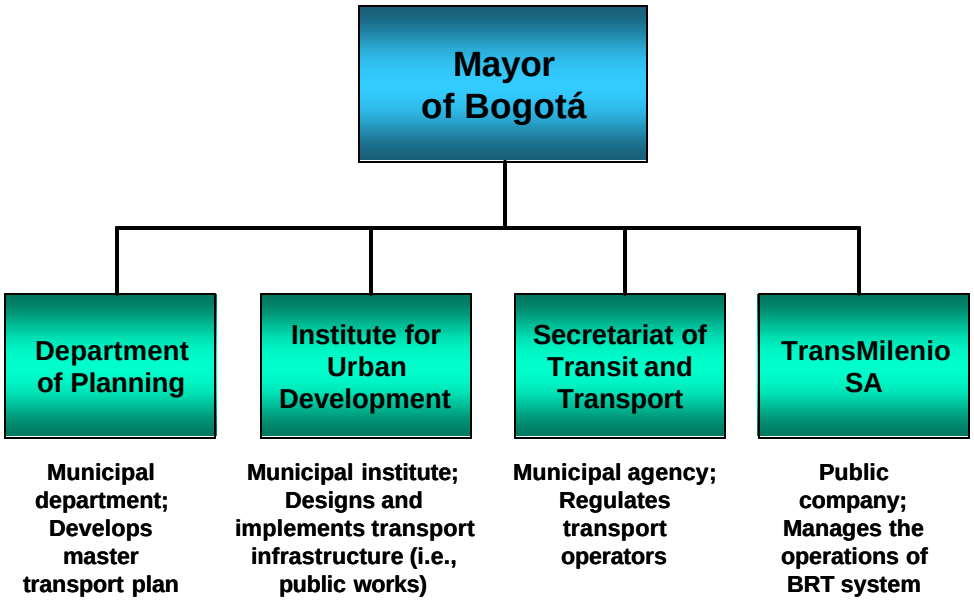
- Mayor of Bogotá

- 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

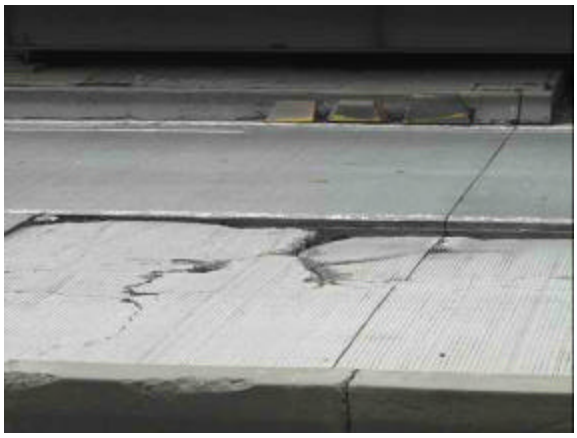
Board meetings are also attended by the General Manager and Assistant General Manager of TransMilenio SA. The staff do not have a vote but are there to answer questions that may arise. The Board of Directors is also served by financial and accounting specialists who can evaluate financial audits of the system.

TransMilenio SA focuses upon mostly on the operational and contracting aspects of managing the BRT system. The organisation is also involved in planning and financial aspects of the system but in coordination with other agencies. Specifically, the city's Institute for Urban Development (IDU) holds responsibility on delivering the system's infrastructure. In many cities, this responsibility is given to a "public works" department. Bogotá also has a Secretariat of Transit and Transport (STT), which plays a regulatory role in the overall bus transit system. STT continues to regulate and license the conventional bus services that still operate in many parts of the city. Figure 85 provides a schematic of the different institutional entities with a role in the Bogotá transport sector.

**Figure 85 Transport institutions in Bogotá**




Smaller, specialised agencies can be more efficient and more customer responsive than larger organisations. TransMilenio SA is able to manage a BRT system that currently serves nearly one million passenger trips per day with a staff of only approximately 70 persons.



Despite the relative efficiency of a small public company like TransMilenio, such specialised entities do bring with them other challenges. TransMilenio SA has interfaced well with the city's transport regulator and public works department, but in other cities, conflicts between such organisations can stifle progress on transit initiatives. Disagreements and "turf" conflicts can over-ride other shared values between agencies. Further, when problems arise, each organisation can blame the other without anyone taking responsibility. A recent problem with material failures on the concrete busways in Bogotá demonstrated the ease in which responsibility can be denied amongst a complex group of actors (Figure 86).

However, Bogotá's introduction of a new organisation, TransMilenio SA, provided a crucial catalyst to innovation. Trying to implement a radically different transit product through an existing entity can be difficult. Entrenched mindsets and vested interests can stifle the creativity required to develop a bold new approach such as BRT. Thus, by bringing together an entirely new team with a fresh perspective, Bogotá created something quite special. For other cities, the development of a new institutional entity may also be necessary in order to avoid established agencies that have a reputation for inefficiency and corruption. It would be unlikely to be able to create a major new initiative in such an environment. Further, given the legal and political difficulties in re-shaping existing agencies and replacing civil service staff, changing the existing agency structure and mindset may not be realistic within the confines of a relatively short political term.

London and Bogotá possess widely different institutional arrangements to oversee their transit services. While TfL is a broad-based organisation with multiple roles and TransMilenio is a smaller, more focused public company, both organisations have achieved considerable success. The lessons from London and Bogotá show that while the form of the institutional structure is highly dependent on local circumstances, bus priority measures can succeed in a variety of institutional forms when innovation and competitiveness are introduced.

### 3.5.3 Incentives for competition

#### 3.5.3.1 Qualities of a successful incentive scheme

The right set of financial incentives can encourage contractors and concessioned firms to operate a BRT system at the highest levels of quality and performance. The wrong set of incentives will cause operators to compete against each other in a manner that risks financial sustainability and customer safety. The success of BRT systems such as Bogotá and Curitiba owe much to achieving an incentive structure that is a win for the operators, a win for the municipality, and most importantly, a win for the customer.

For a “closed” type BRT system, incentive mechanisms can be erected in at least two distinct areas. First, an incentive bidding scheme can be established to determine which operators should be allowed to gain access to the system. Second, once the operators are in place, “quality incentive contracting” can be utilised to ensure that the firms are properly motivated to achieve high levels of service.

A successful incentives process will likely evoke the following qualities:

- Transparency
- Clarity
- Simplicity
- Integrity
- Risk

*Transparency* and *clarity* refer to the development of a contracting and concessions process that is open and fair to all. The bidding processes should 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 minimised. Dates for submission of bidding documents should be chosen to give a fair opportunity for all.

Incentives work best when the opportunities for “gaming” the system are minimised. Ideally, the right incentives will directly lead to competitive behaviour in a positive environment. Simplicity in the structure of the incentive scheme can thus contribute to an environment of contractual clarity. However, simplicity does not mean that contracts and concessions documents will lack the needed legal rigour. Rather, the documents should not be so overly complex that misunderstandings occur or that opportunities for gaming arise.

The *integrity* of the competitive process implies that the contracts will be honoured and respected. For instance, a change of political leadership should not suddenly mean that contracts are forcibly negated or re-negotiated. Maintaining the process’ integrity does not entirely mean that the contracts are completely inflexible. Opportunities for re-negotiation can be explicitly included in the contractual language. However, any such re-negotiation, stemming perhaps from extraordinary circumstances, should involve open and fair procedures.

*Risk* is an important part of ensuring operators and contractors are properly focused upon providing a quality service. The element of risk implies that if operators fail to perform, there will be financial penalties and/or even removal from the system. Without risk, the leveraging ability of the municipality to control system performance is greatly compromised.

#### 3.5.3.2 Non-competitive examples

The introduction of a BRT system is the perfect time to initiate a highly competitive structure for public transport operations. The new system can be a discernible

break from the past and a legitimate time to consider other options. Unfortunately, many cities do not avail themselves upon such an opportunity.

Despite the overwhelming advantages of competitive structures, cities such as Quito, Leon, and Jakarta have elected to essentially "grandfather" the rights of existing operators into the new BRT system. The results are quite predictable. 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 are to repay the municipality for the vehicles using revenues collected from the system. Unfortunately, fare collection is done directly by the operators so the municipality actually has little knowledge on actual passenger counts and revenues. Quite worryingly, the operators' repayment of the articulated vehicles is tied to profit guarantees related to the number of passengers. Clearly, the operators have a strong incentive to underestimate passenger and revenue numbers in order to minimise any repayment of the vehicles.

Leon's BRT structure is likewise skewed towards 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 also does not have a termination date, implying a monopoly in perpetuity. However, on the positive side, the consortium did invest directly in new vehicles.

In Leon, 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 ticketing system and a single fare, fares collected by the feeder buses are kept by the feeder bus operators. The income of the feeder operators is thus based on the number of passengers. The fares collected on the trunk corridors are deposited into a fund established by the consortium. Funds are reportedly distributed to trunk operators on a basis of number of kilometres 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.

Besides the non-transparency and lack of competitiveness within the system, the market design also has negative consequences for quality of service. 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 are collecting the revenues. Not surprisingly, then, the feeder companies provide very little service in the afternoons, and thus make the trip home a relatively unpleasant and difficult experience for the customer. The City is trying to fix the problem by creating a compensating fund. However, the only influence that the City and the State have over the regulation of the system is through a Technical Committee of the Coordinadora de Transporte.

Given the predictable results of manipulation and inefficiency, why do municipalities choose uncompetitive structures such as those in Quito, Leon, 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.

However, the choice between appeasing existing operators and creating a competitive environment is a false one. It is possible to design a system that gives an adequate opportunity to the existing operators without compromising the overall competitive structure.

3.5.3.3 Competitive bidding

*a. Trunk corridor bidding*

The 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 centre management, and infrastructure maintenance.

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
- Environmental quality
- Opportunities for existing operators
- Local manufacturing of vehicles
- International experience and partnerships

Bogotá's competitive bidding process provided the incentives to completely modernise its transit 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 25 provides a summary of the bidding categories and weightings.

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 more manageable groupings. TransMilenio established eligibility criteria that mandated a certain minimum working capital and firms to be legally incorporated as formal businesses. These requirements prompted small operators to seek out partners and to professionalise 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, as was the case in Quito and Leon. This uncertainty provided the necessary risk to drive a more competitive offering.

**Table 25 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 | - | - |
| Experience in operation | Passenger public transport fleet in operation | | 30 | 150 |
| | Specific experience providing passenger services in Colombia | | 50 | 250 |
| | International experience on mass transit projects | | 0 | 50 |
| Economic proposal | Offer price per kilometre to operate the service | | 0 | 350 |
| Proposal to the city | Right of exploitation of the concession | | | |
| | Valuation of the share given to TransMilenio SA from the revenue of the concessionaire | | 21 | 50 |
| | Valuation of the number of buses to be scrapped by the concessionaire | | 14 | 50 |
| Composition of equity structure | Share of company's stock held by former small bus operators | | 32 | 200 |
| Environmental performance | Level of air emissions and noise; disposal plan for liquid and solid wastes | | 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 categorised as ELIGIBLE.

* If the proposal is below any given minimal value, then the proposal will be categorised as NOT ELIGIBLE.

** If the proposal does not meet the established range, then the proposal will be categorised as NOT ELIGIBLE.

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 15 per cent of the total value of the buses being offered to the system. The minimum owner's equity is defined by the formula:

Mininum Owner's Equity = NMV x US$200,000 x 15%
NMV = Maximum number of buses offered to the system

The value of US$ 200,000 is the approximate cost of an articulated bus, based on the specifications required by TransMilenio SA.

“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 passengers are utilised. Companies are 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 operating firms. The idea is to encourage a sharing of knowledge that will improve the performance of the local operators.

The “economic proposal” is perhaps the most important bid category in terms of creating incentives for system that is cost-effective in operation and affordable to the majority of the population. The bid process ensures that firms closely analyse their cost structures to be as competitive as possible.

The salaries, office space, and other costs of the public company, TransMilenio SA, are not funded through municipal payments. Instead, the public company receives a portion of the system revenues. Thus, in the bidding process, the interested private firms must state what percentage of operating revenues will be given to TransMilenio SA.

In order to help eliminate the more polluting vehicles from the city, the private firms 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 over-supply 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 (Figure 87). The process is designed to avoid any corruption or any “leakage” of vehicles to other cities.

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. The bidding firm receives more points for the higher number of shares owned by small bus operators.

During the negotiations between the bidding firms and the small operators, the existing assets of buses, drivers, and capital held by the small companies will likely determine their equity stake.

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 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 instil 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. Marco Polo in conjunction with two local firms has built a fabrication plant in Bogotá (Figure 88) 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 26 summarises some of the characteristics from the successful bids for Phase II trunk lines of TransMilenio.

**Table 26 Successful bids for Phase II trunk lines of TransMilenio**

| Company name | Fleet size | Emis-sions | Price / km (Colombian pesos) | Revenues* to Trans-Milenio (%) | Vehi-cles to scrap | Participation of existing operators | |
|---|---|---|---|---|---|---|---|
| | | | | | | Own-ers | % 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 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Connexión 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 26 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 buses. The final columns set out the amount of participation each firm has given to existing small operators.

*b. Feeder service bidding*

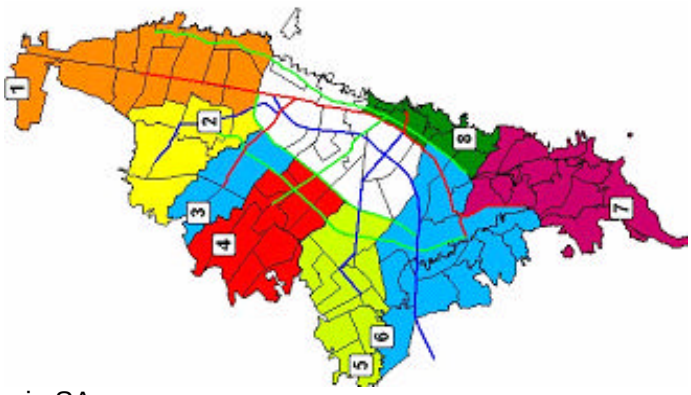
A similar bidding process is conducted for feeder services. Table 26 is a summary of results from TransMilenio Phase II bids for the feeder routes. Due to reasons of practicality, a single feeder company operates in a given zone of the city. A total of eight zones are demarcated for the feeder services in Bogotá (Figure 89). Six of these zones were open to bidding during the tendering process presented in Table 27.

**Table 27 Successful bids for Phase II feeder services of TransMilenio**

| Zone | Company | Price / km (Col. pesos) | Price / passen-ger | Emissions Techno-logy | Vehicles to scrap | Number of owners |
|---|---|---|---|---|---|---|
| Norte | Alnorte Fase 2 | 0.0 | 263.0 | Euro III | 3 | 240 |
| Suba | Alcapital Fase 2 | 0.0 | 260.0 | Euro III | 3 | 457 |
| Calle 80 | TAO | 0.0 | 295.3 | Euro III | 3 | 1151 |
| Americas | ETMA | 279.6 | 292.0 | Euro III | 3 | 807 |
| Sur | Si – 03 | 0.0 | 332.2 | Euro III | 3 | 1333 |
| Usme | Citimovil | 0.0 | 347.1 | Euro III (35%) | 3 | 997 |

Source: TransMilenio SA

**Figure 89 Distribution of feeder zones in Bogotá**




Source: TransMilenio SA

The results of the Phase II bidding for feeder services in Bogotá indicate the great capacity of competitive bidding to achieve particular results. Specifically, the number of existing operators forming partnerships is quite impressive. As many as 1,333 small owners are participating in a single firm within the Phase II bids for feeder services. It is unlikely any sort of mandatory grouping could have derived such a large consortium. The power of the market in conjunction with a well-designed bid process can provide significant motivation to achieve desired results.

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 match the estimated useful life of the new vehicles. Each successful firm thus receives a concession for ten years.

The ten-year concession period 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 are able to purchase new vehicles and amortise the vehicles over the course of the contract.

#### 3.5.3.4 Quality incentive contracts (QICs)

The competitive bidding process ensures that the most able and most cost-effective companies will participate in the BRT system. Likewise, though, it is important to develop the right incentives to ensure continued high-quality service in the system's operation. A "quality incentive contract" is an effective mechanism to encourage operators to deliver excellence in service. In essence, a quality incentive 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 actually be rewarded with additional payments.

Once again, Bogotá provides an excellent example of how quality incentive contracting can be used to motivate operator performance. However, many cities other cities, such as London and Hong Kong, also make use of quality incentive contracts in their bus operations. In the case of Bogotá's TransMilenio system, poor performing operators can experience revenue reductions of up to 10 per cent 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 kilometres travelled, penalties for poor performance are imposed by reducing the number of kilometres 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 28 summarises the types of infractions and their associated penalties.

**Table 28 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, non-functional signal lights, unclean bus, or damaged seating. | 50 kilometres |
| | Failure to follow pre-determined schedules for maintenance, repair, or inspection. | 50 kilometres |
| | Non-functional doors or worn tires. | 100 kilometres |
| | Alteration of or damage to the GPS system or the radio communication system. | 250 kilometres |
| Customer service / operations | Stopping at a different station than the assigned station or not stopping at an assigned station | 25 kilometres |
| | Stopping for a longer period than requested | 25 kilometres |
| | Blocking an intersection | 25 kilometres |
| | Use of stereos, driver's cellular or walkman devices. | 50 kilometres |
| | Parking bus in an unauthorised location | 60 kilometres |
| | Changing route without authorisation | 60 kilometres |
| | Delaying system operation without a valid reason | 60 kilometres |
| | Over-passing another bus with the same route without authorisation | 60 kilometres |
| | Operating during unauthorised hours | 175 kilometres |
| | Permitting the boarding or alighting of passengers in places other than stations. | 250 kilometres |
| | Operating bus on streets different than the formal trunk lines without authorisation | 250 kilometres |
| | Abandoning a bus without a valid reason | 250 kilometres |
| Consistency of driver performance | Performance difference between best operator and other operators, < 20% | 0 kilometres |
| | Performance difference between best operator and | 30 kilometres |

| | | |
|---|---|---|
| | other operators, 20% - 25% | |
| | Performance difference between best operator and other operators, 25% - 30% | 75 kilometres |
| | Performance difference between best operator and other operators, > 30% | 120 kilometres |
| Administrative / institutional | Failure to send reports required by TransMilenio | 50 kilometres |
| | Impeding the work of inspectors from TransMilenio SA | 50 kilometres |
| | Hiding information or providing incorrect information | 50 kilometres |
| | Inappropriate administrative or accounting procedures | 100 kilometres |
| | Abuse of power in relations with staff | 100 kilometres |
| Environmental | Fuel / oil leaks and spillages | 25 kilometres |
| | Noise and air pollutant levels above the levels stipulated in the bid contract.<br>Mishandling of hazardous materials | 50 kilometres<br><br>50 kilometres |
| Security | Any security violations not in compliance with contractual obligations | 100 kilometres 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 29).

**Table 29 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 kilometres |
| Failure to provide first aid | One day suspension | 100 kilometres |
| Refusal to provide customer with information | One day suspension | 100 kilometres |
| Accident between to TransMilenio buses<br>Running red light | Penalty depends upon investigation<br>Immediate suspension | 100 kilometres<br><br>100 kilometres |
| Backing up while on a trunk line | One day suspension | 50 kilometres |
| Possession of a firearm | Immediate suspension | 100 kilometres |
| Disobeying police instructions | One day suspension | 200 kilometres |
| Driving while under the influence of alcohol or other prohibited substances | Immediate suspension | 200 kilometres |
| Accident resulting from an irresponsible action | One day suspension | 200 kilometres |
| Improper approach to station platform | Three times in a single day results in a one day suspension | 50 kilometres |

| | | |
|---|---|---|
| Excess velocity | One day suspension | 100 kilometres |
| Encroachment onto pedestrian crossing | | 100 kilometres |
| Mechanical problems that are not resolved in less than one hour | | 50 kilometres |
| Verbal or physical aggression to passengers | Immediate suspension | 100 kilometres |
| Conducting fare collection on board vehicle | Immediate suspension | 200 kilometres |
| Disobeying instructions from Control Centre or traffic authorities | Immediate suspension | 100 kilometres |

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 centre staff can record average speeds and vehicle movements, and thus staff can determine when speeding or other vehicle violations occur.

Ninety percent of the fines and penalties are collected into 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 penalising poor quality service and then rewarding excellence. In addition, since the penalised operators also forfeit a certain number of kilometres serviced, the well-performing operators also gain by receiving increased service allocations.

Penalised 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.

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 regime, operators will be given the right level of incentives to remain focused on providing a quality product.

#### 3.5.3.5 Duration of concession contracts

The duration of the concession contract affects the potential profitability of the service for the operating company. In turn, the projected profitability will affect the amount of investment the operating company is willing to make towards the system. Longer concession periods will thus tend to increase both profitability and investment levels. However, longer-term concessions have the negative effect of reducing the public sector's flexibility and control over the future direction of the system. Very long-term concessions can result in monopolistic behaviour that ultimately reduces system quality. 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, the ten-year concession period is equated to the expected life of the new transit vehicles. By allowing the operators to fully amortise 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 under-utilised 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.

The optimum concession length will vary by local circumstances and the project's specific cost analysis. Acceptable vehicle ages and amortisation rates will vary. However, the over-riding principal is to select a contract duration that maximises competitiveness and cost effectiveness.

### 3.5.4 Operational cost analysis

Once a framework for the business structure has been determined, the information from section 3.4 (operations) can be integrated to derive an initial operational cost analysis. The calculation of system operating costs will be significant not only for determining tariff levels but also for defining incentives and profitability with operators. Systems in cities such as Bogotá and Curitiba depend upon a strict calculation of operating costs in order to properly distribute revenues between operators, fare collection firms, and system administrators. System designers must also be explicitly aware of the magnitude of operational cost components in order to properly set fare levels.

#### 3.5.4.1 Operating cost elements

Operating costs can be divided into both fixed and variable components. The fixed portion includes the cost of capital and the depreciative value of the rolling stock (buses) assets. Additionally, there will be fixed costs associated directly with system operation such as the salary of drivers, mechanics, and administrative staff. Variable costs will include such operational consumables such as fuel, tires, and lubricants as well as maintenance items. Table 30 provides a summary of operational cost components along with sample values from Bogotá's TransMilenio system. The values shown in Table 30 will vary greatly, depending on local circumstances. For example, labour costs in developing cities may be in the range of 10 percent to 25 percent of total costs. By comparison, labour costs in developed cities can range from 35 percent to 75 percent of total costs.

**Table 30 Operational Cost Components of BRT**

| Item | Measurement units | Consumption per vehicle |
|---|---|---|
| Repayment of Capital | | |
| Vehicle depreciation<br>Cost of capital | % of value of vehicle / year<br>Effective annual interest rate on invested capital | 10%<br>15% |
| Fixed Operating Costs | | |
| Driver salaries | Employees / vehicle | 1.62 |

| | | |
|---|---|---|
| Salaries of mechanics | Employees / vehicle | 0.38 |
| Salaries of administrative personnel and supervisors | Employees / vehicle | 0.32 |
| Other administrative expenses | % of variable costs + maintenance + personnel | 4.0% |
| Fleet insurance | % of value of vehicle / year | 1.8% |
| Variable Operating Costs | | |
| Fuel | Gallons of diesel / 100 km<br>m3 of natural gas / 100 km | 18.6<br>74 |
| Tires<br>- New tires<br>- Retreading | <br>Units / 100,000 km<br>Units / 100,000 km | <br>10.0<br>27.6 |
| Lubricants<br>- Motor<br>- Transmission<br>- Differential<br>- Grease | <br>Quarts of gallon / 10,000 km<br>Quarts of gallon / 10,000 km<br>Quarts of gallon / 10,000 km<br>Kilograms / 10,000 km | <br>78.9<br>4.5<br>5.8<br>3.0 |
| Maintenance | % of value of vehicle / year | 6.0% |

Source: TransMilenio SA, Bogotá, Colombia, June 2002.

The values presented in Table 29 are used to calculate an overall operating cost per kilometre for the system operators. This value is the basis for the renumeration given to the concessioned firms providing the transit services.

When comparing such operating cost values between mass transit modes (e.g., BRT with rail), one must be certain that a like for like comparison of variables is being made. BRT systems typically amortise vehicle purchase costs within the operating cost calculation while rail systems sometimes list rolling stock as a capital cost. Further, because of rail's high cost structure, certain maintenance and replacement part items are sometimes capitalised. To make a correct comparison, adjustments will need to be made to ensure capital and operating costs are appropriately categorised.

The initial analysis of operating costs will depend on many assumptions about the ultimate design and operation of the system. Undoubtedly, these factors will change as the planning process progresses. Further, the initial estimation may also utilise base values from other cities that may not be wholly applicable to the local situation. Nevertheless, the initial analysis of operating costs provides an important first step in understanding the potential financial viability of the system. As the planning process continues, a feedback loop between design and operating costs can help the decision making process.

#### 3.5.4.2 Capital costs versus operating costs

In general, the division between capital costs and operating costs are quite clear. The capital costs represent the initial investment required to establish the system. Thus, infrastructure costs fall into the category of capital costs. Operating costs refer to those costs that occur during the operation of the system over the life of the infrastructure. Thus, labour, fuel, and maintenance costs typically fall into the category of operating costs.

In most BRT systems, the classification of capital costs versus 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 utilise 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 upon local circumstances.

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. For example, many African nations have per capita incomes of US$ 200 or less. 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. In general, it is quite desirable to avoid operating subsidies since the subsidy process adds much administrative complexity to the system, as well as creates opportunities for the misappropriation of funds.

However, moving equipment purchases to the capital cost category can bring with it some unintended consequences. In general, it is best to have the companies utilising the equipment to pay for it and to maintain it. Companies that operate buses that they do not purchase or do not own the vehicles will tend to not maintain the vehicles properly. These companies may also not pursue the most cost-effective models at the time of purchase. Thus, public procurement of equipment can result in many misplaced incentives. A compromise to such circumstances 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 for 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 their own vehicles, based upon 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 tariff.

There are also circumstances that

may permit the shifting of costs in the other direction, from capital costs towards operating costs. 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 (Figure 90). The private fare collection firm thus amortises the cost of this infrastructure through their share of the fare revenue. In effect, the concessioned firm is acting as a financing agent for the particular piece of infrastructure.

Although less common, the maintenance of the BRT infrastructure (busways, stations, etc.) may be another area where costs can be moved from public responsibility to the private sector. System maintenance is most commonly performed by a public entity. However, on some busway corridors in Sao Paulo (Brazil), the private operators are providing the maintenance of the stations and roadways. The private operators agreed to the provision of road and station maintenance in exchange for a longer-term concession. Previously, the operators paid 15 percent of their revenues to the public transit authority (EMTU) to provide roadway maintenance. The public entity, though, delivered relatively poor maintenance services. The resulting poor quality of the roadways meant that the vehicles would incur higher maintenance costs. Thus, an agreement was reached in which the private operators would be responsible for infrastructure maintenance. Since the operators' own operating costs are affected by the quality of the infrastructure, they have a significant incentive to maintain it to higher standards.

The Sao Paulo example, though, is relatively rare. While private operator responsibility for maintaining system infrastructure does make some sense from an incentive perspective, it does create other cost and quality issues. To accommodate the maintenance costs, a longer concession period is offered. The longer concession implies that the public authority has less flexibility in shaping the system as circumstances change. Longer concession periods can thus result in oligopolistic behaviour that ultimately reduces the quality of the service.

### 3.5.5 Tariff options

Tariff levels will greatly determine the ultimate size of the customer base and the segments of society that can afford to use the system. The tariff levels will also determine the financial stability and sustainability of the overall system. Fortunately, the relative cost effectiveness of BRT compared to other mass transit options means that operating subsidies are typically not necessary, even with readily affordable fares. The avoidance of public subsidies can greatly simplify system management as well as reduce the continual need to justify a system's financing with public officials and the electorate.

#### 3.5.5.1 Tariff levels

The actual tariff charged to the customer will depend upon many factors and decisions. Most importantly, the cost levels of operating the system are a principal consideration. To avoid the need for an operational subsidy, covering these basic

costs is essential. Thus, a starting point for considering tariff levels is an analysis of operational costs (see section 3.5.4). To the extent possible, most developing cities structure BRT systems to avoid operating subsidies. By avoiding subsidies, the city is also avoiding the complexity and added costs of managing a subsidy scheme. Further, the appearance of subsidies generally creates a negative public perception on a system that is unable to pay its own way. Few developing cities are equipped to commit to long-term transport subsidies, especially in the face of other basic needs such as education, electricity, health care, water, and sanitation. Thus, a viability test for a new public transport system is whether expected operating costs can be covered by the proposed fare level.

Of course, affordability is also a primary consideration. If the proposed fare levels consume a large percentage of the daily income of low-income citizens, then the system will fail to deliver its social development objectives. The elasticity of demand for low-income groups can be quite high. Low-income residents may not place a high premium on reduced travel times, and thus may continue to utilise lower-cost options even with the improvements presented by a BRT system. Nevertheless, some price premium can be acceptable, especially if the proposed BRT system is providing a significant improvement over existing informal services.

In the case of Bogotá, the city permitted the existing operators to increase fares one year prior to the introduction of the TransMilenio service. While the population was not entirely pleased with the increases, in general, any displeasure was directed at the private operators and not the municipality. Thus, when TransMilenio was finally introduced into operation, the cost was approximately the same as the existing services. In other cases, such as Quito, the BRT service was introduced at a slight premium to the existing services. However, the vast difference in quality between the new system and the previous older buses meant that the public was supportive of the new system.

Thus, as noted, an initial estimation of potential tariff levels can be achieved through an initial calculation of operating costs (see section 3.5.4), an analysis of tariff levels with existing services, and an understanding of affordability levels for different segments of society.

#### 3.5.5.2 Tariff types

There are two types of tariffs used in the fare calculation process. The first is the "customer tariff", which is the fare price seen by the customer. The second tariff is the "technical tariff", which reflects the actual cost per passenger of operating the system. In the case of Bogotá's TransMilenio, the customer tariff is slightly higher than the technical tariff. This difference occurs because TransMilenio also generates what is known as a "Contingency Fund" (equation 4).

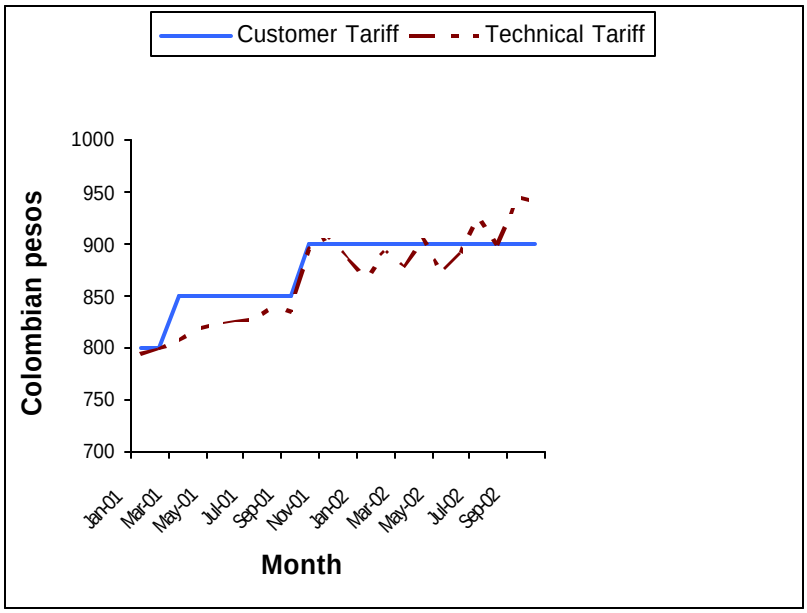
**Equation 4**

| | | | | |
|---|---|---|---|---|
| **Contingency fund** | **=** | **Revenues based on customer tariff** | **-** | **Revenues based on technical tariff** |

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 tariff will be greater than the technical tariff, and thus the contingency fund will build up a positive balance. When unforeseen circumstances occur and the technical tariff exceeds the customer tariff, then proceeds from the contingency fund will be drawn upon for a temporary period. If the changed circumstances become permanent, then an increase to the customer tariff can be expected in order to ensure the financial stability of the system.

Figure 91 graphs the customer tariff and the technical tariff for Bogotá's TransMilenio system for the system's first 22 months of operation. As expected, the customer tariff is generally greater than the technical tariff. As the technical tariff has increased with time, the customer tariff has also increased in order to maintain a comfortable margin. The graphic also demonstrates the difference in fluctuations between each tariff types. The customer tariff 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 91 Changes in customer tariff and technical tariff with time**




Source: TransMilenio SA

3.5.5.3 Fare adjustments

During the course of a ten-year concession, there are undoubtedly cost elements that will change with time. Fuel prices will vary based on world demand. Base labour 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, a system is needed to adjust fares as base costs elements change.

Unfortunately, costs tend to rise over time, implying that fares must also rise. However, raising fare costs to the public can be politically difficult. If a transit 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 upon key trigger points.

In the case of Bogotá, all operating costs are calculated on a bi-weekly basis. If a particular trigger point is reached (such as the technical tariff exceeding the customer tariff), then a fare adjustment is authorised by the municipality. The mayor and other political officials are still involved in the authorisation 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. Fare level changes should not be frequent events; otherwise customers can become confused and angry. 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 short-falls. The contingency fund thus provides a buffer that allows the system management company to stabilise fare levels even in turbulent times.

#### 3.5.5.4 Fare discounts

Segmenting markets by fare levels can make sense from both a business and social standpoint. Providing fare discounts to special groups is a relatively common practice in mass transit systems around the world. However, a fare discount system can add considerable complexity to the fare collection and fare verification processes. Further, unless effectively designed, fare discounts can also lead to wide-spread fraud within the system.

Some of the groups that often receive fare discounts are:

- Children
- Students
- Elderly
- Frequent users

An additional type of discount sometimes employed relates to travel during non-peak times. Since peak-hour travel can strain system resources, encouraging shifts to non-peak times can be beneficial. Thus, a lower fare during non-peak hours can help balance demand and reduce overall system costs.

The determination of discount eligibility for children and the elderly is typically based upon age limits. For example, system managers and operators may decide that children under five years of age and adults over 60 years of age qualify for special discounts. The determination of student eligibility is often predicated upon either age limits and/or the possession of a valid student identification. Student discounts may be limited to only certain student segments, such as primary, middle, secondary, and university levels of education. A frequent user is typically determined by the mere purchase of a monthly or annual travel pass, regardless of other customer characteristics.

Discounts to children, students, and the elderly are typically given for reasons of social equity. Discounts to frequent users via monthly passes are sometimes given as a means to attract customer loyalty and to ensure a solid ridership base. Economically, a discount strategy can make sense provided that the discounted fare covers at least the marginal cost of each passenger. 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 utilised, it is usually best for the discounted fares to at least cover marginal costs.

Discounted fare systems are also highly susceptible to fraud. As noted above, the qualifications for a child, student, or elderly discount is 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 worryingly is the development of a grey 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 amongst several persons.

There are mechanisms to combat fare fraud to an extent. First, the avoidance of discount passes that allow unlimited travel is recommended. Instead, discount fare passes that deduct credits for each trip undertaken can somewhat help avoid shared passes. Second, advances in biometric technologies can quite effectively eliminate unauthorised usages. Biometric systems use inherent biological information, such as fingerprints or iris pattern, to assure that the person using the transit pass is the same as the person who was issued the pass. At the point of entry a scan verifies the identity of the user. The current cost of biometric technology, its complexity, and its impact on the speed of fare verification mean that it is not expected to be in widespread use for the short to medium term. However, the city of Goiania (Brazil) is already testing such systems. Thus as the technology improves and the costs decrease, biometric systems may have a future role in fare verification processes.

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. 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.

An effective fare discount system also implies the need for more costly fare collection and fare verification technologies, such as magnetic strip or smart card technologies. The software to incorporate a fare discount system within these technologies will increase fare collection and verification costs to a degree. Further, the added complexity is another factor that can lead to system failure.

In summary, fare discounts are well-meaning attempts to increase affordability and social equity within a transit 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.

3.5.5.5 Fare-free systems

A relatively new approach to transit fares is to eliminate the fares altogether. Transit systems in Belgium have realised that their fare collection process is actually so costly that it makes sense just to provide free transit. By eliminating the fare fees for transit, there is no need for fare collection and fare verification equipment, no smart cards or other fare mediums, and no customer wait times for fare purchases. Further, the design of bus interiors and stations is void of the requirements from the fare system.

Of course, the main benefit from fare-free systems is the impact on passenger numbers. In Hasselt (Belgium), bus patronage jumped from 23,000 passengers per month to 300,000 passengers 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 in much of Belgium.

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.

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 kilometres 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, petrol taxes, and parking fees.

### 3.5.6 Collection and distribution of revenues

The distribution of revenues is another process which will greatly influence the behaviour of the system operators. Distributing revenues on a basis of the number

of passengers or on a basis of kilometres travelled will affect behaviour in different ways.

#### 3.5.6.1 Fundamentals of revenue distribution

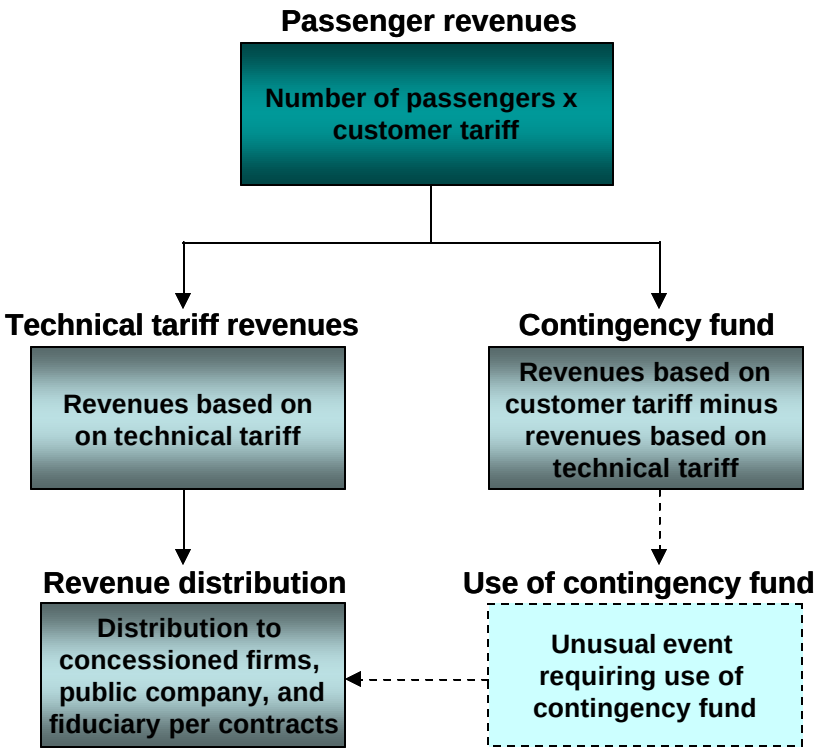
Traditionally, the handling of fare revenues in a developing-city transit system is a rather opaque process. Portions of the fares may be kept by conductors or drivers with understood amounts being handed over to owners. There also may be payments to police or other official entities. As such, this process does not lend itself to a transparent business model in which the public interest is carefully weighed. This process also inherently rewards drivers to maximise the number of passengers they collect during the day. With the incentive of maximising passengers, drivers then work in a manner that can conflict with public safety and rider comfort.

The transparent and fair distribution of revenues is fundamental to operating a network of integrated transit providers. If operators do not have confidence in the distribution of revenues, then their behaviour will revert to self-interested actions that undermine customer satisfaction. The most important elements in a transparent system for revenue distribution are:

1. A business and institutional structure that provides for an independent fare collection system;
2. Checks and balances in place to verify revenues at different stages of process;
3. Revenues distributed based upon a clear set of rules and procedures;
4. An independent auditing system.

Figure 92 outlines the general process of fare collection and revenue distribution in Bogotá. The fare collection and fare verification system is managed by a separate private company that successfully bid for the fare handling concession. The fare handling company has no involvement with any of the bus operating companies on the BRT system. In Bogotá, the bus operators and their drivers never handle customer fares. Alleviating bus operators of this responsibility reduces system delays due to on-board fare collection and also reduces the likelihood of misappropriation of the revenues.

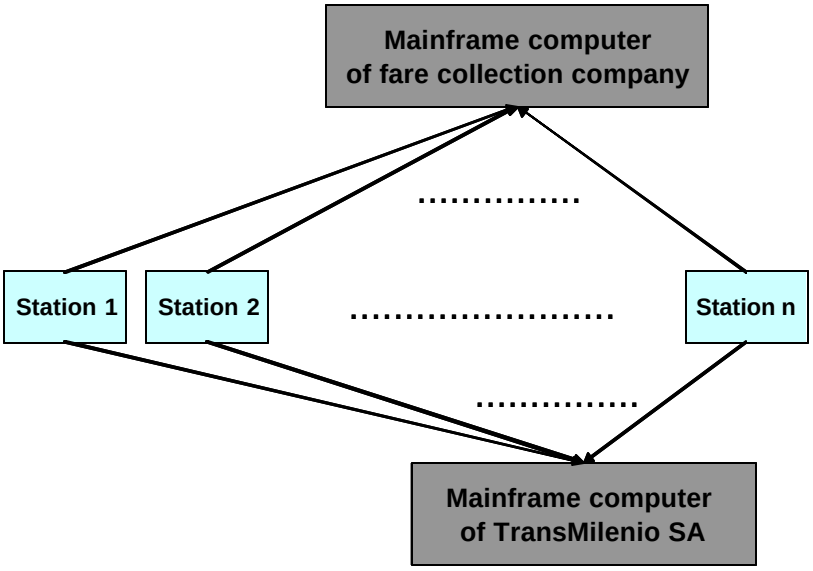
**Figure 92 Revenue flows**




3.5.6.2 Revenue verification

In systems such as Bogotá where smart card fare systems are utilised, the data from the electronic system can act as a verification of the revenues collected. The revenues from a particular station or terminal should match the electronic records of the passengers entering the system. In the case of TransMilenio, the electronic records are actually independently verified in two locations. The electronic data is downloaded to mainframe computers at both the fare collection company and the public management company (Figure 93). This sort of electronic verification is an effective mechanism in building the confidence level of all parties in the fare collection system.

**Figure 93 Electronic verification of fare information**




Source: TransMilenio SA

3.5.6.3 Feeder fare collection

As noted, fare revenues on the trunk corridors can be collected and verified by a concessioned private firm. Fare collection on feeder routes can be more complicated. Typically, the same fare collection infrastructure cannot be cost justified on feeder routes. Further, the lack of closed stations on feeder routes creates physical challenges to controlling passenger fares.

Thus, the fare handling system for feeder services will often follow a different operational process than the fare system for trunk lines. Cities such as Bogotá and Quito now compensate feeder operators by a combination of the vehicle-kilometres travelled and the number of passengers carried. This compensation package attempts to balance incentives in order to motivate operators to provide a 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 passengers boarding at feeder shelters. Instead passengers only pay once they reach the terminal stations or intermediate transfer stations. For the return trip home, passengers pay upon entering the trunk-line corridor, and then transfer fare free to the feeder services. However, for the return trip, entry into the feeder service is restricted to those persons collecting a transfer slip upon exiting the trunk service (Figure 94). This system holds the advantage of not making the feeder operators handle any revenues from passengers. 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 passengers to travel from one feeder stop to another feeder stop without paying anything. This situation occurs due to the fact that payment is only made once passengers 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 neighbourhood 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 kilometres travelled to being a combination of kilometres travelled and passengers carried. It is possible that the addition of passengers 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 passengers 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. Passengers 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 bus to continue to the next stop while passengers are being processed through fare collection. The reservoir concept is already utilised extensively in countries like 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 labour costs in conjunction with political needs to maximise 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 passenger volumes are sufficiently high, then other options utilising more sophisticated fare technologies may be possible. These options include:

- Fare collection vending machines at feeder shelters (either open or closed shelters)
- Smart card readers upon entering a closed feeder station

- ✍ Smart card readers upon entering the feeder vehicle

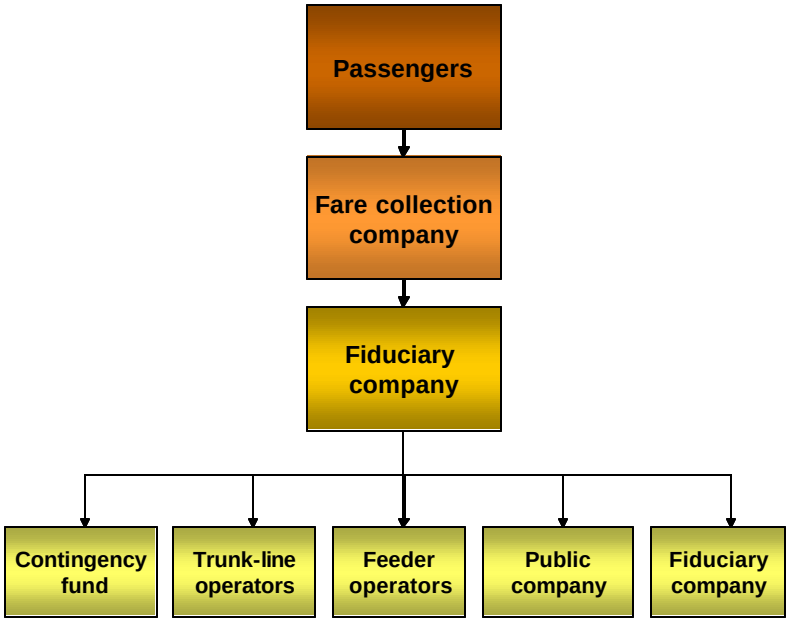
Cities such as London are utilising coin-fed fare collection machines at conventional open bus stations. This type of technology could be adaptable to feeder services in some developing cities. If the shelter was closed (i.e., no entrance without fare payment), then a coin-based or even smart-card based system could permit entrance to the shelter. Alternatively, a fare card purchased at a vending machine in an "open" shelter 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 honour system where passengers self-validate their fare tickets. If smart cards are utilised, 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 "honour" payment and verification systems in developing cities is still not proven. Fourth, costly fare collection machines left unprotected at feeder shelters could be subject to maintenance issues and even theft.

#### 3.5.6.4 Revenue distribution

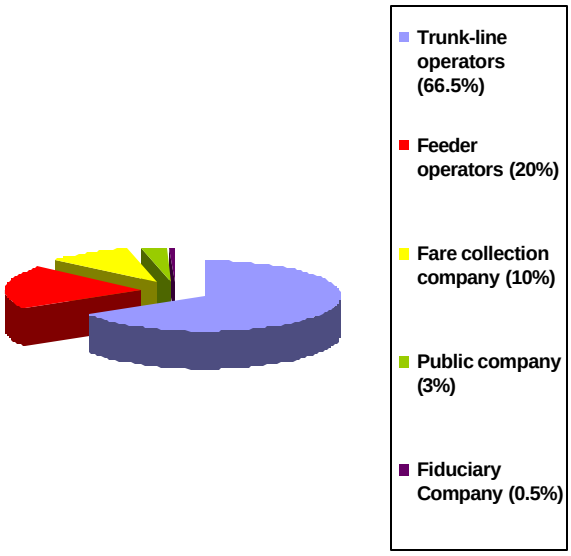
In Bogotá, the concessioned fare collection company does not actually distribute the revenues to the bus operating companies. Since the fare collection company itself is due part of the proceeds, it would be a source of potential suspicion if the fare collection company was to fulfil this function. Instead, an independent fiduciary company (such as a bank) is the depository of the actual fares. At this stage, the public oversight company will then use the agreed upon formulas from the concession agreements to distribute revenues amongst the operating companies. Thus, the actual handling of the revenues follows the path outlined in Figure 95.

**Figure 95 Flow of fare revenues through distribution process**




For TransMilenio, most of the revenues are distributed to the concessioned private operators who are providing either trunk line (66.5% of revenues) or feeder services (20% of revenues). These percentages were pre-determined based on negotiations and the terms of the bid process. The company with the concession for the fare collection receives 10% of the technical tariff revenues. TransMilenio SA, the public company with overall management responsibility for the system, receives 3%. Finally, the fiduciary company, called the Trust Fund Administrator, retains 0.5% of the technical tariff revenues. The fiduciary company is responsible for managing the incoming assets as well as distributing the funds to the other entities. Figure 96 summarises these distribution amounts.

**Figure 96 Distribution of system revenues from TransMilenio**

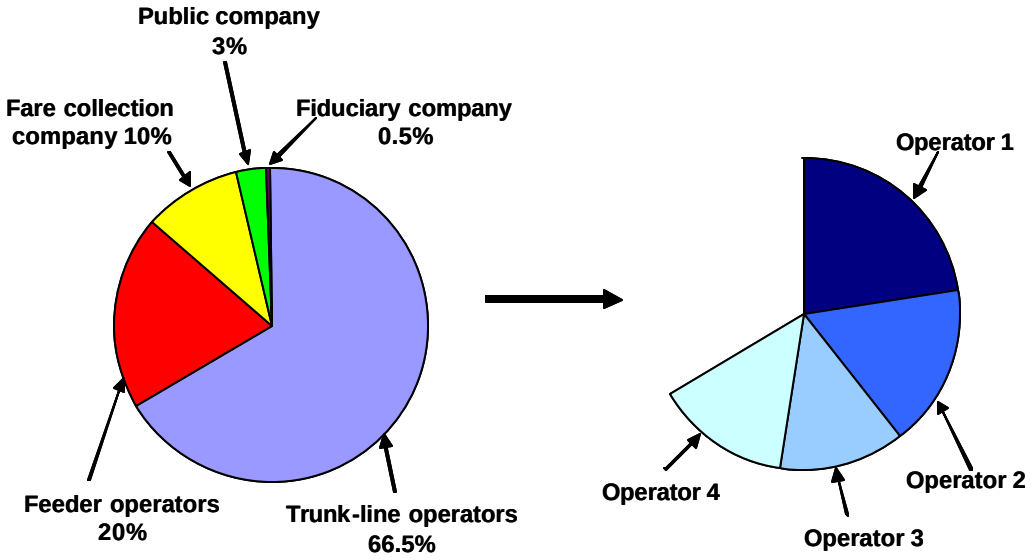


The categories of "trunk-line operators" and "feeder operators" actually consist of many different private firms. Thus, there is a further distribution process to divide these shares to each of the participating operating companies.

As noted earlier, the trunk-line operators are compensated strictly upon the number of kilometres travelled. The distribution of revenues based on distance travelled helps eliminate aggressive behaviour between operators. If the operators were instead compensated by the number of actual passengers carried, then each operator would seek to maximise their own passenger counts . This sort of incentive could lead to dangerous driving and poor customer service.

The number of kilometres each operating company is assigned is negotiated beforehand amongst all the interested parties. In some cases, there will be adjustments based upon any fines that an operating company has incurred. Thus, the revenue distribution process to the trunk-line operators looks something like the process shown in Figure 97.

**Figure 97 Distribution of revenues to trunk-line operators**




The basis for revenue distribution to feeder services is somewhat different than the trunk-line operators. On the trunk-line corridors, the activities of the operators are relatively controlled, due to the fixed nature of busways and the control centre oversight. Driver infractions such as not stopping at a station are readily observable on the trunk lines. However, feeder services are less easily monitored and controlled. Thus, the revenue distribution system must account for any misplaced incentives.

For example, if the feeder services are compensated exclusively based on kilometres travelled, then the feeder operators have an incentive to drive as quickly as possible without picking up any passengers. Conversely, if the feeder operators are compensated exclusively on the number of passengers, then the operators will not operate during non-peak periods. Also, when the compensation is exclusively based on passenger numbers, the feeder operators are exposed to considerable

demand risk. Thus, the right incentive package for feeder operators may be compensation based upon BOTH the number of kilometres travelled and the number of passengers carried. In this scenario, the operators have an incentive to both provide services across the daily schedule and to cater to passenger needs. In both Bogotá and Quito, feeder services were originally compensated only by the number of passengers served. However, both of these cities have now switched to a combined incentive scheme (distance travelled and passengers served) in order to improve feeder performance.

#### 3.5.6.5 Auditing the process

The entire process should be independently audited by another professional firm. This auditing process provides a check on the handling of revenues by the fare collection company and the fiduciary company.

The auditing process in conjunction with the electronic verification of fares collected, as well as the presence of the fiduciary company, all help contribute to an environment of confidence in the system. Without such a rigorous and transparent process, operators would be less trustful of the system and less willing to act in a manner supporting the common good.

## 3.6 Planning Stage VI: Infrastructure

The physical design of the BRT system begins to give the project a physical 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. The infrastructure components include:

- Busway infrastructure
- Feeder infrastructure
- Stations
- Intermediate transfer stations
- Terminals
- Depots
- Control centre
- Pedestrian infrastructure
- Bicycle infrastructure
- Commercial space
- Traffic control signals
- Public utilities (electricity, gas, water, sewage, telephone, etc.)
- Landscape

The design and engineering of these components is dependent upon several key factors that will dictate the eventual form of the infrastructure. Theses factors include: cost, functional attributes, and aesthetic attributes. Like so many topics in BRT, there is no one correct solution to infrastructure design. Much depends upon local circumstances such as climatic and topological conditions, cost structures, and cultural preferences. For instance, what is aesthetically pleasing in one culture will not be considered as such in another.

The physical design and engineering of the system directly follows from the operational characteristics chosen in section 3.4. The corridor selected, expected capacities, and service options all influence the physical design. However, the physical design may also exert influence on the operational characteristics as well. Given the varying cost ramifications of different physical designs, several iterations between operational design and physical infrastructure design may be required. Thus, physical or financial limitations that are placed upon infrastructure design can necessitate a revision of the previous work on operational characteristics.

The initial stage in the infrastructure design process is to develop a conceptual design framework for the system. Based upon the inputs from the previous demand modelling and the operational study, the physical location and initial designs are completed for the various infrastructure elements. 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, detailed engineering designs can proceed.

The topics presented in Planning Stage VI, “Infrastructure”, are as follows:

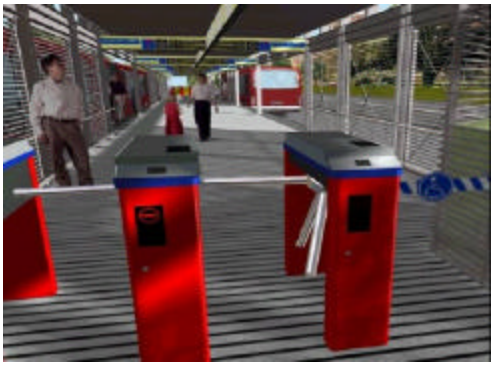
### 3.6.1 Conceptual study versus detailed engineering study

The level of detail in the infrastructure plan will evolve as the BRT project progresses. In the first stage, conceptual designs will be developed in tandem with the emerging operational plan. More detailed engineering analyses will follow once the conceptual study and the initial cost estimates warrant a commitment towards a particular design. Thus, for each infrastructure component discussed in this section (e.g., busways, stations, terminals, etc.), the planning team will first complete a conceptual study prior to moving towards more detailed engineering plans and specifications.

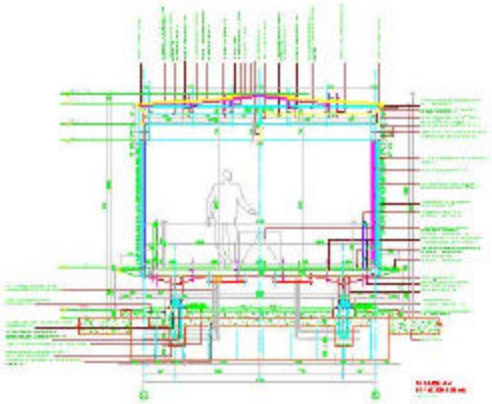
#### 3.6.1.1 Conceptual study

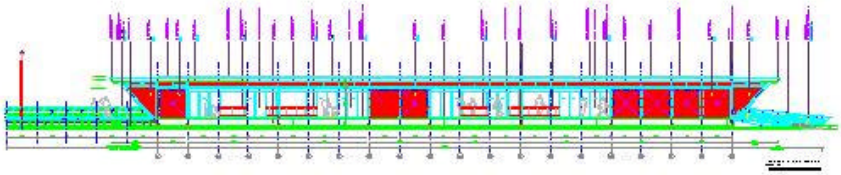
The infrastructure conceptual study should provide a reasonable level of detail so that decision-makers may properly evaluate the cost, functionality, and aesthetics of the proposed system. Thus, the conceptual study will include overall dimensions of the infrastructure components, basic drawings, and sufficient description to develop an initial cost estimate.

Many of the initial artistic impressions and drawings of the system infrastructure will be used to help decision-makers and interested parties to begin to visualise the system. Figures 98 and 99 are examples of these types of drawings.



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 100 and 101 are examples of these types of drawings.





3.6.1.2 Detailed engineering study and design specifications

Once a conceptual design is completed and initial cost estimations are within an acceptable range, then more detailed engineering work can be undertaken. 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.

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.

### 3.6.2 Busways

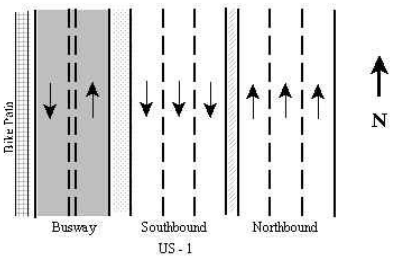
#### 3.6.2.1 Lane selection

The location of the segregated busway within a specific roadway is a design decision that holds more options than might be immediately apparent. The most common option is to locate the busway in the centre median or in the centre two lanes (Figure 102). This configuration reduces turning conflicts to the right (in countries that drive on the right-hand side of the street). The median location also permits a central station to serve both busway directions. A single station reduces infrastructure costs in comparison to the construction of separate stations for each direction. The median-based station also allows for more integration options with busway lines that may cross on a perpendicular street. It is far simpler to link two median stations by way of tunnels or bridges than trying to link four stations along the sides of the roadway. Two corridors may also be linked by having bus routes turn onto the perpendicular busway. Again, a median station is advantageous as customers have the option of changing routes and selecting from multiple directions within a single station.

Along with a centre lane configuration option, one can opt for either “with flow” or “counter-flow” bus movements. “With flow” means that the buses drive in the same direction as the mixed traffic in the adjoining lanes. “Counter flow” means that the buses drive in the opposite direction of mixed traffic (Figure 103). “Counter flow” is sometimes used if the doorways on the existing buses require the bus to drive on a certain side. Obviously, it is preferable to derive the bus design from the optimum busway design, but this situation is not always possible. “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.

Beyond the centre lane configuration, there exists a full range of alternatives that all too often do not receive complete consideration. In Miami, the two busway lanes operate entirely on one side of the roadway while the mixed traffic is given several

lanes (in both directions) on the other side (Figure 104). This configuration works well when one side of the road lacks many turn offs, such as when a roadway runs along a body of water or a large park. In Orlando, a similar concept is used but with a roadway of significantly fewer lanes (Figure 105). In some cases it may be possible to give over the entire roadway to the BRT system. In Pittsburgh, USA, the East and West busways operate on exclusive road networks that have virtually no interactions with mixed traffic. The East busway is in fact a former rail corridor. Likewise, segments of the Brisbane busway system operate on streets with exclusive use for BRT vehicles (Figure 106).



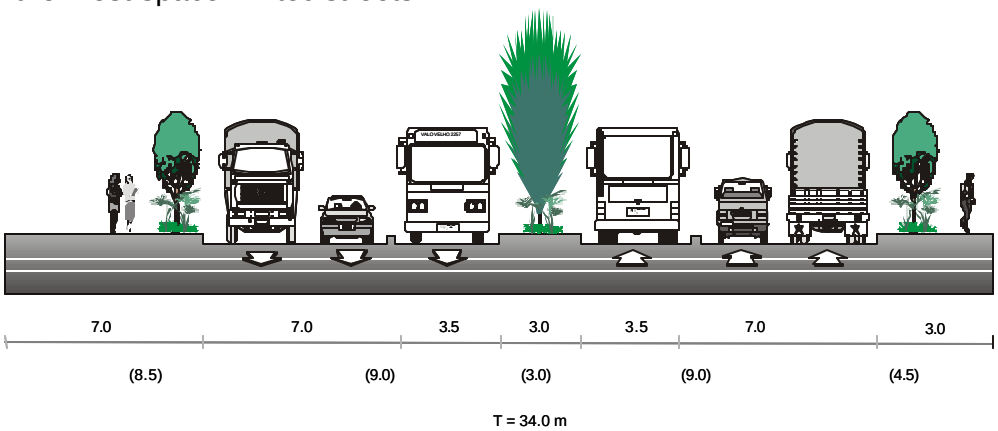

A surprisingly rare BRT configuration is the placement of the busway on the sides of the roadway. While this configuration is fairly common with bus lanes, busways generally do not utilise the design, primarily because of the conflicts with turning traffic. Such conflicts will greatly inhibit the system's capacity. Achieving capacities over 5,000 passengers per hour per direction is quite difficult if vehicles are frequently interfering with busway operations. Turning vehicles create the potential for the entire busway to be stopped due to an accident or congestion. Such a configuration also creates difficulty when trying to allow free-flow transfers between perpendicular lines. To do so, one would have to construct a rather elaborate set of overhead or underground pedestrian passages to keep the system closed off. In general, customers will not pay twice merely to change directions.

Like many other design decisions associated with BRT, there is no one correct solution to roadway configuration. Much depends upon the local circumstances. Additionally, it may be possible to use several different configurations in a single system. Curitiba, Brazil uses centre lanes, both lanes on the side, and streets exclusively for BRT (Figures 107, 108, and 109). It most cases the only limitation is to keep the doorway on the same side, so that one has the flexibility to use the same buses on multiple lines. However, even this caveat has been circumvented in some cases; Porto Alegre possesses buses with doorways on both sides to allow maximum flexibility.



3.6.2.2 Busway dimensions

The availability of road space will likely be a significant design consideration in the development of the busway. Providing space for busways, pedestrian and bicycle access areas, and mixed traffic lanes can be a challenge when given the inherent limitations of existing road widths. However, typically solutions can be found to even the most space-limited streets.



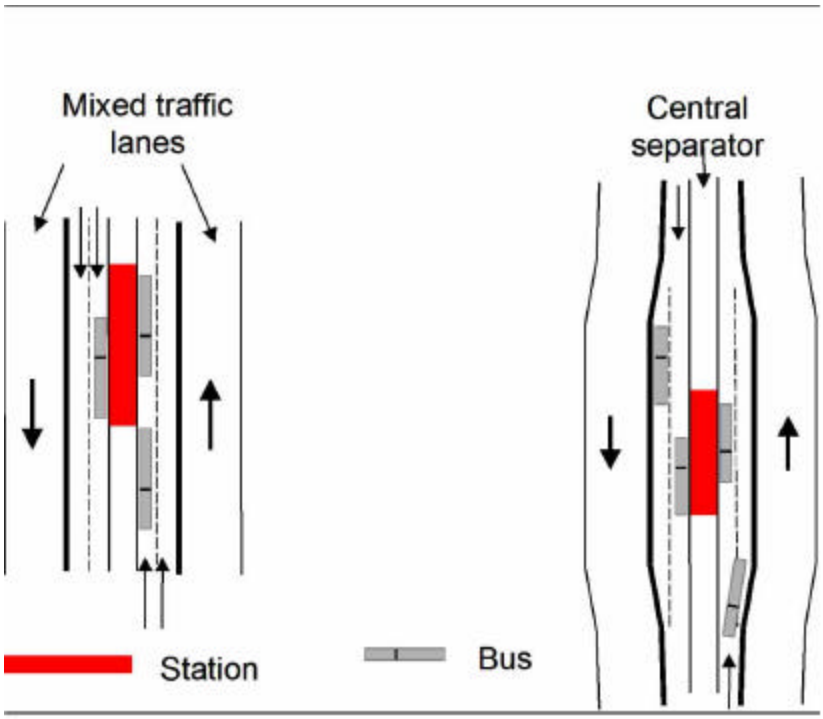

Buses are generally in the area of 2.6 metres in width. To provide safe manoeuvring space for the vehicles, a standard lane of 3.5 metres is typically provided. As lanes narrow, the safe operating speed of the vehicle will likely be reduced. The width of a median station will vary depending on customer flows, but, in general, a median station will range from 2 metres to 5 metres in width. A typical roadway cross-section is presented in Figure 110.


If sufficient road space is not available to meet a preferred design option, there are still options for municipal officials to consider. Eliminating some mixed traffic lanes may seem politically difficult to achieve, but by doing so, the resulting design provides a strong incentive for shifts

to the new system. Further, the promise of a new, high-quality mass transit system can help stem concerns over reduced space for private vehicles. Quito has managed to develop a busway along an extremely narrow corridor in its historical centre. In this instance, the city was able to provide an exclusive busway with as little as 3.2 metres in road width (Figure 111). Other options include the grade separation of the bus infrastructure through the use of underpasses, tunnels, and overpasses.

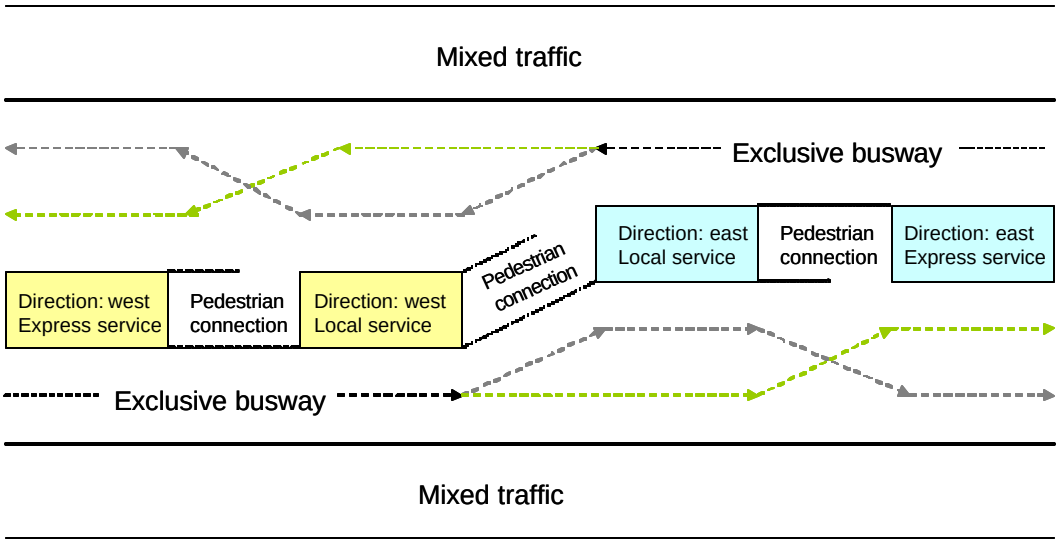
3.6.2.3 Passing lanes

With a single busway lane in each direction, a BRT system will reach a capacity limit at approximately 14,000 passengers per hour per direction (pphpd) (see table 19). This capacity level can be increased with the platooning of vehicles and multiple stopping bays, but such a configuration is relatively complex to manage and control. Instead, for capacities above 14,000 pphpd the best option may be to consider a passing lane at stations or even a second lane throughout the full corridor (Figure 112). By permitting a passing lane at stations, buses can comfortably overtake other buses. Thus, multiple stopping bays and express services can be accommodated with a passing lane. A passing lane also gives a system considerable flexibility in terms of future ridership growth.




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 to permit passing lanes, even in relatively tight corridors. Figure 113 provides an illustration of this type of design option. The preferred median station design is retained, but its shape is elongated to help accommodate the passing lane. Passengers can still change directions within the closed station area by crossing a

connecting platform. In this case, the higher passenger 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. The viability of property purchases for this purpose depends upon local property costs as well as the existence of a well-designed compensation programme for property owners.

3.6.2.4 Construction techniques and materials

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 re-paving or reconstruction after just a few years.

In terms of longevity, concrete is typically a better choice than asphalt. Concrete is more resistant to the forces of heavy buses passing on a frequent basis. While concrete is more costly than asphalt, in general, the longer life of the surface will justify the higher initial cost. One cost-cutting option is to consider concrete only at stations. In such instances, the runways between the stations are constructed with lower-cost asphalt. The station areas are the most important in terms of retaining a stable roadway level. If station areas subside from the weight and force of the vehicles, then maintaining a level boarding height between the vehicles and the station platforms will be quite difficult. Station areas also see the most demanding surface impacts due to the forces generated by decelerating and accelerating vehicles.

The surface material, though, will only endure as long as the base materials are in tact. 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 Avenue Caracas corridor. Bogotá has largely relied upon a technique known as "white topping" for its concrete busways. The white topping method utilises the existing asphalt lane as the base material for the 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.

#### 3.6.2.5 Lane separation

Busways are generally separated from mixed traffic lanes by the use of blocks, curbing, permanent traffic cones, or other types of barrier devices. The design of the separator should be sufficient to physically prohibit mixed traffic vehicles to enter the busway. However, it may be useful to design the separator to permit buses to leave the busway in the event of unforeseen events. For example, if a bus breaks down on the busway, it can be useful to allow other buses 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. Like all aspects of the system, the aesthetics of the separator design should also be a consideration.

#### 3.6.2.6 Intersection design

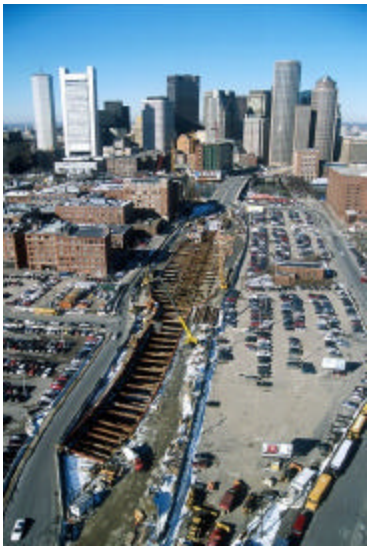
Intersections represent several design challenges for a busway system. If not designed to give priority to the BRT system, intersections will have negative effects on travel times, system capacity, and safety. Intersections can create bottleneck points due to congestion from other vehicles as well as from traffic light phasing. Intersections will also create design challenges when it is necessary for BRT vehicles to turn from one corridor to another.

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. In turn, such unpredictability with congestion delays can create havoc for system controllers who are attempting to maintain frequent services and evenly-spaced distances between transit vehicles.

However, there are some solutions to the difficulties posed by roundabouts. First, the most elaborate solution is to construct a busway underpass that goes below the roundabout, and thus avoids all conflicts with mixed traffic. Quito has achieved great success with its "Villa Flor" station that goes beneath the heavily-trafficked roundabout on Maldonado Avenue (Figure 114). Second, the busway can be given special signalling and a dedicated lane cutting through the centre of the roundabout area. Quito's Ecovía line provides an example of this technique (Figure 115). The ability to construct a dedicated lane through the centre of the roundabout will only be feasible when the centre 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. A third technique for permitting a BRT vehicle to efficiently cross a roundabout involves a combination of signalling and a dedicated lane on the inside of the roundabout. In this case, the BRT vehicle is given signal priority to enter the roundabout and then follows a dedicated inside lane. Another set of signals permit the vehicle to exit from the roundabout on the opposite side.

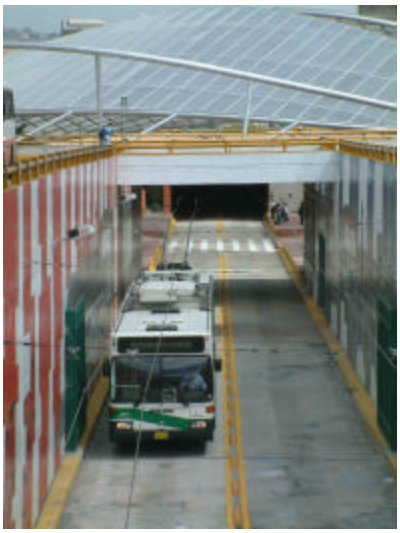
3.6.2.7 Grade separation

The exclusive busways, rapid boarding and alighting techniques, and the well-spaced stations all give BRT customers reduced travel times to their destinations. However, intersections and other points of interference with vehicles will negatively affect speeds and travel time. Separating the busway from these points of conflict will substantially improve travel times as well as safety.



Busways can be either "at-grade" or "grade-separated". An "at-grade" busway runs along at street level and thus must eventually cross signal-controlled intersections, which may greatly reduce the overall potential throughput of the system. "Grade-separated" busways avoid such conflicts by being constructed in a manner completely separated from any conflict with other lanes. Overpasses, underpasses, and tunnels are a few of the options available to create grade separation. In fact, the use of tunnels in cities such as Seattle and Boston has made the terms "surface subway" and "BRT" no longer synonymous (Figure 116). Clearly, such designs undercut the cost advantages that surface BRT systems hold over rail, but it does provide further indication of the blurring of the line between bus and rail options.

In Quito, both the “Trolé” corridor and the new “Central North” corridor make extensive use of underpasses. The “Villa Flor” interchange along Quito’s “Trolé” corridor is a set of underpasses that help avoid several intersecting roadways and a major roundabout (Figure 117). The interchange has reduced north-south travel times from 55 minutes to 45 minutes. Quito has determined that the large travel time savings will deliver sufficient cost savings to justify the additional construction costs of the underpasses. Figure 118 notes that a typical underpass in Quito costs in the area of US$ 1 million. By factoring in the value of time for transit users and the associated impacts of traffic congestion that at-grade intersections produce, the underpasses deliver relatively short pay-back periods for Quito.




3.6.2.8 Coloured lanes

The aesthetic appearance of the lanes will have an impact on the public’s image of the system. The colouration of the busway is one option for creating a special and attractive BRT environment (Figures 119 and 120). A smartly coloured busway not only raises the image of the system but also creates a greater sense of permanence to the existence of the system. Coloured 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 recognise that they are committing a traffic infraction by blocking a highly visible bus lane, especially when compared to the crossing of a lane that is indistinguishable from a normal mixed-traffic lane.

Colouration of busway lanes can be accomplished by at least two techniques. First, a road surface paint can simply be applied to the busway. The advantage of simply painting the lane is that colouration 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 colour and the long-term maintenance costs. A second option is to utilise a coloured emulsion within the asphalt or concrete mix. In this case the colouration is a permanent part of the surface material. As the surface begins to wear down, the colour is retained.

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 colour is highly specific to local preferences and local conditions. Local aesthetic values play a role in choosing a colour that will produce a readily identifiable and positive image for the BRT system. Further, a city-wide colour coding scheme should be considered as a mechanism to differentiate between various infrastructure purposes. For example, it might be useful to use a colour for the busway that is different than the colour utilised for the city's cycle ways. In this way, each set of sustainable transport infrastructure has its own unique visual identity.

3.6.2.9 Guided busways

A guided busway is a special type of BRT system in which the lateral movement of the bus is controlled by side roller wheels (Figures 121 and 122). A few guided systems have been developed in cities such as Essen (Germany), Adelaide (Australia), Leeds (UK), and Bradford (UK). The guidance systems consist of a physical bus track that steers the bus by way of a mounted side roller wheel.


These systems can have a positive effect on speed and safety since the guideway better controls the vehicle's movements. Guided busways also permit a more narrow lane to be constructed, and thus is helpful when road space is limited. However, guided systems are still relatively rare due to their added costs, complexity, and lack of flexibility in use of the vehicles. Table 31 summarises the advantages and disadvantages involved with guided systems.

**Table 31 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 utilise the busway |
| Allows construction of lanes without paving the centre strip | Speed advantages of guided busways are only realised when the distances between stations are quite significant |

Additionally, since busways do not require the need for vehicle lane changes, some system developers have elected to not pave the centre of the lane (Figures 123 and 124). The resulting savings in construction costs can be substantial. Further, the existence of earth or grass beneath the bus can help absorb engine noise; noise reductions of up to 40% have been reported using this technique. Not paving the centre of the lane is also an option that other busway developers are considering, even when roller guides are not being utilised. 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 centre lane area will depend on local construction costs and practices. In some instances, local contractors may not be well-versed in utilising 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.

### 3.6.3 Stations

#### 3.6.3.1 Station location

The design and location of the BRT stations will affect system flow capacities as well as key customer service parameters such as safety and convenience. Station location is largely demand driven with access to primary destinations such as shopping complexes, stadiums, major office buildings, and schools being a determining factor. The optimum distance between stations is a trade-off between demand at key locations and the time penalty incurred for each stop added. A

standard distance between stations is approximately 500 metres but can often range from 300 metres to 1000 metres, depending upon local circumstances.

### 3.6.3.2 Station size

The entry areas, fare sales area, turnstiles and the station structure must all be designed to sufficiently handle projected peak customer flows. Key factors for this determination include the number of bus stopping bays, peak frequency times, and expected bus dwell times. The floor space dedicated to the expected number of waiting customers should be sufficient to avoid user discomfort. Adequate customer space will also help to reduce incidences of pick-pocketing and other crime. However, floor space is limited to an extent by the available street space that may be allocated to the station footprint. Station widths typically vary from 2.5 metres to 5 metres. Passenger space in narrower stations can be partially gained by increasing the overall length.

The overall length of the station facility will depend upon the length of the vehicles and the number of stopping bays. If a system utilises multiple routes and/or multiple service types (e.g., local, limited-stop, and express), then several stopping bays are likely to be required. The distance between each stopping bay will in part be determined by the required turning distance needed for vehicles to enter and exit the individual bays. If the distances between stopping bays are too close, then congestion between vehicles is likely to occur.

Different stations will have different space requirements. If a particular station hosts a wide number of routes and services, then several additional bays will be needed. Conversely, if the station is just serving a few routes, then possibly only a single bay will be required. Figure 125 provides an overview of the different types of stations utilised in phase I of Bogotá's TransMilenio system.

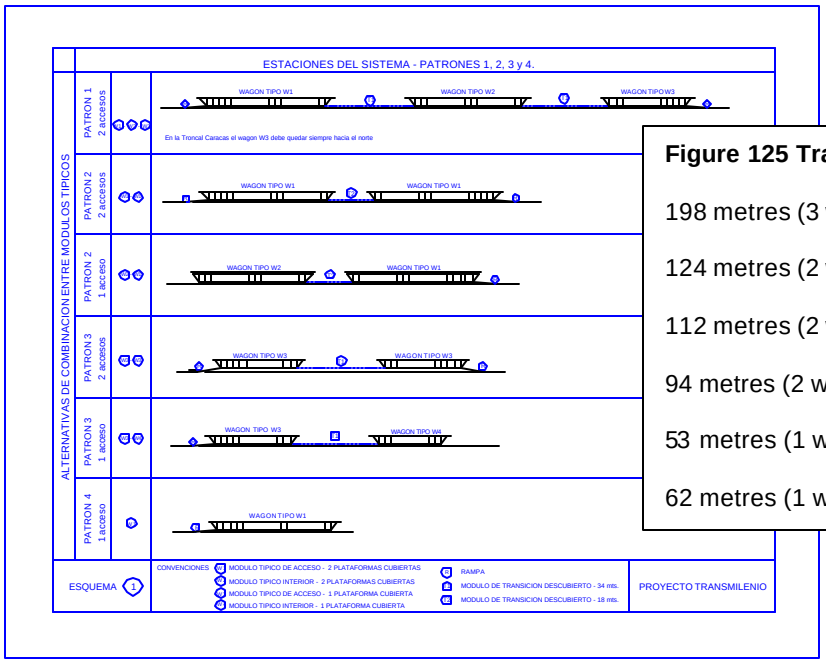



**Figure 125 TransMilenio stations**

198 metres (3 wagons, 5 platforms)

124 metres (2 wagons, 4 platforms)

112 metres (2 wagons, 4 platforms)

94 metres (2 wagons, 2 platforms)

53 metres (1 wagon, 2 platforms)

62 metres (1 wagon, 2 platforms)

Source: TransMilenio, SA

### 3.6.3.3 Boarding and alighting

Station design depends greatly upon an interaction with bus technology decisions, especially with regard to the point of interface between the vehicles and the stations. Decisions on the number of boarding doors and the width of the doorways must reflect both passenger flow requirements and the availability of options from bus manufacturers.

The design of the boarding and alighting interface will affect the likely dwell times of the buses. BRT systems in cities like Bogotá are able to reduce dwell times to 20 seconds using an array of rapid boarding and alighting strategies. TransMilenio relies upon close alignment between the bus and the station docking area to allow quick access. Minimising the bus to station distance is a key factor in realising high customer flows as well as making boarding practicable and safe for individuals with physical disabilities (Figure 126). Optical and mechanical guidance devices can also be utilised to ensure swift and accurate docking. Las Vegas (USA) utilises an optical guidance system that automatically docks the vehicle without driver intervention. Of course, the added hardware and software costs of an optically automated system can push vehicle costs well over US$ 1 million. Further, automated systems can actually be slower than manual alignment in decelerating towards the station, due to the inherent limitations of the software.


Cities such as Curitiba and Quito utilise flip-down ramps (also known as boarding bridges) attached to the bus to speed up customer flows (Figures 127 and 128). Bogotá's TransMilenio system opted not to utilise flip-down ramps in order to save the few seconds that the flip-down device consumes when opening and closing (Figure 129). However, the 1.5 seconds gained from not waiting for the ramp to deploy can be lost elsewhere. When a gap exists between the vehicle and the

station, passengers will tend to look down to make sure they safely cross. This small action of looking down actually delays each person's alighting time. Further, passengers have a greater tendency to depart the vehicle one-by-one when a gap exists between the vehicle and the platform. The flip-down ramps utilised in Curitiba and Quito avoid these cumulative customer hesitancies that will slow boarding and alighting. With the ramps customers will tend to move with greater confidence and speed.

Bogotá has made use of sliding doors at the station to vehicle interface (Figure 130). Automatic station doors give a degree of safety to waiting passengers as well as protection against wind, rain and cold. Additionally, the sliding doors can help prevent fare evaders from entering the system. The disadvantage of the doors is that they are susceptible to mechanical failure and can thus add to system maintenance costs.

3.6.3.4 Access

Ease of access to the stations will play a role in determining the size of customer base. The development of pedestrian and bicycle corridors around the station will help ensure that customers are able to conveniently and safely make their way to the station. Recognisable signage in the area will also help to attract customers. Street lighting, adequate sidewalk widths and quality surfaces all contribute to ensuring that customers can confidently utilise the system.

Access of entry is also an issue for boarding and alighting the vehicles. If crowding occurs at the station doorways, then the overall travel time will be delayed. Chaotic boarding areas also act to negatively affect customer satisfaction and ridership. If the entry area is sufficiently spacious, then boarding and alighting may not be problematic. In other cases it may be practicable to designate particular doorways for either boarding or alighting. In Curitiba, for example, the rear doorways are for alighting while the front doorways are for boarding. This arrangement helps to reduce station dwell times. However, this arrangement does require the customer to know when to move towards a doorway for alighting. Customers who are unfamiliar with a corridor may not realise in time that they must move towards a particular doorway.

3.6.3.5 Interchange stations

As a system expands across a wider network, intersecting stations will require mechanisms to transfer from one corridor to another. An “interchange station” is a facility that permits such transfers, and thus has additional design considerations than a standard station.

There are several options for facilitating transfers between corridors. These options include:

- Multiple routings (Figure 131)
- Interchange facility
- Underground tunnels / overhead pedestrian bridges (Figure 132)

A system may use a combination of these interchange options, depending on the local circumstances at the interchange point.

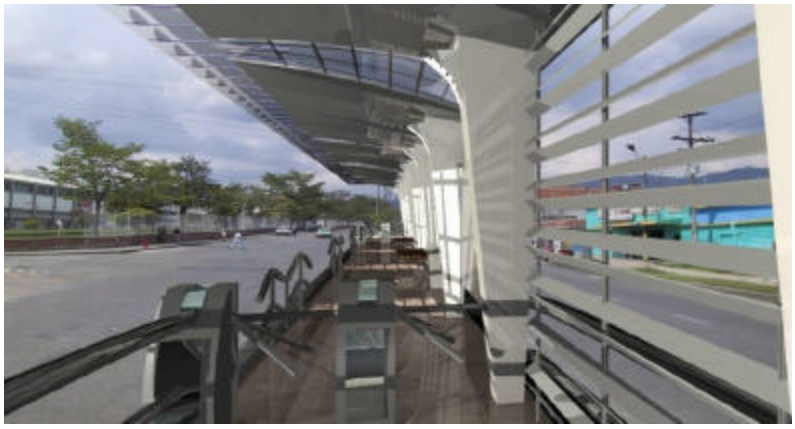
The multiple routing technique permits corridor changes without passengers needing to transfer vehicles. Instead, different route structures call for vehicles to turn from one corridor to another. From the customer perspective, this option can be quite convenient since no transfers are necessary. However, the added complexity of providing many route permutations can make for a relatively confusing system. This complexity is multiplied if there are also various limited-stop and express services. This technique also requires vehicle turning actions from one corridor to another, which again increases complexity through the need to control traffic lights and the provision of more complicated intersection infrastructure.

Another option is to construct an interchange station in which two (or more) trunk lines are physically joined by the same station infrastructure. This infrastructure can take the form of a single-level, multi-bay facility or of a multi-level facility in which one line is physically above the other. This option closely approximates transfer points within a rail underground system. Within this closed environment, passengers then transfer from one route to another. Disadvantages of this approach are the cost of the infrastructure and the space required to construct the facility. However, in comparison to requiring passengers walk from one corridor to another, there is less distance to walk between vehicles.

The final option is to simply have passengers physically transfer from one corridor to another by way of a pedestrian tunnel or pedestrian overpass. The tunnel or overpass will have to be closed to outside access; otherwise, fare evasion can be a problem. While tunnels and overpasses add cost, this type of infrastructure is less costly than a multi-level interchange facility. The main disadvantage is the need for customers to change from one vehicle to another, and thus incurring longer wait times and overall travel times.

#### 3.6.3.6 Climate protection

Protection from weather is a major consideration in station design. The image of the station as a refuge from the outside world can help attract customers. In many developing-nation cities, high temperatures and humidity are a concern. Open designs can also be an option, especially in warm locations. More open designs, though, do increase the need for protection against fare evasion. However, the example in Figure 133 shows that it is possible to achieve both an open design and relatively good natural deterrents to fare evasion. However, open designs will likely make waiting customers more exposed to wind and rain.



Air conditioning and ventilator fans are also options to consider. The use of air conditioning in both stations and vehicles can contribute greatly to the desirability of the system, especially with respect to capturing customers who were previously private vehicle users. Air conditioning in tropical climates can contribute to the image of the transit system as a city oasis. However, the use of air conditioning units brings with it cost and technical considerations. Air conditioning will likely reduce fuel economy by approximately 20 percent. Thus, if fuel costs represent a significant portion of operating costs, then the use of air conditioning in vehicles can contribute to noticeably higher fare levels.

Systems in cities with cold climates may also wish to consider climate control options. Heated station areas and heated vehicles will likewise create an image of the transit system as a refuge from a hostile environment.

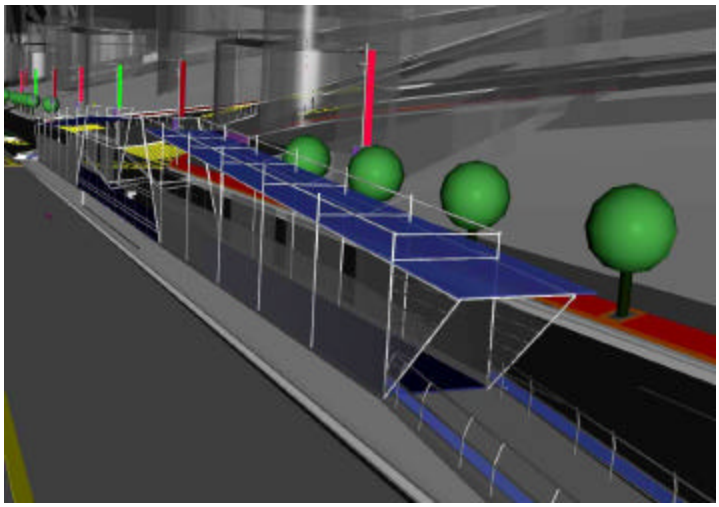
Passive solar design and natural design techniques can be utilised to overcome climatic extremes. Passive designs can help shield the station from direct sun as well as stimulate natural ventilation flows (Figure 134). However, passive design options should not detract from the aesthetic quality of the system. The curved overhangs on the Leon (Mexico) system are helpful in terms of climate control but have been criticised for aesthetic reasons (Figure 135). Vegetation above the station, either from planted trees or a green lattice, can also be an effective and attractive climate control option.

### 3.6.3.7 Aesthetic design

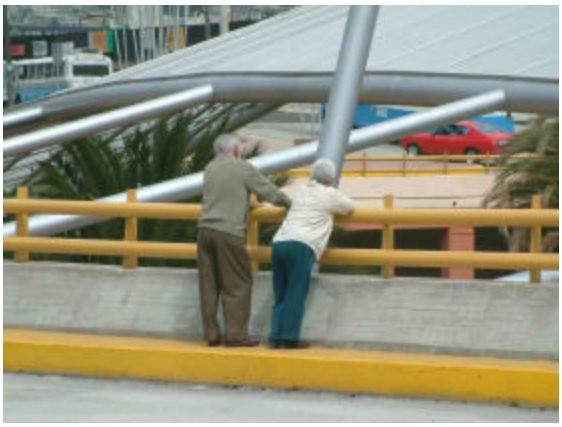
Architectural considerations are also important from aesthetic, cultural and customer-friendliness perspectives. Many systems opt for a highly modernised appearance, which helps to position BRT as a new class of public transport. The station designers in Brisbane have even been the recipients of architectural awards (Figure 136). The modern tube structures in Curitiba have become an international symbol of BRT as well as provide customers with an image representing speed and modernity. The disadvantage of rounded (tube-like) stations is the limitations that the design may impose upon customer capacity. In Bogotá, the city also opted for a modern design but with a squared, box structure. The larger Bogotá stations are able to handle higher customer volumes.



However, the modern look may not always be appropriate. If the system runs through or along corridors of great historical value, designers may wish to seek congruence with the adjoining architecture. Guayaquil (Ecuador) has elected to match the station design to the city's French-inspired style from the 1920s. The chosen style in Guayaquil reflects a connection between the transit stations and their surroundings. Congruence with the surroundings was the reason that Quito (Ecuador) re-designed some of its "Trolé" line stations in the city's historical centre (Figure 137). It was felt that the enclosed stations were visually too forceful within the historical centre, which is listed as a UNESCO World Heritage Site. Thus, the city opted for a more open design for the station at the Santo Domingo plaza.



The ornate style in Guayaquil contrasts with the simpler design for the new Central-North corridor in Quito (Figure 138). The Central-North design provides a lighter look for the roof-line which gives the system a neat, modern appearance. Quito is also home to one of the most spectacular BRT stations built to date in the world. The Villa Flor station on the "Trolé" line utilises an array of aesthetic features, such as plantings and waterfalls, to create a truly beautiful setting for customers (Figure 139). In fact, the Villa Flor station has proven to be so popular that families view the station from the outside as a type of social event (Figure 140). The Villa Flor station would likely benefit from even establishing a formal viewing area.



Station aesthetics can be negatively affected by over-use of advertisement displays. While advertising may be a needed source of revenue, too much advertising will detract from the visual clarity of the system and can lead to customer confusion, especially when system maps and other key information displays are difficult to find due to visual clutter. Thus, any decision to permit moderate amounts of advertising must be taken in conjunction with aesthetic and functional considerations.

3.6.3.8 Amenity features

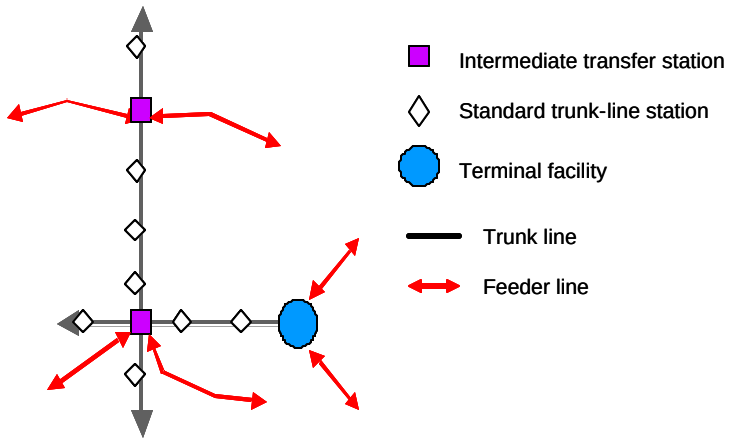
System designers also face decisions regarding the types of additional services that may be offered within a station. Amenity options for customer service are discussed in section 3.4.5.10 of this guidebook. The provision of video, audio, seating, restrooms, etc. involves decisions about costs and local preferences. As noted in section 3.4.5.10, though, serving the customer's needs is the paramount consideration.

The provision of seating at stations and terminals can help relieve tired bodies during the waiting period. The options for customer resting include formal benches as well as customer leaning posts. Formal benches can sometimes be problematic if certain customers choose to lie down upon it, and subsequently pass long periods there without the intent to actually travel on the system. Thus, some systems, such as the Bogotá TransMilenio system, have purposely chosen not to provide seating for customers within the stations. TransMilenio also believes that its short wait times (usually less than three minutes) void the need for station seating. For systems with longer headways and thus longer wait times, some form of resting infrastructure may be considered. However, the placement of resting infrastructure should be such that it does not conflict with doorway locations or cause congested customer movements during the boarding and alighting process.

Security is frequently a major determinant in the desirability of system use by women, children, and other vulnerable groups. A demonstrable presence of security staff in buses and stations is a strong deterrent to crime. Security cameras and good night-time illumination are effective infrastructure elements that contribute to a more secure environment (Figure 141).

### 3.6.4 Intermediate transfer stations

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 somewhat a hybrid facility between ordinary local stations and terminal facilities. Figure 142 provides an overview of the relationship between standard stations, intermediate stations, and terminal facilities.




Unlike terminal sites, intermediate transfer stations may not have the luxury of space to easily accommodate both feeder platforms and trunk-line platforms. Thus, a bit of creativity is required to design and control the transfer process. Ideally, the feeder vehicles can enter a "closed" space in which a fare-free transfer can take place without concerns over fare evasion. However, this ideal is typically not the case. Instead, feeder vehicles arrive from a smaller side street, and passengers must walk from the feeder station to the trunk-line station. A crosswalk or pedestrian bridge will often link the two stations (Figure 143). A further discussion on fare collection and fare verification techniques for feeder services is included in section 3.6.1.6.

### 3.6.5 Terminals

Terminals involve many of the same design issues as stations. However, given the larger number of passengers and transfer options, terminals obviously require more space. The architectural design of terminals can either mimic the style of the system's stations or take on a different look. Terminal platforms are typically not enclosed with walls since entrance to the terminal site is controlled from a distance (Figure 144). Terminal facilities in cities such as Bogotá and Quito have high ceiling designs with modern roof structures (Figure 145). The scale and style of these facilities imparts an impression of importance to the customer and helps to instil the system's professional image.

The number of terminals depends in part on the length of the system, the number of corridors, and the number of feeder routes converging upon a site. Typically, there are terminals at each end of a trunk-line corridor. However, if the end of the corridor does not host large numbers of feeder services, then a terminal may not be entirely necessary. It is also possible to site a full terminal in the middle of a corridor. This scenario may arise when multiple corridors cross one another in a single location. However, siting a large terminal within a central city location can be quite costly from a property purchase standpoint. Thus, terminals are more frequently developed in lower-cost peripheral areas.

Whether or not the system is designed for fare-free transfers will have a significant impact on terminal design. Fare-free transfers mean that passengers can move from feeder services to trunk-line services without an additional fare. If an additional fare payment is required, then space must be given to fare collection and fare verification activities. The physical division between the different fare areas must also be sufficient to avoid problems with fare evasion. Given the large numbers of passengers passing through terminal areas, design against crimes such as pick-pocketing should be considered. Thus, measures such as security cameras may be appropriate.


The design of the terminal space should strive to minimise both customer and vehicle movements to the extent possible. Thus, the most likely transfer points between complementary routes should be located closely together. As both feeder vehicles and trunk-line vehicles will be staging at the terminal, the movement of vehicles should be devised to avoid congestion. Most typically, feeder vehicles arrive on one side of a platform area with trunk-line vehicles awaiting on the opposite side (Figure 146).

The larger space at terminal sites can permit the hosting of additional facilities such as information kiosks, lost and found offices, restrooms, and commercial establishments. Allowing shops within terminals are possible but can create an array of complications, including litter and security issues. Food and beverages should be kept out of the system to the extent possible since their presence adds to maintenance costs and ultimately lead to a premature aging of the infrastructure. Some systems intentionally elect not to provide additional services. These system designers feel that the most important task is to keep passengers moving through the system, and that additional services are an impediment to that over-arching goal.

### 3.6.6 Depots

#### 3.6.6.1 Functional design

Bus depot areas serve an array of purposes including bus parking areas, re-fuelling facilities, maintenance areas, and office space for bus operators (Figure 147). The location of a bus depot is ideally within close proximity to the actual system since operators will want to have the ability to rapidly introduce additional buses to meet peak demand. Further, since buses enter and leave the depot without passengers, the “dead” kilometres incurred between the depot and the passenger corridor can have a discernible effect on operating costs. However, since bus depots can consume considerable space, the location is often dependent upon the economical

acquisition of sufficient property. Ideally, depots will be located near terminal facilities.

The internal design of the depot area should allow for a logical movement of vehicles based on their typical requirements. Thus, upon entering the secured area, vehicles will likely first stop at the fuel re-fuelling station. Here fuel levels and vehicle kilometres are checked as a way of monitoring usage and operating costs (Figure 148). If required, vehicles would be re-fuelled at this time. Next vehicles that are not required on the corridor will be parked until peak periods necessitate their return. Alternatively, vehicles may move to the wash station for exterior and/or interior cleaning. Finally, vehicles requiring maintenance or a periodic maintenance check would enter into the repair area. A channelled work space below each bus in the maintenance area permits repair staff to easily access the bus chassis for inspection and repair (Figure 149).


Offices for operating companies are likely to be best provided at the depot areas. By being located at the depots, operating company officials can better monitor activities and oversee staff.

3.6.6.2 Aesthetic design

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 as well as local residents. Thus, the visual aesthetics of the depot will affect the local population's image of the system. It is always important to be a good neighbour with populations living near the system. Second, a well-

designed work environment can have a positive impact on employee satisfaction and work effectiveness.

#### 3.6.6.3 Ownership

Depot areas may be owned by either the public transit agency or the private bus operator. In some instances, the depot area may have previously served the same operating company, and thus it may be simplest to permit the operator to retain control of the site. Further, public purchasing of the depot site will obviously add considerably to the overall infrastructure cost.

However, public ownership of the site will likely be in the best interest of the overall system. Since the operators will hold a concession for a set period of time (10 years in the case of TransMilenio), it is probably best that they only have access to the depot site for the duration of the concession. Otherwise, the existing operators will hold too much leverage when the concession is completed. Thus, the best option is for public ownership of the depot site with a lease agreement to the operator through the concession period. The proper maintenance and upkeep of the depot area can be stipulated within the concession agreement.

### 3.6.7 Control centre

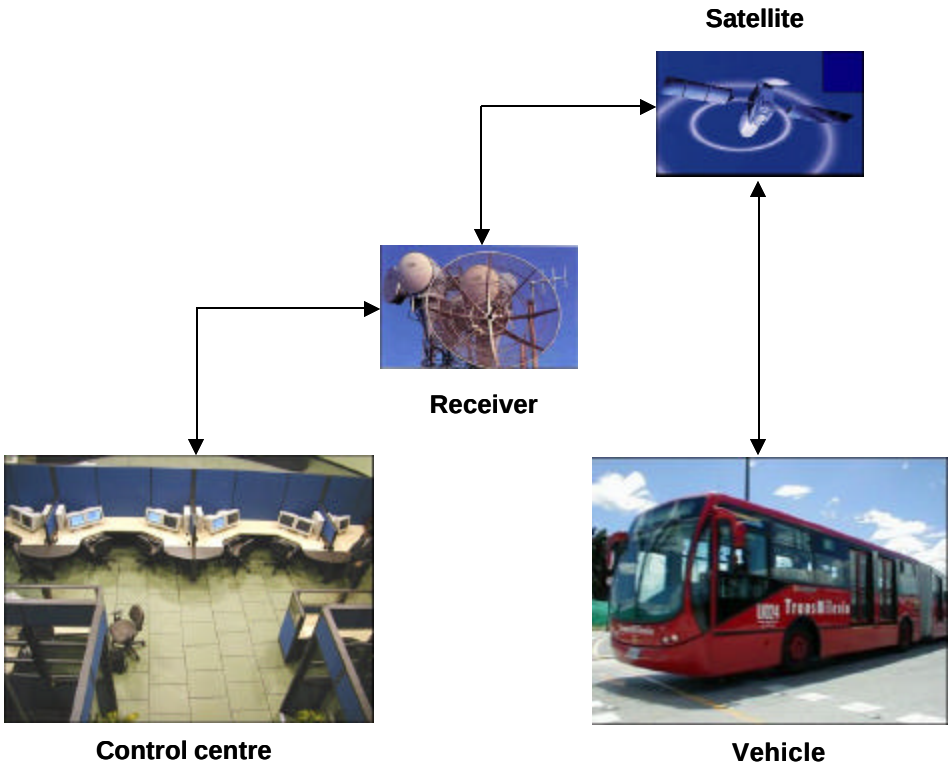
A centralised control centre will help ensure smooth and efficient BRT operations. Controlling a high-volume BRT system spread across a major developing city is a complex and highly-involved activity. As noted in section 3.4.5, a centralised control and management system brings with it the following benefits:

- Immediate response to changes in customer demand
- Immediate response to equipment failures and security problems
- Efficient spacing between vehicles and avoidance of vehicle “bunching”
- Automated system performance evaluation
- Automated linkages between operations and revenue distribution

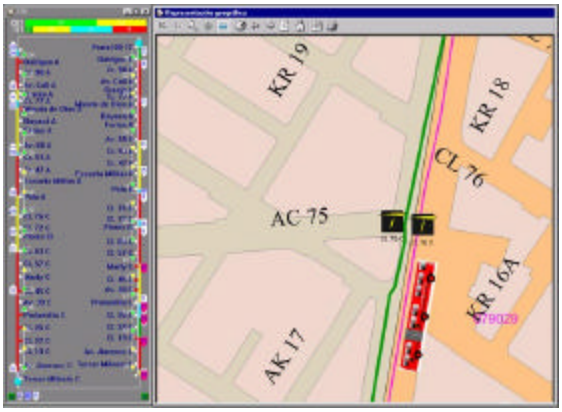
This section reviews the various technological and infrastructure aspects of developing an effective control centre.

#### 3.6.7.1 Control centre technology options

While the benefits seem clear, the costs of a real-time control system would seem prohibitive for a developing city. However, the cost of central control technologies has steadily decreased during the past few years. Thus, even cities in developing nations may now wish to consider the advantages of a central control system.




Several options exist to link buses and stations with a central control office. In some instances, a simple radio or mobile telephone system may suffice. However, increasingly Geographical Positioning Satellite (GPS) technology is providing an effective communications link (Figure 150). GPS technology permits real-time information on bus location and status. Bus location is generally known to an accuracy of approximately one metre through GPS. GPS technology is utilised within the control system of Bogotá's TransMilenio system. By using the GPS technology in conjunction with vehicle tracking software and a voice communications system, Bogotá is able to closely control vehicle headways (Figures 151). A control centre operator will direct a driver to slow down or speed up depending on the location of other vehicles and the demand requested. Further, if a surge in demand occurs at a particular station, a new vehicle can be sent in to alleviate crowding.




The Bogotá control centre also includes staff from the city's police department. If a security problem arises on a vehicle, a police dispatcher will immediately send officers to the location as well as advise the driver as to the appropriate action.

In addition to GPS technologies, non-satellite based options can also be effective. For example, infra-red technology can track vehicle movements in a similar fashion utilising local beacons distributed through the transit area. This type of technology can be

an effective alternative when topography and tall buildings act to block satellite-based communications.

3.6.7.2 Control room infrastructure

*a. Location of control centre*

The control centre does not need to be located in any one special location. The control centre functions remotely from the corridor through its information and communications system. The control centre must be situated in a place that has highly reliable communications connections and electrical power connections. Since the centre may also be receiving information by way of satellite or infra-red communications, the centre should not be located anywhere signals could be potentially blocked.

There could be some benefits to locating control centre staff in management facilities or in terminal facilities. These locations would allow greater interactions between control centre staff and management staff or vehicle operators. This sort of interaction could lead to certain synergies in gaining further insights on system operations.

*b. Work space*

The control room itself will require particular spatial features. The size of the control room will depend upon the number of workstations required. Since a BRT system is likely to be developed in phases, the control room will probably be only partly utilised during the initial years. However, planning for future space requirements at the outset is probably the best strategy. Otherwise, a disruptive move to larger facilities will be required later.

Each control centre operator will require space for a computer terminal, voice communications equipment, and additional work space (Figure 152). 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 quality of the controller software package will play a role as well in determining the number of transit vehicles a control centre staff person can effectively oversee. Additionally, since the operators must be able to clearly communicate with drivers, the acoustical arrangement of the workstations should be considered. If noise from one workstation interferes with the communications in another workstation, then the potential for lost or misinterpreted communications will be a problem.

As noted previously, other municipal staff, such as police representatives, may also require their own workstations in the control centre. Supervisory personnel will likely

require work space that allows them to easily oversee the entire control centre operation.

Control centre operators can become fatigued by long hours of looking at monitors and tracking vehicles. Holding focussed concentration for long periods of time can be quite mentally exhausting. Typically, operators will have frequent scheduled breaks in order to maintain their alertness. Thus, the control centre should also have a relaxation area or break area that allows operators to refresh themselves.

*c. Equipment requirements*

The ergonomics of the workstation furniture should also be an important consideration. Comfortable seating and correctly adjusted placement of monitor screens can help prevent undue stress and discomfort.

In some instances, it is useful to permit visual tracking of vehicles not only by individual monitors but also by way of a large-screen display for the entire centre (Figure 153). The large screen can provide control centre supervisors with a macro-perspective on the system. The large screen would also help in circumstances when multiple staff members are resolving a complex issue together.

The entire control centre facility should have not only high-quality primary systems, but reliable back-up systems as well. Spare workstations should be available in case of a technical problem. Further, back-up electricity generators and telecommunications options should also be part of the infrastructure.

### 3.6.8 Feeder infrastructure

Feeder services will likely provide a substantial percentage of a system's ridership since the feeder corridors are the key link into residential areas. Quality infrastructure should not just be given only to trunk lines. Feeder lines should also receive a high level of quality service; otherwise, a large part of the customer base will never engage the system.

This section discusses several components of feeder infrastructure and service, including road infrastructure, stations, and the fare collection and fare verification process for feeder services. A discussion of feeder vehicle types is found in section 3.7.

#### 3.6.8.1 Road infrastructure

Feeder services typically are not provided with dedicated busways but instead utilise mixed-traffic lanes. Since many feeder routes extend into fairly narrow residential streets, exclusive vehicle lanes is not always a practical option. However, there

may be instances where road spacing permits exclusive feeder bus passing lanes or feeder "queue jumping" lanes. A queue jumping lane is an exclusive bus lane at a signalled intersection. By entering this exclusive lane the vehicle is able to jump ahead of other waiting vehicles. A separate traffic light for the bus lane can in fact give the feeder vehicle a few seconds of a head start against the other traffic.

Passing lanes may also be feasible in sections of the roadway that have sufficient width. Even a relatively short passing lane can be beneficial if it permits the feeder vehicle to avoid an area prone to congestion. London has successfully utilised short passing lanes with its conventional bus services (Figure 154). The London passing lanes have been effective in reducing the unpredictability of bus schedules due to traffic congestion.

Unlike busways, feeder vehicles typically use the lanes adjacent to the street curb rather than in the median. Thus, any bus lanes for feeder services may not be protected by a barrier from the mixed traffic. The mixed traffic will need to access the curb lane in order to negotiate turns or to access parking. Under such conditions, infringement of the bus lane by private vehicles can undermine its usefulness. To combat private vehicles from illegally entering the passing lane, London utilises enforcement cameras that will record the license plate number of vehicles using the bus only lane. The key to maintaining the usefulness of a bus lane resides in the enforcements mechanisms utilised.

Since feeder vehicles are typically smaller than trunk-line vehicles, the need for special surface materials (such as concrete) is not necessary. The lower vehicle weights do not damage streets to the same degree. Nevertheless, the proper maintenance of asphalt streets is important in maintaining the quality of the feeder fleet and in reducing maintenance costs. Thus, feeder streets should receive priority treatment for repairs and maintenance. Also, feeder vehicles will likely have less suspension support than trunk-line vehicles, so the smoothness of the ride and the comfort of the customers will be more dependent upon road conditions.

#### 3.6.8.2 Stations

Feeder services should not merely replicate the previous informal services that preceded the introduction of the BRT system. While previous services likely boarded and alighted passengers at random locations, depending on customer preferences, a formal feeder service should establish formal station areas. Just as travel times along the trunk lines benefit from well-spaced station, the same holds true for feeder corridors. However, it may be justifiable to place feeder stations somewhat closer together than the range recommended for trunk-line services, which is approximately 300 metres to 1000 metres. Since pedestrian conditions

along feeder routes may be less developed than trunk-line routes, it can be difficult for some residents to access the system in such circumstances. The actual distance spacing between feeder stations will depend upon several factors, including the population density of the area as well as the location of major trip destinations and origins.

These stations will likely not be as architecturally sophisticated as trunk-line stations, but nevertheless, the feeder stations should provide a quality wait environment. A shelter should be provided to protect customers from rain and heat. Given cost considerations and the nature of feeder services, the shelter does not need to be closed as is the case for the trunk line. However, a roof cover along with back and side panels can be appropriate. In many instances, feeder shelter construction and maintenance can be funded in part by panel advertising. However, in such instances, the advertising should not detract from the functionality of the shelter. For example, advertising panels should not block the vision of passengers towards the arriving feeder vehicle. Panels should also include a full system map. Further, third party construction of a shelter should follow strict design guidelines developed by the public agency.

Since wait times for feeder services tend to be somewhat longer than trunk-line services, some shelter amenities may be appropriate. For example, seating or a leaning post can be a low-cost way of significantly improving the comfort of those waiting.

### 3.6.9 Integration infrastructure

Public transport will almost never be the sole modal technology for any customer trip. The initial part of the trip may involve a walk, a bicycle ride, or even a car trip to a transit station. Likewise, once a customer exits a station near his or her destination, another modal option will likely complete the journey to the ultimate destination.

Ensuring that the transit system is well integrated with these other modal options is critical to developing a truly usable system. The difference between a pleasant and safe walking environment and a poorly maintained pedestrian path can be the difference between customers choosing public transport over other options. Thus, the quality of the integration infrastructure is one of the determining factors in ridership and customer satisfaction.

The integration infrastructure will likely be composed of a range of components, including infrastructure components for the following types of modal options:

- Pedestrian infrastructure
- Bicycle infrastructure
- Integrated taxi stations
- Integration infrastructure for other public transport systems (e.g., water transport, rail transport, etc.)
- Park and ride facilities

Section 3.8 discusses issues concerning each of these types of integration infrastructure.

### 3.6.10 Commercial space

In many developing cities, a close relationship exists between the location of transit infrastructure and the location of commercial traders. The high volume of transit customers through stations and terminals provides vendors with a concentration of potential clientele. Additionally, the proximity of vendor products to a person's daily travel route can be a task-saving convenience for some. The provision of infrastructure for commercial activities within or near transit stations can be a source of controversy. Some transit agencies may not view commercial activities as being consistent with the objective of encouraging rapid customer movements. This section refers some of the options for combining vendor activity with BRT operation.

#### 3.6.10.1 Small-scale vendors

Small-scale vendors are closely tied to transit provision in many cities. These informal vendors often constitute a large portion of the city's overall workforce. Thus, there are many economic, social, and political reasons for considering the role of these vendors in conjunction with the transit system.

Conversely, the presence of vendors can also be a detriment to the transit system. If left uncontrolled, vendors may tend to block walkways, and thus inhibit access to stations. Aggressive sales techniques may also make some transit customers uncomfortable with using the system. Further, waste and debris left behind by vendors can lead to an aesthetic deterioration of the station environment. Some systems, such as TransMilenio in Bogotá, have largely prohibited vendor activity near stations in order to avoid these types of problems.

However, in many cultures, the employment and social justice impacts of vendor displacement is a highly sensitive matter. Simply evicting these individuals will have traumatic impacts on these person, their families, and society at large. In Delhi (India), the BRT development team is seeking a novel approach of integrating vendor space formally into the infrastructure design process (Figure 155). By providing vendors with a formal space near the station, all sides can win. The higher quality space provided to the vendors can in fact improve their work conditions and their care of the transit environment. Further, the formal inclusion of vendor space in the design process can ensure these sites do not conflict with passenger movements.

#### 3.6.10.2 Larger commercial sites

Transit stations may also attract the attention of large commercial retailers seeking to reap the benefits of passenger flows. Likewise, the ability to conduct grocery shopping and other tasks near the transit corridor is a benefit to customers. The presence of these commercial entities also offers some opportunities for financing the station and terminal construction costs (see section 3.10.2).

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. The Bangkok SkyTrain system hosts small shops within its elevated concourse. If a BRT system has an underground tunnel connecting interchange stations, then an underground shop location could be feasible. Terminals perhaps offer the greatest potential since space is typically more readily available. Terminal sites often also reduce the distance goods must be carried home.

Commercial enterprises can also benefit by locating near to station and terminal locations without actually being within the transit property. In Bogotá, large commercial centres have opened near the TransMilenio corridor (Figure 156). Capturing the value added to these property developments and applying the added value to system financing is a subject of much interest. More information on land-value taxation can be found in section 3.10.2.

However, as noted previously, retail integration with the transit system brings with it unintended complications. The presence of shops within the system adds a layer of complexity to passenger flows and can retard throughput. Retailing employees are typically given free access to the shops, but such exemptions can spiral into abuse of system entry. Finally, deliveries to shops can also create congestion if not carefully controlled or relegated to non-operating hours.

### 3.6.11 Traffic signal control

The development of a BRT system can also present a unique opportunity to upgrade the traffic signal technology along the same corridor. A new BRT system will imply several changes that will affect traffic signal technology. These changes include:

- New priority treatment for transit vehicles;
- New exclusive lanes;
- New turning movements for transit vehicles;

- New restrictions on private vehicle turns.

With new electronic signalling technologies and software programmes now available, an upgrade of the traffic signal system should be integrated into the BRT planning process.

The appropriate synchronisation of traffic lights often does not currently exist in developing cities. A readjustment of phase lengths and synchronisation should be undertaken with a special focus on smooth transit vehicle flow. Priority signal technology is an option, but is not always feasible in high-frequency systems. In cities such as Los Angeles, signal priority is given to transit vehicles by way of a message relayed from a vehicle transducer to the signal control box. As a transit vehicle approaches, the traffic light will extend the green phase to allow the bus to pass. However, even with relatively long peak headways of five minutes or more in Los Angeles, the signal prioritisation will only function every other phase cycle. If the phase priority is given more frequently, it will essentially give a permanent green to the direction of the transit corridor. Thus, other vehicle directions will essentially become unavailable. In developing cities with high population densities, peak transit headways may be in the range of one to two minutes. In such a scenario, signal prioritisation becomes less viable. Nevertheless, other improvements such as adjusting phase lengths are still quite possible in the developing city context.

Integrating traffic signal control into the centralised transit control system is also an option to consider. In cities such as London, traffic cameras at key intersections permit control centre staff to directly observe potential congestion points. This technology can be used to provide priority to transit vehicles entering a bottleneck point.

### 3.6.12 Public utilities

City streets are complicated environments. The same space that provides widespread mobility may also serve as corridors of telecommunications, electricity, water, flood control, and sewage. When implementing a busway through such a complicated area, it is not surprising that there will be competing uses of the public space. The location of public utility poles, pipes, and tubes will undoubtedly require some alteration in the BRT design work.

In some cases, especially in the case of median busways, the area may actually be relatively free of conflicts between the road work and the public utilities. Nevertheless, the existing public utility scheme should still be reviewed. The construction of a BRT system represents a unique opportunity to address many physical street structures simultaneously. In some instances, the BRT system may be the catalyst to install fibre-optic cable lines for high-speed communications systems.

Effective water drainage will directly affect busway operation and the longevity of the pavement materials. A drainage scheme to avoid episodes of flooding even in fierce storms can help ensure that the city's principal transit artery continues at critical times.

### 3.6.13 Landscape

BRT systems should add to the aesthetic quality of a city's public space rather than detract from it. All efforts should be made to retain existing green spaces. If the centre median is utilised as the location of the stations, the existing landscape can be left significantly in tact. Only the station footprint may require landscape alterations. The other areas can be enhanced with additional plantings. Greenery may also be an option as a divider between the BRT system and other traffic lanes. 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.

Some environmental groups in Jakarta expressed concern about the impact of the busway on the trees planted in the median. However, in many respects, the busway will serve as a protective buffer between the mixed traffic lanes and greenery in the median. Prior to the development of the busway, the lane nearest the trees was used for mixed traffic vehicles. Thus, previously the trees were subjected to a constant bombardment from heavy traffic congestion and intense emissions. Now, cleaner transit vehicles are operating along the corridor at frequencies of every three to five minutes. The busway has therefore calmed the environment around the greenery which should improve the health of the trees.

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 buckling of the busway materials. Each type of tree has inherent growth characteristics, and thus some research is needed 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 which 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.

Priority should be given to selecting indigenous trees rather than species that are not common to the area. Indigenous species create fewer problems regarding invading species and also typically are more suited to local soil and water conditions.

### 3.6.14 Infrastructure cost analysis

#### 3.6.14.1 Infrastructure cost categories

An initial infrastructure cost analysis can help focus the possible design work on financially realistic options. 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. Cities should be encouraged to experiment with a range of possibilities with respect to both design options and the amount of financial resources likely to be available. If the design team is overly pessimistic about the likely financial resources available, then the quality of the system may be needlessly compromised by an inadequate design. Several iterations of physical designs and operational designs are likely before finding a balance between system cost and system performance.

Infrastructure costs for BRT systems can vary considerably depending on the complexity and sophistication of the system as well as the local economic and topographical characteristics. Successful systems have been developed for as little as US$ 500,000 per kilometre (Taipei). However, in general, developing-city BRT systems will cost in the range of US$ 1 million to US$ 10 million per kilometre. Some of the principal factors in determining the actual infrastructure costs will include:

- Number of exclusive lanes
- Materials utilised in the construction of the lanes (asphalt or concrete)
- Expected system capacity, and thus the capacity and size of stations, terminals, and depots
- Local construction costs
- Amount of property expropriation required

Table 32 lists the actual infrastructure costs for Phase I of TransMilenio.

**Table 32 BRT construction cost breakdown, Bogotá's TransMilenio**

| Component | Total Cost (US$) | Cost per Kilometre (US$) |
|---|---|---|
| Trunk lines | 94.7 | 2.5 |
| Stations | 29.2 | 0.8 |
| Terminal | 14.9 | 0.4 |
| Pedestrian overpasses | 16.1 | 0.4 |
| Bus depots | 15.2 | 0.4 |
| Control centre | 4.3 | 0.1 |
| Other | 25.7 | 0.7 |
| *Total* | *198.8* | *5.3* |

#### 3.6.14.2 Estimation techniques

The limited number of BRT systems to date combined with the lack of a shared costing database makes local estimations of infrastructure costs somewhat 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; and,
- Survey work by consultants, which may incorporate all of the above estimation techniques.

More accurate cost estimates will be generated at a later time when the project approaches the implementation stage (see section 3.10). In the early development phase, the estimation techniques presented above should help narrow the design and performance characteristics into a relatively focused area of values.

3.6.14.3 Property acquisition

One of the most variable cost items when comparing different BRT systems is the level of property acquisition required. In many instances, the municipality will need to impose eminent domain upon private properties. Since the exclusive busways are most typically in the centre median, the private properties along the corridor remain relatively untouched. Space for terminals and depots can be more problematic due to the larger property requirement. However, these sites are often located farther from the centre, and thus more open space and lower cost properties are generally available at such peripheral locations.

In instances that property purchases are necessary, infrastructure costs can quickly skyrocket. Infrastructure costs on Bogotá's TransMilenio system jumped from approximately US$ 5.3 million per kilometre in Phase I to US$ 13.5 per kilometre in Phase II. Much of this increase was due to the much greater need for property 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 157).

The use of eminent domain law is a highly sensitive political and social issue. Emotions can run quite deep when businesses and families must give up workplaces and homes, especially when such sites have been owned for generations. Further, since low-income groups often live closest to the busiest corridors, social justice issues will also come into play. International lending agencies, such as the World Bank, are quite sensitive to the appropriateness of eminent domain procedures. Failure to handle the property purchases in a fair manner can result in the loss of international financing. For all these reasons,

property expropriation must be handled carefully and with the highest degree of transparency.

Some characteristics of a well-designed property purchase programme include:

- **Clarity** in the procedures;
- **Transparency** and **openness** of the process;
- **Timeliness** in processing and timeliness in resolving conflicts;
- An over-riding sense of **fairness** in the process.

The World Bank has developed a set of recommended procedures for compulsory purchase programmes in infrastructure projects. Likewise, Bogotá has developed a similar process to fairly deal with property purchases required by the expanding TransMilenio system. The following steps outline the Bogotá process:

1. Map the area plots in relation to the planned BRT system. Design adjustments should be undertaken to minimise land acquisition, even if this implies reducing the number of mixed traffic lanes.

2. Determine the property ownership history of any required properties. This process includes investigating land titles, mortgages, and current occupants.

3. Survey the actual activities and socio-economic 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. Provide information on potential alternatives. This assistance should be particularly directed towards 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 recommended to include a down payment at this stage to help move the transaction towards completion.

8. If the offer is accepted, 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.

This arbitration process should be well-defined at the outset of the purchase programme, and thus be set-up to provide a timely answer.

10. If the offer is declined and 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. Given the lengthy duration of potential legal proceedings, the city may request that the court award the handover of the property immediately for system development. The awarded value of the compensation will then be determined at the termination of the legal process.

The smooth and timely handling of the TransMilenio acquisition process has won praise from the World Bank for the manner in which it was implemented. The TransMilenio property acquisition programme has also now become a model for all the municipality's infrastructure projects requiring purchase of private properties. The key to the programme's success is the quality of the property appraisal and the clarity of the procedures to be undertaken. The entire process is designed to account for all eventualities and to provide timely actions at each step. Even small delays due to legal proceedings can increase construction costs dramatically.

## 3.7 Planning Stage VII: Technology

BRT is not a standard bus service. BRT is a collection of best-practice measures and advanced technologies that deliver a high-quality mass transit experience. BRT's passenger vehicles, fare collection systems, and customer information systems are as sophisticated as most other types of mass transit systems, including rail systems.

However, at the same time, technology should not overshadow the main basis of BRT, which is excellence in customer service. Further, while BRT's technologies are quite advanced, the relative cost of these technologies to other mass transit technologies (e.g., light rail vehicles) is significantly less.

This section outlines the various technological options for vehicles, fare collection systems, and intelligent transportation systems (ITS). This section will also discuss how to design a competitive procurement process that will deliver the most cost-effective product.



### 3.7.1 Vehicle technology

Few decisions in the development of a BRT system invoke more debate than the choice of bus propulsion technology and bus manufacturer. However, it should always be remembered that BRT is far more than just a bus. The choice of bus technology is important, but not necessarily more so than the myriad of other system choices.

Decisions on vehicle ownership will affect the type of vehicles selected. 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 bus operating companies. The public agency will likely develop a detailed set of vehicle specifications that each operator will be required to fulfil. However, it is up to the bus operator, who is paying for the buses, to determine how to best meet the specifications. Thus, 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 buses look and operate identically.

Private procurement of the vehicles also permits public investment to be focused on high-quality infrastructure. Additionally, by keeping public officials away from the bus purchasing process, there is less likelihood of corruption and misappropriation of public funds.

#### 3.7.1.1 Decision factors

Operators purchasing BRT vehicles must weigh many factors in choosing a fuel and propulsion system technology. Beyond basic vehicle prices, there are a host of issues that must be considered. Will the vehicle technology meet required emission standards? Will the size and design of the vehicle fulfil capacity requirements? Does the technology have a history of operating consistently in developing city conditions? Does the technology require maintenance personnel with highly-specialised skills? Are spare parts for the technology expensive and difficult to obtain in a developing city? Are special re-fuelling stations required for the technology? Table 33 summarises many of the factors that an operator will consider in deciding upon a technology and a manufacturer.

**Table 33 Decision factors for choosing a vehicle technology**

| Category | Factor |
|---|---|
| Cost | Purchase cost<br>Maintenance costs<br>Re-sale value in local market |
| Vehicle features | Passenger capacity<br>Interior design options<br>Aesthetics |
| Manufacturer support | Manufacturer support office in country<br>Capabilities of manufacturing technical assistance staff<br>Warranty coverage and conditions |
| Robustness | Track record of technology in a developing city<br>Degree to which specialised skills are required for maintenance and operation<br>Feasibility of making repairs on the road<br>Expected percentage of up-time in operation |
| Re-fuelling | Re-fuelling time<br>Type and cost of required re-fuelling station |
| Environment | Local emissions (NOx, SOx, CO, PM, toxics)<br>Global emissions (CO2, N2O4, CH4)<br>Noise levels<br>Other waste products (e.g., solid waste, waste oil, etc.) |

#### 3.7.1.2 Fuel and technology options

The choice of fuel and propulsion technology will affect operating costs, maintenance costs, supporting infrastructure, and 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 158):

- Standard diesel
- Clean diesel
- Bio-diesel (biomass fuel - diesel)
- Compressed natural gas (CNG)
- Liquid petroleum gas (LPG)
- Hybrid-electric (diesel-electric and CNG-electric)
- Electric
- Hydrogen (fuel cell technology)

**Clean diesel**

**Hybrid electric**

**Electric trolley**


**Fuel cell**

**Natural gas**

A range of other possibilities also exist such as fly-wheel technology, di-methyl ether (DME), and blended fuels (e.g., water-in-oil emulsions).

a. *Clean diesel*

Clean diesel is a technology that both produces relatively low emissions and also is within the technology experience of most developing cities. 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, 2002, p. 61):

> "Diesel engines are recognised and favoured 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 fuelling 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, 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."

The sulphur and aromatic content of the diesel fuel is a particularly telling measure of the fuel quality. In some developing cities, diesel fuels may contain over 2,000 parts per million (ppm) of sulphur. To achieve Euro II standards, a sulphur level of less 500 ppm is likely to be required. To achieve "ultra-low-sulphur diesel" (ULSD), the fuel must contain less than 50 ppm. Many emission-control technologies will only function properly if the fuel sulphur levels are below acceptable levels. Thus, the availability of high-quality diesel fuel is a pre-requisite for cities that wish to mandate Euro II or better emission standards.

*b. Compressed natural gas (CNG)*

CNG is highly touted as a reliable fuel option that "inherently" achieves lower emissions. CNG contains virtually no sulphur and naturally burns quite cleanly. However, CNG is not a perfect solution. The low energy density of the fuel means that the gas must be compressed for on-board storage in large, bulky cylinders. The refuelling infrastructure for CNG can also be costly to develop. The amount of time required for refuelling is also an issue for CNG vehicles. Typically, refuelling time per vehicle will range from 20 minutes to 40 minutes. The CNG vehicles themselves are also typically more costly than clean diesel vehicles. The emission reduction performance, though, is not that much better than clean diesel vehicles. In fact, greenhouse gas emissions from CNG vehicles will likely be even higher than the emissions from clean diesel vehicles. CNG vehicles also require different maintenance skills that may not be common in developing cities.

c. *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. Due to the lower mechanical demands on the electric-trolley technology, the life of the vehicles can be twice that of diesel vehicles.

The principal drawback to electric-trolley vehicles is the cost. Electric-trolleys can be three times the cost of a comparable Euro II diesel vehicle. Further, the added infrastructure costs of the trolley cables and transformers can be significant. Additionally, in some cities there will be aesthetic issues to consider with the introduction of trolley wires. The aesthetic issue can be particularly sensitive in cities with historical centres. The performance of trolley vehicles is generally comparable to conventional vehicles although there are some limitations to steeper road grades.

Quito utilised electric-trolley technology on its first BRT corridor in 1996 (Figure 159). 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 at the time was primarily from hydro-electric sources. The city had two competing bids for provision of the vehicles: 1. The Spanish affiliate of Mercedes Benz; and 2. A Russian company. A concessionary loan guarantee from the Spanish government convinced Quito to accept the offer from Mercedes Benz. 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 kilometre. By comparison a subsequent BRT corridor in Quito using Euro II diesel technology resulted in capital costs of approximately US$ 1 million per kilometre.

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 skyrocket to market levels. Due to these spiralling costs, the city was not able to offer the "trole-bus" corridor to private operators. Thus, the "trole-bus" corridor has remained a public company while all new diesel BRT corridors in Quito are privately operated. Based on this experience, Quito does not expect to utilise electric-trolley technology on any of its future corridors.

Table 34 summarises the advantages and disadvantages of utilising electric-trolley technology.

**Table 34 Advantages and disadvantages of electric-trolley 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 destabilise financial model |
| Smooth ride characteristics | Infrastructure costs can be over twice that of a non-trolley BRT system |
| Longer vehicle life (up to twice the vehicle life of diesel vehicles) | Presence of wiring, posts, and transformers can create aesthetic concerns, particularly in historical centres |

*d. Advanced technologies*

Highly advanced technologies such as hybrid-electric vehicles and fuel-cell vehicles are under going testing in both developed and developing cities. However, none of these cities are actually operating full fleets with these technologies. The costs and performance of these vehicles are not entirely proven.

Hybrid-electric vehicles will likely be the first of these technologies to gain large-scale acceptance in the market. Hybrids utilise 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 utilised 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. However, the complexity of propulsion system and cost of the hybrid components means that hybrids may not be well-suited for all developing city applications. Currently, efforts are being made to produce hybrid-electric vehicles in Brazil.

3.7.1.3 Vehicle cost

A particular technology's purchase price will be perhaps a foremost consideration for private sector operators. Technologies with a longer history and large manufacturing volumes will hold a cost advantage in terms of manufacturing economies of scale. New technologies will generally have lower manufacturing volumes and may incur additional research and tooling costs.

The location of the manufactured vehicle will also be a factor. Production sites in developing countries will hold an advantage in terms of labour 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.

Table 35 provides a summary of vehicle cost estimation based on technology types and location of manufacture.

**Table 35 Bus vehicle costs**

| Vehicle type | Purchase cost (US$) |
|---|---|
| Small, new or second-hand bus seating 20-40 passengers, often with truck chassis | $ 10,000 - $ 40,000 |

| | |
|---|---|
| Large, modern-style diesel bus that can carry up to 100 passengers, produced by indigenous companies or low-cost import | $ 40,000 - $ 75,000 |
| Diesel bus meeting Euro II standard, produced for (or in) developing countries by international bus companies | $ 100,000 - $ 150,000 |
| Standard OECD Euro II diesel bus sold in Europe or United States | $ 175,000 - $ 350,000 |
| Diesel with advanced emissions controls meeting Euro III or better | $ 5,000 to $ 10,000 more than a comparable standard diesel bus |
| CNG, LPG buses | $ 25,000 to $ 50,000 more than a comparable standard diesel bus (less in developing countries) |
| Hybrid-electric buses | $ 75,000 to $ 150,000 more than a comparable standard diesel bus |
| Fuel-cell buses | $ 850,000 to $ 1,200,000 more than a comparable standard diesel bus |

Source: Adapted from IEA, 2002, p. 120.

#### 3.7.1.4 Vehicle size

The size and required passenger capacity of the vehicle are largely determined by the modelling analysis conducted at the outset of the project (see section 3.2). The analysis process will have determined a projected passenger 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.

Manufacturers typically produce vehicles in set range of interior dimensions. The actual number of passengers that can be accommodated in a given interior space will depend on interior layout and the number of seats provided versus the amount of space for standing customers. Table 36 summarises some typical ranges of passenger capacities for standard vehicle sizes.

**Table 36 Standard vehicle types and passenger capacities**

| Vehicle type | Typical number of passengers | Typical vehicle length (metres) |
|---|---|---|
| Vans | 10-16 | 3 metres |
| Mini-buses | 25-35 | 6 metres |
| Standard buses | 60-80 | 12 metres |
| Articulated buses | 120-170 | 18 metres |
| Bi-articulated buses | 240-270 | 24 metres |

A common error is to assume that larger vehicles are somehow “better”. In truth, the best vehicle size is one that permits a cost-effective operation for the given volumes and service frequency. If a large vehicle requires a ten minute headway between vehicles in order to achieve an optimum load factor, then it might be better to choose a lower capacity vehicle. Passengers prefer headways in the range of one to four minutes. Long wait times will ultimately cause passengers to choose alternative modes of transport, such as private vehicles.

High volume systems will likely require both large (articulate or bi-articulated) buses and high-frequency service (Figure 160). Lower volume systems should also strive for high-frequency service, but obviously with smaller bus types. It is also not a matter of just selecting one bus type since feeder and trunk line vehicles will likely be quite different. Bogotá's TransMilenio system, for example, utilises articulated buses on trunk line corridors and standard buses on feeder lines.

Another consideration of vehicle size is manufacturer availability and industry competitiveness. Currently, only one major manufacturer produces a bi-articulated vehicle. Thus, if this type of vehicle is specified there is likely to be less competition within the bidding process. This lack of competition will ultimately force a higher price being paid by the operators, which will then translate into higher customer fares.

3.7.1.5 Environmental performance

*a. Emission standards*

From an emissions standpoint, there is no one clear solution that is necessarily superior to another. 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 can end up emitting more greenhouse gas emissions than even a diesel option. Some fuels may produce less local emissions but will produce more total emissions when the full fuel cycle is considered. For example, electric vehicles and hydrogen-fuelled 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. Bio-fuels may seem to be net-zero producers of greenhouse gases, but agricultural practices can mean that soil-related emissions are quite high. Some fuels may work well in ideal conditions but are more polluting in circumstances when maintenance and road conditions are poor.

Emission standards are the most typical mechanism for differentiating between the emission levels of different options. The standards set forward by the US Environmental Protection Agency and the European Commission are most typically used to classify emission performance of different technologies. Table 37 summarises the "Euro" standards system.

**Table 37 "Euro" emission standards for heavy vehicles**

| Euro category | Date in EU | NOx (g/kWh) | PM (g/kWh) | Engine control requirements |
|---|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| Euro II | 1998 | 7.0 | 0.15 | Minor diesel engine improvements, good maintenance, proper operating settings, and diesel fuel with 500 ppm sulphur or less |
| Euro III | 2000 | 5.0 | 0.10 | Further engine improvements (e.g. closed loop system) and probably a diesel oxidation catalyst. NOx system may require an EGR system |
| Euro IV | 2005 | 3.5 | 0.02 | Ultra-low sulphur diesel (< 50 ppm) and a catalytic particulate filter, with additional NOx control such as advanced EGR |
| Euro V | 2008 | 2.0 | 0.02 | Further NOx reduction such as NOx absorber or SCR technologies |

Source: IEA, 2002, p. 64

Emission standards can be achieved through several options including:

- Fuel quality,
- Engine technologies,
- Emission-control technologies, and
- Driver and maintenance practices.

A strategy incorporating each of these components will be most effective. However, each component has a different ramification in the developing city context. If fuel quality is the focus of the strategy, 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 utilised, how robust are these technologies in developing city conditions? If an improved driver and maintenance programme 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 buses 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 amortisation rate for the vehicle.

*b. Specifying an emission standard or a fuel type?*

Within the vehicle specifications set by the public agency, a decision must be made to specify a particular technology or to only specify a particular emission standard. In general, it is preferable to only specify a particular emission standard, and then allow the private sector find the best means of fulfilling the standard. The operator will need to consider a range of factors such as fuel costs, fuel availability, maintenance, reliability, refuelling times, and performance. 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, TransMilenio specifies that buses 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.

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 utilise compressed natural gas (CNG) as fuel (Figure 161). Some diesel fuel suppliers in India adulterate the fuel with other liquids such as kerosene. The result is poor performing vehicles, higher emissions, 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, 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 intercede and ensure that the conversion process was finally undertaken.

*c. Noise*

Acceptable noise levels should also be specified within the bus procurement specifications. Excessively loud vehicles are both a health hazard as well as a detriment to the marketing image of the transit 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 specified to not exceed 90 decibels (dB).

3.7.1.6 Low-floor vehicles versus high-floor vehicles

There has been considerable amount of attention to low-floor buses in recent years, particularly in Europe and North America (Figure 162). By contrast, most BRT systems in developing cities utilise high-floor vehicles with ramped entry systems.


Low-floor buses permit relatively rapid boarding and alighting without the need for ramped entry stations. However, there are also trade-offs with low-floor buses. Being closer to the ground, the buses typically incur more structural stress and thus have higher maintenance costs. Road surfaces on low-floor bus routes must be maintained at a very high level in order to avoid damage to the vehicles. Small imperfections in the road surface will also tend to make the ride less smooth and comfortable for the customers. Low-floor buses also typically cost US$50,000 – US$100,000 more than standard models.

Ramped-entry vehicles with high floors are typically the most practical for BRT applications in developing cities. A level entry will permit rapid customer boarding and alighting. Only with minimal dwell times can developing city passenger capacities be achieved. High-floor vehicles permit a smooth ride experience as the additional distance permits greater absorption of road imperfections. Low-floor vehicles have a lower equivalent passenger capacity since the wheel-wells will protrude into the passenger space. Standard tow vehicles will not be able to move low-floor vehicles if there are mechanical problems. A more costly specialised tow vehicle will be required. Finally, low-floor vehicles can create difficulties with regard to preventing fare evasion. With a ramped-entry high-floor vehicle, the height of entry acts as a natural defence against individuals trying to enter from outside the station. With low-floor vehicles, fare evaders can sneak between the station and the bus, and then enter the vehicle with relatively little difficulty. Table 38 summarises the advantages and disadvantages of low-floor vehicles.

**Table 38 Advantages and Disadvantages of Low-Floor Buses**

| Advantages | Disadvantages |
|---|---|
| Avoids the need to construct ramped stations | Can cost US$50,000 to US$100,000 more per bus |
| Allows the flexibility to use in low-density communities where station construction is impractical | Higher maintenance costs due to impacts from road surface and vibrations |
| Creates more modern image with the customer | Difficult to tow when break downs occur |
| More rapid boarding in comparison to systems with high steps | Lower passenger throughputs in comparison to buses with ramped entries |
| | More difficult for the physically disabled |

| | |
|---|---|
| | and elderly to enter than buses with ramped entries |
| | Creates difficulties in stopping fare evasion within closed fare systems |
| | Less comfortable ride experience since small road imperfections will affect ride smoothness |
| | Low-floor articulated vehicles will bse as much as 12 seats worth of floor space due to the protrusion of wheel-wells into the passenger area |

3.7.1.7 Double-decker buses

Double-decker vehicles have also maintained popularity with conventional bus services in both developed and developing cities. Although often associated with the buses in London, double-decker vehicles have been employed in Dhaka, Hong Kong, Johannesburg, Singapore, and elsewhere (Figure 163). Double deckers can bring an intriguing image to a public transit system and can be quite popular when applied to tourist routes. The upper deck of the vehicle offers an opportune vantage point for sightseeing.

Other arguments supporting double-decker vehicles revolve around the higher passenger density achieved while maintaining a low footprint density on the in-use road space. Thus, while an articulated vehicle gains passenger numbers by the length of the vehicle, a double decker gains passenger numbers by its height. A double decker vehicle will also consume less road space at stations.

However, double deckers bring with them many complications, not the least of which is added cost. The gain in passenger numbers with the second level is less than the same amount of floor space added to an articulated vehicle. The difference is the floor space consumed by the stairway, both on the lower and upper floors. Thus, the passenger numbers achieved and the vehicle cost per passenger accommodated with double deckers fail to match the performance of articulated vehicles. The stairway also creates a potentially troublesome difficulty for passengers, 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 passenger movement difficult. The net effect is to dramatically lengthen passenger boarding and alighting times.

Double deckers are thus not entirely suitable for high-volume operations where passengers 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 centre of the city and then again at a distant suburban location.

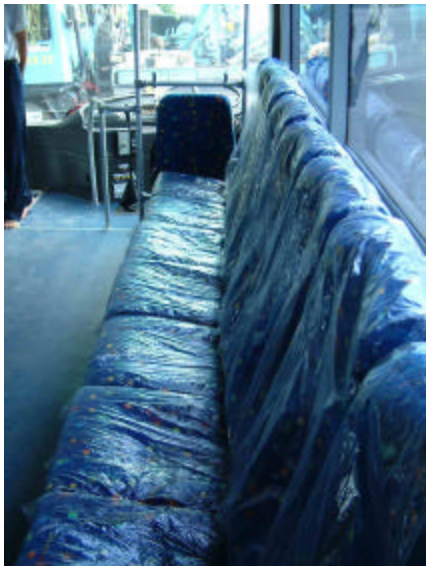
Table 39 summarises the advantages and disadvantages of utilising double-decker vehicles within the context of BRT.

**Table 39 Advantages and disadvantages of double-decker vehicles**

| Advantages | Disadvantages |
|---|---|
| Increases passenger carrying capacity without increasing road space footprint | Adds cost to vehicle; cost per passenger carried is much higher than articulated vehicles |
| Creates intriguing transit image and is attractive for tourism | Stairway consumes passenger space on both floors and thus reduces overall passenger density in vehicle |
| | Can be dangerous for passengers using stairway while vehicle in motion |
| | Boarding and alighting can be delayed due to congestion on stairway |
| | Height of vehicle can be a problem on some routes with low-clearance infrastructure and trees |
| | Height of roof and the structural integrity of the roof creates difficulties in placing cylinders for natural gas or other alternative fuels |

3.7.1.8 Interior design

From a customer perspective, the interior of the bus is far more important than the mechanical components propelling the bus. The interior design will directly affect comfort, passenger capacity, security and safety. The amount of space dedicated to standing areas and to seated areas should be based upon expected passenger flows, especially accounting for peak capacities. The width of aisle ways will also be part of this equation. Standing passengers will require holding devices (poles, straps, etc.) in order to travel safely and comfortably.



Seating facing to the sides rather than to the front can be effective in opening up space for standing passengers (Figure 164). 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.

Cloth and padded seating offers additional comfort to passengers (Figure 165). 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. 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 passengers who wish to view of the outside environment.

Special arrangements should also be made to cater to the needs of physically disabled and elderly passengers. 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.

Bicycles can also be safely and effectively secured inside the bus. Unfortunately, the bicycle is needlessly banned from many bus systems. With the ramped entryways of BRT vehicles, bicycles can be easily boarded, especially during non-peak periods. The space permitted for bicycles can also be an effective open space for standing passengers during peak times. BRT vehicles in Rouen (France) provide this type of open area for easy bicycle entry (Figure 166).

3.7.1.9 Vehicle aesthetics

The aesthetic nature of the bus technology should also be an explicit component of the design and specification process. Bus styling, colour and aesthetic features figure greatly in the public's perception of the system. Some bus manufacturers are now emulating many of the design features from light rail systems (Figure 167). Simply by covering the wheels and rounding the bus body, these manufacturers have greatly increased the aesthetic appeal of their product. These initial bus 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 endeavour.

3.7.1.10 Docking systems

The process of aligning the vehicle to the station will affect the speed of passenger 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.

The type of docking precision required is related to the type of bridging device utilised to link the vehicle to the station. If a flip-down ramp is utilised to extend from the bus to the station platform, exact precision is less important. As long as the separation distance still allows the ramp to securely rest upon the platform, the positioning is less critical. By contrast, if no flip-down ramp is utilised, drivers will seek to minimise the gap left between the vehicle and the station. A large gap will slow customer boarding, create potential safety risks, and impose difficulties on customers with wheelchairs. However, if a driver comes to 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.

Optical, mechanical, electronic, and magnetic docking systems are all possible technologies to assist the driver in the docking process. Of course, as the technology becomes increasingly sophisticated, the vehicle and station costs can rise dramatically.

Optical systems can either be manually or electronically activated. A manual optical system is simply a visual target for the driver to focus upon while nearing the station platform. The driver's focus on the visual target can be improved through the use of a magnified video screen fed by a small camera under the vehicle or integrated into the wheel. Electronically-operated optical systems function in a similar manner but rely upon a micro-processor to actually steer the vehicle. Thus, as the vehicle nears the station, the micro-processor assumes control of the vehicle from the driver. This type of system is utilised on the BRT system in Las Vegas (USA). The Civis vehicle used in Las Vegas can also be set-up to operate the entire route without driver intervention. However, the cost of the automated optical system can push vehicle costs to over US$ 1 million per vehicle. Further, since labour is generally quite cost-effective in developing cities, there is little application for such automated systems in developing nations.

Mechanical guidance systems for station alignment are similar to the mechanical systems used on busways in Essen (Germany) and Adelaide (Australia). Such systems can also be used only at station to bus interfaces. In this case, side-roller wheels are not needed for guidance. Instead, the vehicle enters a mechanical track with soft sides that guides the bus into position.

Finally, similar to the Civis optical guidance system, the Phileaus bus offers a magnetically controlled guidance system. Magnetic materials are inserted into precise locations of the roadway. A micro-processor interface with an on-board magnetic sensor then steers the vehicle along a precise path. Like the Civis, the Phileaus bus can be operated without driver intervention at both stations and along the busway.

For the developing city application, a simple optical system that is manually operated by the driver is quite sufficient. In conjunction with ramped-entry devices, these systems offer a cost-effective way of achieving a sufficiently precise docking position in order to permit rapid boarding and alighting.

#### 3.7.1.11 Vehicle specification matrix

The public planning agency will likely develop an official document detailing the vehicle specifications by which the private operators will select their vehicles. System planners should develop vehicle specifications that best meet the local circumstances of the envisioned BRT system rather than merely follow the specifications put forward by a single bus manufacturer. However, at the same time, system planners must also be cognisant of the vehicle products available on the market so as to specify a vehicle that will be cost-effective. The public agency must also be careful to not over-specify the vehicle to the point that few vehicle options are actually available to the private operators.

Table 40 is a summary of the vehicle specifications put forward by the public company overseeing the Bogotá TransMilenio system. The actual specifications for any given city will vary depending on local preferences and circumstances.

**Table 40 Bogotá vehicle specifications (trunk-line vehicles)**

| Vehicle attribute | Specification |
|---|---|
| **Load weights** | |
| GAWR front axle load | 7,500 kg |
| GAWR middle axle load | 12,500 kg |
| GAWR rear axle load<br>GVWR total weight | 12,500 kg<br>30,000 kg |

| **External dimensions** | |
|---|---|
| Maximum width | 2.60 metres |
| Maximum height<br>Overall minimum length | 4.10 metres<br>17.50 metres |
| Overall maximum length | 18.50 metres |
| 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 | 12,100 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 by obtained by physical proof or computational model<br>Minimum certified roof resistance in 5 minutes: 50% of GMV<br>Maximum deformation in every point: 70 mm |

| **Passenger space** | |
|---|---|
| Total passenger capacity | 160 passengers |
| Seating capacity | 48 passengers |
| Colour of seats | Red |
| Number of preferential seats | 6 |
| Colour of preferential seats | Blue |
| Standing passenger area | 16 $m^2$ |
| Standing design capacity | 7 passengers per square metre |
| Wheelchair capacity | 1 space for wheelchair (90 cm x 140 cm); 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<br>Closed in back<br>Direct anchorage to the vehicle floor<br>Without upholstery or cushioned<br>Without sharp edges or rivets |
| Materials | Plastic<br>Washable<br>Self-extinguishing and flame retardant<br>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<br>End finished in a curve<br>Continuous<br>Non-slip surface |
| Dimensions | Diameter: Between 30 and 45 mm<br>Horizontal handrail height: 1750 mm minimum and 1800 mm maximum<br>Distance between vertical balusters: 1500 mm or very two seats |

| **Windows** | |
|---|---|
| Front window type | Laminated |
| Type, all other windows | Tempered |
| Colour 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<br>Maximum: 50% of total height of the window |

| **Doorways** | |
|---|---|

| | |
|---|---|
| Number of passenger doorways | 4 |
| Position | Left side of bus |
| Minimum free width | 1100 mm |
| Free height | 1900 mm |
| Door opening time<br>Emergency doors | 2 seconds<br>Type: single door<br>Number of emergency doorways: 2<br>Minimum free width: 650 mm<br>Free height: 1800 mm<br>With stairs covered and with a pneumatic opening system |

| **Control and instrumentation** | |
|---|---|
| Logic unit | Communication display in view of driver<br>GPS and communications antennas<br>Tachnograph (with register and storage of instant velocity, distance travelled, times of operation and non-operation over 24-hour period) |
| Control centre 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<br><br>Visibility | 1 in front: 1950 mm x 300 mm<br>2 on left side: 450 mm x 250 mm<br>Visible from a distance of 100 metres |

| **Technical standards** | |
|---|---|
| Bus | NTC 4901-1 Mass Transport Passenger Vehicles |
| Test methods<br>Local standards | NTC 4901-2 Mass Transport Passenger Vehicles<br>ICONTEC (Colombian Technical and Standardisation Institute) |

Source: TransMilenio SA

### 3.7.2 Fare collection and fare verification systems

The method of fare collection and fare verification has a significant impact on passenger flow capacities and the system's overall impression to the customer. Section 3.5 discussed the fare collection system from the perspective of the

business model and the distribution of revenues to different private and public entities. This section outlines some of the technological options for collecting and verifying fares. Additionally, the advantages and disadvantages of different service options are also discussed; these options include:

- On-board versus off-board fare collection
- Distance-based fare collection versus flat fares
- Time-based fare collection
- Actual verification versus "proof of payment" systems.

Both fare collection and fare verification processes are included in this section. Fare collection refers to the fare payment process while fare verification refers to the validation of the fare. Fare collection and fare verification can actually occur simultaneously or in different steps, depending on the process and technology being utilised.

3.7.2.1 On-board versus off-board fare collection and fare verification

The decision to collect and verify fares off-board will have a significant impact on the potential passenger capacity of the system. Off-board fare collection and fare verification reduces the long delays that accompany on-board payment. Once passenger flows reach a certain point, the delays and time loss associated with on-board fare collection become a significant system liability (Figure 168). In Goiania (Brazil) the local transit agency estimates that this point is reached when the system capacity reaches 2,500 passengers per hour per direction.


Pre-board fare collection and fare verification also carries another benefit. By removing the handling of cash by drivers, incidents of on-board robbery are reduced. Further, by having an open and transparent fare collection system, there is less opportunity for circumstances in which individuals withhold funds.

3.7.2.2 Flat fares versus distance-based fares

The customer tariff can either be represented through a flat fare or a distance-based fare. A flat fare implies that the same fare is charged to a customer regardless of the distance travelled in the urban area. A distance-based fare implies that customers are charged based on the distance covered in their journey. The choice between the two fare options involves trade-offs between social equity issues as well as between levels of fare collection complexity.

In much of the developing world, flat fares are utilised for social equity reasons. In many developing cities the lowest income groups often reside at the urban fringe. These peri-urban areas offer property at substantially lower costs than central areas. In many cases, the poor are utilising peri-urban properties that are not owned by the individual. These informally occupied areas quite often lack public services such as water and electricity. Additionally, 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 was 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 city centre services and opportunities. 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.

A flat fare also permits the use of simpler fare collection technologies. Ticket-less options, such as coin-based machines, 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 utilised quite frequently in developed nations as well as some rail systems in developing cities, such as the SkyTrain in Bangkok (Thailand) and the Metro in Delhi (India). Distance-based fare structures most closely mirror actual operating costs and thus provide a truer measure of expenses for system operators. A longer journey implies that more fuel and labour is required. Thus, distance-based systems do not involve the implied cross-subsidy that exists in flat fare systems. Distance-based fares also require a more sophisticated fare collection and fare verification system. Unless an honour system is utilised, distance-based fares will require magnetic strip or smart card technology. These technology choices bring along with them issues of additional costs, customer queuing, and overall complexity.

In actuality, it is also possible to have a mix of both flat fares and distance-based fares. A flat fare may be utilised 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 are less. For example, the busways in Sao Paulo (Brazil) charge a flat fare in central areas but revert to a distance-based scheme for continuing onto satellite destinations. The fare collection system in such instances may require greater sophistication, such as

smart cards. Alternatively, the point between flat fare and distance-based fares may be realised at terminal sites where it is necessary to transfer between vehicles. At this stage, the transfer between vehicles can require an additional payment.

#### 3.7.2.3 Time-based fares

Time-based fares typically enforce a maximum amount of time that a person can reside within the system. A time-based restriction is sometimes imposed in order to prevent some customers from abusing the intent of the transit service. For example, a homeless person may stay on the system for long periods of time just to stay in a quality and protective environment. Pickpockets may also stay on for long periods in order to steal from several different customers.

In less sinister scenarios, a person may also travel a long distance on the system, and then conduct business within the system. The person would then return to the original point of origin, and thus only pay for a short trip. Alternatively, a person may travel some distance on the system and then realise that he or she has forgotten something at home. The total time, including the trip back home, may exceed the allotted time. Also, tourists may travel for long periods of time on the system in order just to see the city. In all of these less sinister cases, the activities are probably not something that should worry a transit agency. The number of persons taking these unusual routes is likely to be quite small. Further, sanctioning persons for such relatively innocent behaviour will only dampen customer relations.

However, some metro systems do put a time limit on travel. By doing so, the complexity of the fare system increases dramatically. Recording the time and distance of a trip requires a fairly sophisticated and costly technology, such as magnetic strip or smart card technology since the time must be recorded upon entry and exit. Further, staff must be posted at exits in order to deal with customers who have stayed beyond the allotted time. The technology should also 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, then the customer should not be held accountable.

In summary, time-based fares are probably not an entirely appropriate idea in either developed or developing cities. To curb extended use of the system by the homeless or by individuals engaged in theft, there are probably other more effective techniques that can be utilised. The presence of security staff and security cameras are likely to be preferred tools to address these issues. In the case of more innocent time violations, such as the use of the system by tourists, there is little to be gained from sanctioning this behaviour. In reality, the use of the system as a tourist sight-seeing vehicle is a complement to the quality and usability of the system, and is not an activity that should be discouraged or berated.

#### 3.7.2.4 Pre-board verification or honour system

The decision on whether to require verification of a ticket will affect the design of the stations and the amount of fare evasion that occurs. Verification is the process of checking whether a person has actually paid for their intended (or completed) journey.

Systems in Europe and North America often employ “proof of payment” techniques, also known as “honour” systems. In such systems, very little actual fare verification is actually conducted. Occasional checks by transit staff is done to control the relative level of fare evasion. The actual payment of the fare is largely reliant on the public’s goodwill and overall willingness to comply. For those caught without a valid fare during the random inspection process, a penalty is applied. Honour systems do entail pre-board fare collection, usually through a vending machine or kiosk (Figure 169). However, from the fare payment point onwards, the customers proceed directly to the transit vehicle without inspection.


The main advantage of proof of payment fare systems is that it allows one to avoid the construction of a closed entry station. No physical separation between the station and the outside area is necessary. This design advantage can help reduce station construction costs as well as permit better station design in areas with limited physical space.

The principal disadvantage of such a system is its great dependence on customer compliance that is sometimes difficult to obtain. Further, the use of fare verification staff for the random checks can sometimes be costly. The viability of operating an effective honour system in a low-income city is yet to be proven. The lack of such systems in developing cities does not imply that developing-city residents are less honest. However, managing such a system in the high-volume applications of developing would be quite difficult. Even with stringent verification requirements, cities such as Quito face non-negligible amounts of fare evasion.

3.7.2.4 Decision factors

Fare collection technologies vary significantly in terms of technical sophistication and cost. The decision-making process will likely encompass the following types of considerations:

- Capital cost
- Operating cost
- Complexity and reliability
- Flexibility
- Physical requirements
- Impacts on queuing
- Service features

One of the principal determinants in choosing the appropriate technology depends on whether a system utilises a flat fare or distance-based fare scheme. Section 3.5.5.3 discussed the various trade-offs in selecting a flat fare or distance-based fare. A flat fare scheme will greatly simply the technology required. With a flat fare

there is no need to verify the distance travelled, so there is no need to check the fare record at the destination side of the journey.

The number of queues that the customer will endure in conjunction with the likely length of time in each queue will affect passenger capacity flows and customer satisfaction. Thus, simpler fare collection systems will likely not only be more robust to maintain but will also be more user-friendly.

Flexibility refers to the ability to adapt the fare collection system to changes in the overall transit environment. If a municipality decides to move from a flat-fare scheme to a distance-based scheme, the existing system may provide sufficient flexibility or may require a complete overhaul.

The physical requirements of the technology are particularly important given the limited space available in most BRT station areas. If a verification turnstile is quite bulky, then only one or two of the devices can be placed at the entry gate. The limitation on the number of turnstiles will affect the maximum number of passengers that may be processed.

3.7.2.5 Technology options

Several different technologies and mechanisms exist to facilitate BRT fare collection and fare verification, including:

- Coin or token systems
- Paper systems
- Magnetic strip technology
- Smart card technology
- Proof of payment systems

No one solution is inherently correct. The choice of fare collection system often involves a trade-offs between costs, simplicity, and service features.


*a. Coin / token systems*

Coin and token systems are amongst the simplest and lowest cost technologies available to handle fare collection and fare verification. Coin-based systems also tend to reduce queuing in comparison to other technologies. However, with this simplicity comes some limitations. Coin-based systems work best with flat-fare structures.

Queuing is reduced with coin-based systems due to the fact that the customer does not need to purchase a fare card. Instead the currency acts directly as the fare payment and verification

mechanism. There is no need to issue any paper tickets to customers. Flat fare systems also typically do not require fare inspection upon exiting the system. Thus, while other systems may involve at least three separate customer queues (purchase fare, verify fare at entrance, verify fare at exit), coin-based systems require the customer to only enter one queue (verify fare at entrance). The time saved to the customer and the reduction in overall system space dedicated to fare verification can be significant. Simpler technologies also produce a savings in terms of maintenance and operation since such the technologies tend to be more robust.

In Quito, Ecuador, a simple coin-based system has worked successfully for both the city's "Trole-line" and "Ecovía" line (Figure 170). The system thus avoids the need for any paper tickets. 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 inherent flexibility to utilise discount fare cards as well. The coin dispenser also has room for a card reader as well. However, the entire turnstile device is relatively narrow, and thus permits two turnstiles in a relatively narrow station.

Naturally, coin-based systems depend upon 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, requiring the customers to purchase tokens means additional queues. Another alternative is to utilise 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 often found in developing nations.

*b. Paper systems*


Simple paper tickets are issued for bus and rail systems throughout the world (Figure 171). Ticket purchases can take place at vending booths, machines, kiosks, and other shops. The ticket will often have enough recognisable detail to prevent counterfeiting.

In some instances, paper ticket systems will require a validation step to the process. The validation will involve inserting the paper ticket into a stamping machine. This machine will mark the time and sometimes the location of the validation. The validation process becomes important when paper systems are distance-based and/or have time limits on usage.

Verification of paper tickets can take place manually upon entrance into the system or may only be verified on the occasion of a random inspection. In some instances, the

verification may be done by the bus driver or a conductor. Such manual verification is quite problematic in high volume systems. The queuing points are likely to be quite lengthy and the detrimental impact on customer travel times would be significant.

Normally, verification for paper ticket systems is conducted on an honour system. However, the viability of an honour system in most developing cities has yet to be substantiated.

Paper systems can permit distance-based fares, but verification of distance travelled can only be verified manually. The feasibility of verifying distances travelled within in a high-volume system is somewhat suspect.

*c. Magnetic strip technology*

Magnetic strip technology has had a relatively long history of application and success in the field. Magnetic strip technology has been used successfully in metro systems around the world (Figures 172 and 173). There are two different standards for magnetic strip cards: 1.) The standard-sized ISO 7810 card; 2.) The smaller "Edmundson" card.


The technology requires the pre-purchase of the magnetic card for system entry and verification. Capital costs can be significant for both the ticket vending machines and the magnetic strip readers at the fare gate. The advantage of magnetic strip technology is the relatively low-cost of the fare cards themselves, US $0.02 - US$ 0.05 per card. However, unlike smart cards, magnetic strip cards have a limited lifetime. In some cases, cards may be issued for only a single uses. The cards are made of coated paper and can be relatively easily damaged.

Depending on the type of magnetic strip card, counterfeiting can also be an issue. Cards with low coercitivity can be relatively easy to counterfeit; more costly high coercitivity cards are more difficult to fake.

The cards may be programmed to allow multiple trips and can also permit different fares to be charged for different distances travelled. Some system providers utilising magnetic strip cards also elect to permit discounted fares for individuals purchasing multiple trips.

The cards typically are verified both at entry into the system and at the exit. Data from the verification turnstile can provide system operators with information on customer movements.

*d. Smart card technology*


Smart card technology is the latest advent in the fare collection field. Smart cards contain an electronic chip that can read a variety of information regarding cash inputs, travel and system usage. Smart cards also 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 and Goiania have successfully employed smart card technologies (Figure 174). Smart cards permit the widest range of fare collection options such as distance-based fares, discounted fares, and multiple trip fares. Such cards also collect a complete set of system statistics that can be helpful to system managers.

The main drawbacks of smart card technology are cost and complexity. The systems require fare vending personnel and / or card vending machines. The system also typically requires verification machines at the system exits, if distance-based fares are utilised. In each instance, there is a risk of long customer queues, especially during peak periods. 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 US$ 1.00 – US$ 2.50 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 such options as PVC, PET, and even paper. The activation mechanism can either be realised by way of “contact” cards or “contactless cards”. As the name implies, contact cards require physical contact with the turnstile scanning beam in order to be verified (Figure 175). Contactless cards permit the user to pass in the vicinity of the turnstile reader to activate verification. For this reason, contactless cards offer greater customer ease and convenience. However, contactless cards are also more costly.

The microchip on the card can either be “memory only” or “memory with micro-processing” capabilities. Cards with a memory chip can only store data. The addition of micro-processing allows the smart card to actually execute applications as well. For example, a micro-processing chip can allow the stored value of the

smart card to be used for purchases outside the transit system. In Hong Kong, the Octopus card permits users to make purchases at shops as well as pay for transit (Figure 176). While this feature can be quite convenient, smart cards with micro-processing capabilities are the most expensive type of card.

Unlike magnetic strip cards, though, smart cards have a long life and can be re-used. As smart cards become more common, this cost will undoubtedly continue to fall. The long-term promise of this technology also extends well beyond transit fares, as some systems are seeking to utilise the same smart cards to permit purchases at shops and the payment of other bills.


*e. Summary of fare collection technologies*

This section has provided an overview of each of the major fare collection technologies. Table 41 summarises the major decision factors for each technology.

**Table 41 Summary of fare collection technologies**

| Factors | Coin system | Paper system | Magnetic strip system | Smart card system |
|---|---|---|---|---|
| Set-up / equipment costs | Medium | Low-Medium | High | High |
| Operating costs | Low | Low | Medium | Medium |
| Level of complexity | Medium | Low | High | High |
| Number of customer queues in a single trip | 1 | 1-2 | 2-3 | 2-3 |
| Can provide customer tracking information | No | No | Yes | Yes |
| Allows automated fare verification | Yes | No | Yes | Yes |
| Allows distance-based fare schemes | No | With difficulty | Yes | Yes |
| Supports high customer flows | Yes | No | Yes | Yes |
| Supports high-tech image of system | Medium | Low | Medium-High | High |
| Space requirements for fare equipment | Medium | Low | High | High |
| Susceptibility to counterfeiting | Medium | High | Low to medium | Low |

### 3.7.3 Intelligent transportation systems (ITS)

Information technology is changing all aspects of daily life. Public transport has likewise benefited from the reach of information technologies as well as the continuing reduction in technology costs. “Intelligent transportation systems” (ITS) refer to a range of information technologies that provide more choices and better quality for the customer.


Real-time information displays are one application of ITS that can alleviate concerns over the reliability of a service. Information on the transit vehicle’s location can be relayed via several technologies to displays at stations informing waiting passengers of the next available vehicle (Figure 177). Real-time information helps to reduce customer “waiting stress”, which affects passengers who do not know when or if a particular route is going to arrive. By knowing the expected arrival time of a bus, the customer can mentally relax as well as potentially undertake another value added activity to make best use of the time. Some systems, such as the Singapore MRT system, even place a real-time information display at the outside of the station. Again, this allows customers to make best use of their time as well as helps reduce stress and rushing.

In high-frequency systems where headways are three minutes or less, real-time information displays may be of less value. However, even in these circumstances, customers can be aided in making travel route decisions. For example, passengers may be in a position to decide between taking a local or express route. With the expected arrival times of both options posted, the passenger can determine which route is optimum from a travel time perspective. Also, in cases of a vehicle being quite full, a passenger may decide to wait for the next vehicle if it is only a few minutes away. In this sense, real-time information can help balance passenger loads naturally, and thus mitigate the system delays when vehicles are overly loaded.

This type of information can also be useful inside the vehicle as well. A video or digital display inside the vehicle can list the next station (or even the next three stations) as well as the final destination of the route. In conjunction with a recorded audio announcement of the next station, customers can enjoy a more relaxed ride without having to repeatedly check their position. Passengers can undertake other value-added activities, such as reading, without worrying about missing their destination. Further, in crowded vehicles, consulting the posted system or route map can be difficult. The video and audio information helps persons easily gain information without jostling about the vehicle.

Similar types of technology can also be integrated with transit security efforts. Security cameras both inside stations and vehicles are increasingly cost-effective approach to system policing. The mere presence of the cameras themselves is often associated with a reduction in criminal activity. The cameras are also a visible sign to the customer of system security and can help reduce anxieties, particularly amongst vulnerable groups.

Signal prioritisation techniques give preference to system buses at intersections where the system must cross mixed traffic. Los Angeles' Rapid Bus system utilises signal prioritisation with great success. As a bus approaches a signalled intersection, a transponder on the bus communicates with an induction loop located in the lane. A message is then sent to the intersection's signal controller to give a green light to the approaching bus. In the case of Los Angeles, the prioritisation is only given every other signal cycle so as to not disrupt all traffic flows. Signal prioritisation works best when separation times between buses are over 4-5 minutes. In systems like Bogotá's TransMilenio, the high flow rates mean that buses are separated by as little as 30 seconds. In such circumstances, signal prioritisation probably has relatively little useful application.

Overall, though, ITS can deliver substantive improvements to system efficiencies. With the cost of such systems falling each day, even developing nation cities should conduct a full review of the options and potential implications.

### 3.7.4 Equipment procurement process

The appropriate structuring of the procurement process can create a competitive environment that will drive cost reduction and efficiency. Additionally, a well-designed procurement plan will promote an open and transparent process that will help to eliminate corruption and graft. System developers should seek a wide range of bidders for each piece of equipment needed. To achieve this environment of competitiveness, the procurement specifications should be sufficiently rigorous to meet system requirements while also permitting bidding firms the ability to innovate. Prior to issuing tenders, an explicit set of criteria should be created that sets forth the determining parameters for selecting a bid and the relative weight given to each factor (cost, experience, quality, etc.). The determination of winning bids ultimately should be decided by an objective, independent body whose members have no commercial interest with the overall project and have no relationship in any form to the bidding firms.

## 3.8 Planning Stage VIII: Modal Integration

BRT systems like all public transport systems cannot be designed and implemented in isolation. Instead, such systems are just one element in a city's overall urban framework and set of mobility options. To be effective, BRT should be fully integrated with all options and modes. In truth, other transport options such as walking, cycling, driving, taxis, and other public transport systems should not be seen as competitors with the BRT system. Rather, such complementary services should interact with BRT as a seamless set of options serving all aspects of customer needs. Additionally, BRT systems are often implemented simultaneously with restriction measures on private vehicles. Auto restrictions, as well as Travel Demand Management (TDM) techniques, provide an appropriate set of incentives for residents to switch to more sustainable options.

By maximising the BRT system's interface with other options, system designers are helping to optimise the potential customer base. The BRT system does not end at the entry or exit door of the station, but rather encompasses the entire client capture area. If customers cannot reach a station comfortably and safely, then they will cease to become customers.



### 3.8.1 Pedestrians

If it is not convenient or easy to travel to a BRT station, then the other qualities of the system become somewhat irrelevant. Without adequate access to stations, customers will simply not utilise the system. The walking environment is a key determinant in whether the transit system is of use to the customer.

The development of dedicated pedestrian zones around a BRT station can be mutually synergistic for both the pedestrian and public transport systems. The BRT system helps alleviate the necessity of costly car-based infrastructure in the city core. The dedicated pedestrian zones provide a concentration of customers that can feed directly into the BRT system. Curitiba, Brazil is a leading example of integrating dedicated pedestrian zones with its BRT system (Figure 178).

A well-designed pedestrian access plan will provide a natural flow of walking customers from the surrounding area. Pedestrian access routes should be planned over a radius of at least 500 metres around each station. System planners should ask a few basic questions regarding the quality of the pedestrian access. Are the pedestrian walkways leading to the station well maintained? Are they sufficiently broad to comfortably handle the expected pedestrian traffic? Are they safe and well lit? Is there adequate signage to lead individuals easily to the stations? Are there logical pedestrian connections between major origins and destinations such as shops, schools and work places?

#### 3.8.1.1 Qualities of pedestrian infrastructure

In designing pedestrian infrastructure, a few characteristics are paramount in providing ease of access to the BRT system:

- Safety
- Security
- Directness
- Ease of entry
- Comfort
- Aesthetics

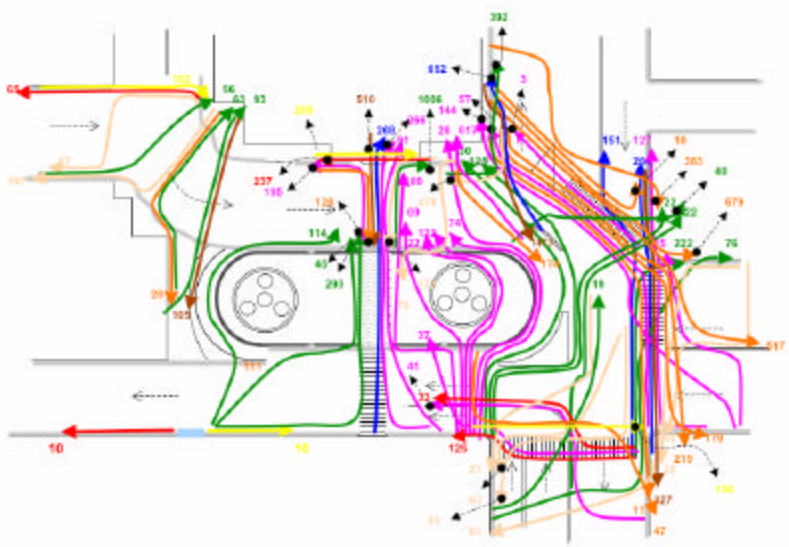
A “safe” pedestrian pathway implies that pedestrians are well protected from road hazards such as vehicles. “Security” refers to providing an environment where pedestrians are not susceptible to robberies or other crimes. “Directness” involves a pedestrian path that minimises the distance travelled. “Ease of entry” means that the walk to the station does not involve onerous actions, such as walking up steep inclines. “Comfort” refers to the quality of the pathway and provisions for protection from inclement weather, such as strong sun, wind and rain. “Aesthetics” imply that the walking environment is pleasing to the eye and inspires a person to use public transport.

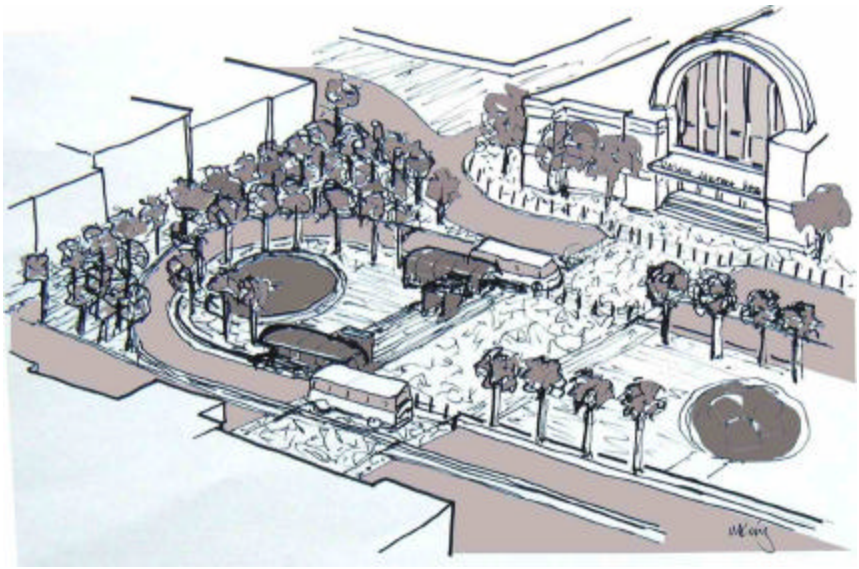
These qualities are not necessarily always mutually compatible. For example, the most direct path may mean reduced safety from conflicts with vehicles, or the safest route may imply climbing over a difficult set of stairs. The design challenge is to find a balance that optimises the total package of characteristics.

### 3.8.1.2 Pedestrian modelling

Mapping pedestrian movements in the area of the proposed BRT station provides the baseline data that will help shape the optimum design of the supporting pedestrian infrastructure. Just as traffic counts were an important element input to the BRT modelling process, pedestrian counts and pedestrian movements are important parts of understanding issues around station access.

Figure 179 shows a mapping of pedestrian movements near a BRT station in Jakarta (Indonesia). In this case, the pedestrian flows are fairly unfocussed in terms of destinations and origins. Thus, a single pedestrian bridge would likely be insufficient to satisfy the intended pedestrian movements. Figure 180 is an illustration of a potential solution for the situation described in Figure 179.





Another type of pedestrian mapping exercise involves recording travel distances from the station based on walking travel times. Maps showing areas covered in such intervals as one minute, five minutes, ten minutes, twenty minutes, and thirty minutes not only indicate the potential catchment area for the station, but this analysis 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 pavements or the lack of pedestrian pavements will also 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.

3.8.1.3 Types of pedestrian infrastructure

Pedestrian access infrastructure can take the form of at-grade entry (e.g., crosswalks) or grade-separated entry (e.g., overpasses and tunnels). Customers typically prefer the most direct routing, and thus at-grade entry options usually deliver the most rapid approach.

However, at-grade entry by way of crosswalks can involve greater safety risks if not designed properly. Transit station areas can be prone to higher pedestrian accidents for several reasons. First, as customers approach a station and see their route vehicle nearing, there is a tendency to run to catch the vehicle without paying close attention to signals (Figure 181). While frequent services mitigate this tendency, customer care in crossings can be

compromised when persons are in a hurry. Second, vehicles in mixed traffic lanes may also be less prepared for transit pedestrian crossings. In some instances, transit pedestrian crossings will be placed at mid-block (non-intersection) locations. Inattentive drivers may thus not realise a crossing exists and will fail to properly yield to pedestrians or to obey traffic lights at mid-block locations. Thus, the combination of rushing transit customers and inattentive drivers can produce lethal consequences.

There are many solutions to providing safer and more effective pedestrian crossings at transit stations. The design of the crossing itself will play a role. The areas on the pedestrian sidewalk should provide clear visibility, so that both pedestrians and vehicle users can see the space without visual restrictions from signage or vegetation. Signage and advertisements can also create an area of visual clutter that will distract motorists from seeing traffic signals and pedestrians properly. The crossing's painted surface should be highly visible and well maintained. Luminescent paints or reflectors can provide additional visibility for evening hours. Additionally, well-illuminated and well-maintained street lighting should be placed over the crossing area.

Curbs along the pedestrian route to the transit stations should all be ramped to provide access to customers on wheelchairs and to those carrying wheeled objects such as bicycles or trolleys (Figure 182). There is little value in making station platforms and transit vehicles friendly to the physically disabled if it is impossible for those individuals to reach the stations in the first place.

At-grade crossings should be placed as closely to the station point of entry as possible. Otherwise, customers may simply cross at an uncontrolled point closer to their intended destination. Figure 183 illustrates a poorly placed crossing in Leon (Mexico) that forces some passengers to walk nearly 200 metres farther than is necessary. In this location, a person working in front of the station must walk 100 metres down the roadway and then 100 metres toward the station to access a point that is actually less than 12 metres away from their starting point.

Several different types of signalling options may be employed at crossings. In some countries, a flashing yellow signal indicates that pedestrians have priority at all times. In this case, if a pedestrian appears on the sidewalk near a crossing, then motorists have the obligation of stopping, even if the pedestrian has not yet entered the crossing area. The effectiveness of this approach will depend on the local culture and the level of enforcement. Another option is a standard phased signal that alternates green signals between pedestrians and motorists. The cycle should be frequent enough so that pedestrians do not become impatient to the point of crossing on red. The cycle can also be controlled by a request button on the sidewalk. In these instances, the cycle for vehicles will be shortened when a pedestrian activates the button. The request button, though, should not become a substitute for maintaining a regular phase cycle between motorists and pedestrians. If the burden is always placed on the pedestrian to signal his or her intent, then motorists will interpret this as indicative of their greater rights to the road space. In all cases, traffic signals should be properly maintained and functioning at all times.

Well designed at-grade crossings can be the right choice under the appropriate conditions:

- Low to medium traffic levels
- Controlled traffic speeds
- Relatively few lanes to be crossed
- Appropriate supporting infrastructure (signals, marked crossings, etc.)

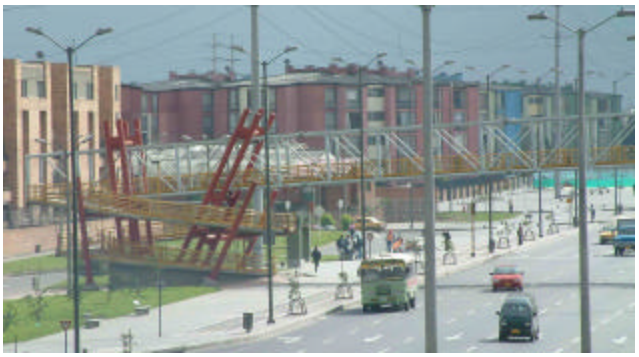
There may be instances when traffic levels, speeds, and the number of lanes to be crossed present an unacceptable danger to transit passengers. In such instances, grade-separated infrastructure (overpasses and underpasses) may be an option to consider. The challenge in designing grade-separated infrastructure is creating a walking environment that persons will actually use. If passengers ignore the overpass and instead run across uncontrolled road space, then the situation has only been made worse (Figure 184). While informal pedestrian crossings can be controlled through the imposition of barriers along the pedestrian pavement, it is better to also encourage overpass usage by way of good design.

Overpasses are often avoided by pedestrians for very rational reasons. Steep stairways make overpasses a physical challenge for many, especially the young, the elderly, and the physically disabled (Figure 185). Overpasses may cultivate an environment inducing criminal activities such as theft and violence. Since pedestrians are contained in a relatively tight space with few options for escape or help, criminals may view such spaces as easy targets. The overpasses may also become inundated with vendors selling goods (Figure 186). Since informal vendors see such constrained spaces as a profitable density of potential customers, the

overpass space can become filled with a variety of informal goods. In turn, the tight space and aggressive selling will dissuade persons from using the transit system. Overpasses may also force transit customers to walk considerably longer distances to access the station. The location of the overpass may be constrained by other overhead structures, and thus may be placed many metres away from the intended destination.

Underpasses share virtually all the same drawbacks as overpasses but also face some additional challenges. While overpasses gain outdoor light to improve safety, underpasses depend upon installed lighting. Too often poorly designed or poorly maintained lighting make entering a pedestrian underpass appear to be a step into a dark void. Crime, graffiti, and unclean surfaces frequently plague poorly-designed underpasses. Additionally, underpasses can be susceptible to flooding during storm periods, and thus require a well-engineered drainage plan.

However, with a well-designed plan, both overpasses and underpasses can be successfully implemented as access infrastructure for transit systems. Bogotá's modern pedestrian ramps serve as a good example of providing a functional and aesthetically pleasing overpass (Figures 187 and 188). To enter the overpass, Bogotá provides a ramped entry with a sufficiently gradual slope to ease the climb. In some instances, Bogotá also provides a stairway in conjunction with the ramps so that persons wishing to access the station more rapidly can do so. The overpasses themselves are significantly wider than the typical overpasses found in developing cities. Utilising a 2.5 metre-wide pedestrian space and an open design, Bogotá's pedestrian bridges alleviate many of the security concerns normally associated with overpasses.



3.8.1.4 Pedestrian corridors

The planning of station access extends beyond the immediate transit corridor and into the origin communities themselves. Since customers may be walking to stations from distances of one kilometre or more, analysing the quality of the pedestrian infrastructure over this distance can be important to achieving ridership goals. By mapping concentric circles of varying distances from the station, the planner can examine key corridors for improving pedestrian facilities. Greater investment is likely to be made on pedestrian linkages within 250 metres and 500 metres since these distances tend to represent the greatest share of pedestrians attracted to a station. However, if major origin/destination sites are farther than these distances, it may still be worthwhile to invest in a few quality pedestrian corridors.

Some of the design factors to consider within these corridors include:

- Quality of pavement materials
- Aesthetic value of walking environment
- Number of trees, vegetation, verandas, etc. providing climate protection
- Quality of street lighting
- Pedestrian priority at intersections
- Absence of major barriers / severance issues

Some cities now are providing low-cost, covered pedestrian walkways in order to eliminate the disincentive that the weather can bring to walking and cycling (Figure 189). In cities with extreme heat, covered walkways can reduce temperatures by 5-8 ºC, and thus make the difference in the viability of comfortably reaching a BRT station.

Addressing these details is a relatively small investment in comparison to the total investment for the BRT system. However, providing a safe, attractive, and convenient pedestrian environment can deliver significant benefits in terms of customer satisfaction and total ridership.

### 3.8.2 Bicycles

The provision of bicycle infrastructure serves a purpose similar to that of pedestrian access infrastructure. Namely, bicycles are an important feeder service providing customer access to the transit system.

Most customers will consider the public transport system a viable option if it is within a certain time budget of their home. For instance, individuals may consider a time travel budget of 20 minutes acceptable in reaching a BRT station. Bicycles are capable of covering a distance five to ten times greater than walking in the same time period. Thus, bicycles present the opportunity to increase one's effective customer catchment area by 25 to 100 times (since area is the related to the square of the distance travelled). Unfortunately, the lack of adequate cycleways and bicycle parking at stations means that many systems forgo this profitable opportunity.

#### 3.8.2.1 Bicycle parking facilities

At the station, the provision of secure bicycle parking infrastructure is essential for cyclists to feel comfortable in leaving their bicycles prior to boarding the system. Another option is to allow the cyclist to enter the BRT vehicles with the bicycle, so that the person may use the bicycle to access his or her destination on the other end of the trip (Figure 190). The viability of permitting bicycles to be brought on board the transit vehicle is discussed in further detail in section 3.7. This section will review options for bicycle parking at the station area.

The challenge with bicycle parking facilities for BRT systems usually relates to the space available. For stations located in the median of the roadway, space may be available in front of or behind the station structure. Underneath the entry ramp may

also be a possibility. Alternatively, bicycle parking could be provided on the curb side of the street. In all cases, the security of the bicycle becomes an over-riding consideration.

An area being in view of security staff or transit staff is preferred since a watchful presence can be a significant deterrent to theft. Security camera coverage of the bicycle parking area is also quite helpful. At the TransMilenio Americas Terminal, bicycle parking is provided inside the terminal, at a point after a person has paid to enter the system and in clear view of the fare collection agent.

The type of bicycle parking can also affect security and usability. The upright storage facility shown in Figure 191 provides secure parking, but it is quite difficult for children, women, and the elderly to lift their bicycle into position. TransMilenio selected this design to minimise the space required per bicycle, but the end result clearly has disadvantages in terms of usability for some individuals. Another option is known as the bicycle locker (Figure 192). The locker is easy to use and provides a highly secure space which controls entry by a key. However, the disadvantage of the locker is its relatively high cost (approximately US$ 300). Likewise, covered bicycle sheds provide both protection from rain and from theft, but can be costly to construct.

One of the best options for a simple, self-locking device is a "U" shaped tube cemented to the base layer (Figure 193). The "U" shape permits secure locking of both the front and rear wheels. Other self-locking devices that only permit the locking of a single wheel are less secure (Figure 194).

If a sufficient number of cyclists are utilising the station, it may be economically viable to offer a formal cycling storage area with a permanent attendant. The attendant ensures a secure environment through personal surveillance. Also, a system can be established in which the bicycle can only be taken by providing the appropriate "claim ticket". Financing the operating costs of the storage area (principally the salary of the attendant) can be accomplished in several ways. Preferably the cost is seen as part of the overall service provided to customers and thus included as part of the system's overall cost structure. In this sense, the cost is

covered by the system management organisation, which could be the fare collection company, the bus operating companies, the public agency, or even by way of a separate concession. Alternatively, it would also be possible for the attendant to charge a standard fee to each cyclist to cover the labour cost. Cycling storage facilities are quite common at European rail stations (Figure 195).



3.8.2.2 Cycleway infrastructure

Of course, reaching the station by bicycle can be a challenge if quality cycleways are not provided. It is no coincidence that cities with world-class BRT systems also possess exceptional bicycle networks. Bogotá is home to Latin America's largest bicycle network with 250 kilometres of dedicated cycleways (Figures 196 and 197). Likewise, Curitiba has done much to promote bicycle use as well. Merging BRT systems with bicycle networks requires integrated planning that connects stations and terminals with the cycleways. The combination of a BRT system with a cycleway network can do much to provide city-wide mobility on a sustainable basis.


The BRT system and the cycleway network should ideally be planned jointly. The planning process should aim to connect major cycleways with BRT stations at strategic locations. The idea is not to force cyclists to transfer to the BRT system but rather to offer the option of a combined public transport-bicycle commute.

Using concentric circles of two kilometres or more from the transit station, important corridors should be analysed for the quality of the cycling environment. Key aspects to consider are:

- Quality of road surface
- Existence of segregated cycleways or bicycle lanes
- Provisions for bicycles at intersections
- Bicycle bridges or other grade separation at key junctures
- Street lighting for cyclists
- Tree cover along cycle route
- Signage for cyclists.

### 3.8.3 Other public transport systems

BRT can also be complementary with other urban and long-distance transit options. Cities with existing metros and urban rail services can integrate these options with BRT. Cities with water transport systems should also seek to closely integrate these systems with the bus network.

Sao Paulo, for instance, uses BRT to connect the end of its metro line with other communities. Some cities with existing metro systems are unable to finance the completion of the metro. In such instances, BRT has been an economical option that will help bring a public transit connection to the entire city.

The key to a successful integration lies in the physical connection between the two systems, the complementary marketing and promotion of the two systems, and the unification of fare structures. In Sao Paulo, the physical connection is made simple by ramps departing the metro system leading directly to the BRT system. Clear signage also helps make this integration relatively seamless. Further, the two systems can be marketed jointing under one name and logo, so that the systems are clearly unified in the eyes of the customer. Finally, an integrated fare structure permits customers to leave one mass transit mode to another without the need of purchasing an additional fare.

BRT should also be integrated with long-distance public transport infrastructure such as long-distance bus stations and train stations. Again, the physical planning of the interface is key to making this option viable. Passengers from such modes often are carrying luggage or goods, and thus particularly need a convenient transfer mechanism.

### 3.8.4 Taxis

Another forgotten integration opportunity concerns the car taxi industry. In developing-nation cities, taxi associations can be politically powerful and are often left relatively uncontrolled. In such cities, the taxis also constitute a large

percentage of the vehicles creating congestion. In many cases, this congestion is largely due to taxis without passengers (i.e. taxis in search of passengers). Taxis in Shanghai, for instance, are estimated to spend 80% of their travel time without passengers.

The strategic location of taxi stands in close integration with BRT stations can prove to be a win for system designers, taxi drivers, city officials, and the public (Figure 198). System designers win by adding another important feeder service to their route structure. The 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 petrol. 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 transit system that also reduces urban emissions and promotes greater overall efficiency.

### 3.8.5 Park-and-ride

Private vehicle owners can also be successfully integrated with the system through the development of "park-and-ride" or "park-and-kiss" facilities. These facilities allow private vehicle users to access the transit system, and therefore complete their total commute by way of public transport. A park-and-ride facility provides a parking garage or parking lot for vehicles to be kept securely during the day. A kiss-and-ride facility does not provide parking but rather includes a passenger drop-off area for private vehicles. A park-and-ride facility should also include space for the kiss-and-ride option.

Park-and-ride and kiss-and-ride facilities are effective options in suburban locations where population densities may be insufficient to cost justify feeder services. In developing cities, these areas may include more affluent households that have sufficient disposable income to own a private vehicle. Attracting this income group to the transit system can deliver several benefits. First, offsetting private vehicle use pays significant dividends in terms of emission reductions and congestion relief. Second, a public transport system that is of sufficient quality to attract even the highest income groups is a worthy objective. Third, 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. Finally, systems which serve all income groups also serve an important social function since the public transport system may be the one location where are segments of society come together.

The park-and-ride and kiss-and-ride facilities are best situated at stations as close to the target customers as possible. 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 transit only for a small final portion. The time and cost of switching

to public transport only for the final few kilometres means that few customers will utilise the system under such circumstances. The principal incentive to these customers will be the time savings achieved by the exclusive busways over the main portion of the commute.

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 particular set of incentives in place. A parking charge is a disincentive to the use of the park-and-ride facility, and thus may work against the objective of encouraging a mode shift from private vehicles to public transport. However, a broader set of vehicle charges, such as petrol taxes and road pricing, can change the balance to permit a parking charge. If the cost of commuting entirely by private vehicle is relatively expensive, then the advantage will remain with the transit system.

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 is appropriate to establish a fee for parking facilities at transit stations. The challenge is to develop a fee structure that still provides a strong incentive for using the transit system.

### 3.8.6 Auto restriction measures

Part of the equation for transforming a city and its mobility structure is providing high-quality public transport, such as BRT. At the same time, the strategic use of incentives to discourage private vehicle use can provide multiple dividends. The use of the appropriate incentives can further bolster the ridership of the new transit system, support the sustainable restructuring of the city, lead to additional environmental and economic gains, and create a greater sense of equity through improved access and mobility. Recent experiments with Travel Demand Management (TDM) techniques have demonstrated the cost-effectiveness and ease with which the right incentives can direct persons towards more sustainable transport forms. The development of a BRT system is an ideal time to investigate the adoption of TDM measures.

Mechanisms that help discourage private vehicle use and thus encourage public transport use include the following:

- Reduction in available parking areas
- Increased parking fees
- Increased parking enforcement
- Parking cash-out programmes
- Day restrictions by license plate number
- Congestion charging and road pricing

- Travel Blending or TravelSmart™
- Green travel plans
- Traffic calming measures.

3.8.6.1 Parking restrictions

Restrictions on parking can be an effective incentive to discouraging private vehicle use. The availability of subsidised low-cost or even no-cost parking at office buildings has contributed to rampant private vehicle use in many countries. A reduction of parking availability within the city will work to change the current market dynamics that facilitate low-cost private vehicle usage.

At the same time as the development of Bogotá's BRT system, the municipality eliminated on-street parking from much of the central portion of the city. Off-street, private parking facilities took up some of this demand. However, unlike on-street parking, the private parking facilities charged a fee for the service. The end result was the termination of free city parking and the reclamation of public space. In many instances, the previous parking spaces have been converted to an attractive new environment for pedestrians (Figure 199).

A mandatory parking fee throughout the city can be part of a financing strategy for the BRT system. A parking fee at all commercial sites and private parking facilities can provide a double incentive for supporting public transport. First, the fee adds to the cost of private vehicle commuting, and thus provides a direct economic incentive to use transit. Second, if the revenues from the parking fee are then applied to improving the transit system, public transport will become increasingly attractive.

The site of a vehicle parked on the pedestrian pavement is not uncommon in many developing cities (Figure 200). Police are often unable or unwilling to deter such practices. The result is a culture that permits private vehicles to consume public space, which further weakens the social position of walking and other sustainable forms of mobility. However, enforcement of traffic and parking laws can immediately produce the opposite effect. Applying fines and penalties to illegally parked vehicles will discourage the practice as well as curb the overall parking supply. Further, revenues from improved enforcement could potentially be dedicated to improving the public transport system.

### 3.8.6.2 Day restrictions by license plate number

Severe traffic congestion and air contamination in some developing cities has prompted officials to enforce vehicle bans based on license plate numbers. The last digit in a vehicle's license plate number determines the day(s) during which the vehicle is permitted to operate in the city. Travelling with a license plate that is not valid for a particular day will result in a penalty or fine.

The success of licenses plate restriction programmes has been mixed. In cities such as Mexico City and Sao Paulo, the programmes have had some unintended consequences. Many residents in these cities avoided the restrictions by simply purchasing a second vehicle with a licence 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 put into the air.

A well-designed programme, though, can avoid the problems experienced in Mexico City and Sao Paulo. Bogotá has developed a license plate restriction programme 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 for several reasons. First, Bogotá has chosen to prohibit four license plate numbers each day from use instead of just two or three. Table 42 lists by the day of the week the licence plate numbers that are restricted. The restriction of four license plate numbers each day implies that a person would have to purchase three vehicles instead of two in order to cover every day of the week. Second, Bogotá's vehicle prohibition only applies during peak hours. These hours are from 06:00 to 09:00 in the morning and from 16:30 to 17:30 in the afternoon. Thus, vehicles with the prohibited numbers for a given day may still travel at non-peak hours. The net effect is to encourage a shift either to using public transport or to use a private vehicle at a non-peak 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 private vehicle users to shift to public transport as their daily commuting mode.

**Table 42 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 problem of motorists purchasing a second vehicle to circumvent the license plate restriction can also be controlled through the manner of issuing plate numbers. If the purchase of any vehicle, new or used, is accompanied by a mandatory re-issuing of plate numbers, then a person cannot choose an additional vehicle based

on its plate number. Further, if the regulatory agency purposefully gives owners a plate number ending in the same number as their other vehicle, then the practice of purchasing a second vehicle would be effectively terminated.

3.8.6.3 Congestion charging and road pricing

*a. Defining congestion charging*

A city's road infrastructure has a finite ability to accommodate ever increasing amounts of private vehicles. The resulting congestion places innumerable costs upon a city in the form of air contaminants, noise, personal stress, unreliable delivery services, and the inability of persons to travel efficiently. One strategy to combat these problems is through charging private vehicles to access urban roads in central districts. Such schemes are known by different names, including congestion charging, road pricing, and cordon pricing.

Congestion charging places a monetary value on using the road space 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.

London, Singapore, and three cities in Norway have implemented pricing schemes. The results have shown a marked reduction in congestion as well as the generation of revenues for supporting sustainable transport options.

*b. Electronic Road Pricing in Singapore*


From 1975 until 1998, Singapore operated a manually-controlled road pricing scheme. The scheme requires motorists to pay for entry into a central Restricted Zone. Technological advances enabled the city to implement an Electronic Road Pricing (ERP) scheme in 1998. The system utilises short-range radio signals between in-vehicle electronic units and overhead gantries (Figures 201). There is also a control centre to manage and coordinate the system. A smart card is inserted into the in-vehicle unit to validate entrance into the Restricted Zone. Topping up the value on the smart card can be done at petrol stations or automatic teller machines (ATMs). If the communication between the in-vehicle unit and the gantry radio antennae indicates that the road charge is not being paid, a camera on the gantry will photograph violating vehicles.

The system software allows a different fee to apply during different half-hour periods. The highest peak rate is currently US$ 1.71 per half-hour spent in the Restricted Zone. The infrastructure cost of the Singapore ERP system was approximately US$ 114 million. Each year the system generates US$ 46 million in revenues with operating costs of US$ 9 million. The ERP scheme is credited with reducing traffic levels by 50 percent and increasing average traffic speeds from around 18kph to 30kph.

*c. Congestion pricing in London*

The introduction of the congestion charging scheme in London has now helped to 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 utilised in London during the nineteenth century. In response, London's Mayor Ken Livingstone decided to implement a congestion charging scheme in the centre core of the city.

Beginning in 2003, a £ 5 (US$ 9) fee was imposed for vehicles entering the central zone from 07:00 to 18:30 (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 202). Motorists have until midnight on the day of entry to pay the charge, although payments after 22:00 increase to £ 10 (US$ 18). Subsequently, an £ 80 (US$ 144) fine is applied to motorists who fail to pay by midnight.


London's technology is somewhat different than the short-wave radio frequencies and overhead gantries utilised in Singapore. London chose to use a camera-based system in which license plates entering the zone are photographed (Figure 203). At the end of each day, the list of vehicles entering the zone is compared to the list of vehicles that have had payments sent to the scheme operators. Any unpaid owners are referred for enforcement actions.

London chose the camera-based technology due to aesthetic concerns over the large overhead gantries employed in Singapore. Additionally, officials were also

concerned over the limitations of GPS-based systems to operate without interference in narrow urban roads lined by tall buildings. However, London's technology does have its disadvantages as well. Some license plates can be difficult to read due to glare or other sight restrictions. Further, while the system currently exempts motorcycles from the charge, the current technology would not be capable of fully capturing the smaller motorcycle license plates.

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. Also, persons who reside inside the zone receive a 90 percent discount on the congestion charge fee. The exempted vehicles represent 23 percent (25,000 vehicles) of the total traffic in the zone.

After one year of operation, London's congestion charge has produced some impressive results. Congestion levels have been reduced by 30 percent, and the total number of vehicles entering the zone has dropped by 18 percent. Average speeds have increased from 13 kph to 18 kph. 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 start-up costs of the scheme (excluding traffic management costs) totalled £ 180 million (US$ 324 million). The annual operating costs are currently £ 97 million (US$ 175 million). With total annual revenues of £ 165 million (US$ 297 million), the system nets the city £ 68 million (US$ 122 million) each year. These revenues are then applied to supporting bus priority schemes and cycleway projects. London is currently planning an extension of the congestion charging zone.

*d. Developing city applications for congestion charging*

The success of the London and Singapore pricing schemes has attracted interest for similar projects in developing cities. However, the applicability of congestion charging depends very much on local circumstances. The complexity of such schemes in conjunction with the relatively high initial costs may mean that other auto-restriction measures, such as parking charges, could be more appropriate for developing cities. For example, the combination of day restrictions by license plate numbers and parking restrictions in Bogotá have been highly successful in reducing private vehicle use without the difficulty of implementing a road pricing scheme. Likewise, parking fee schemes can produce as many or more revenues (due to lower operating costs) than road pricing schemes.

The attraction of road pricing is the political advantages of dealing with a relatively sophisticated technology (as opposed to parking fees). Thus, if the high-technology nature of road pricing helps propel its implementation, then it may be an option to consider. Further, auto-restriction measures are not mutually exclusive. Road pricing schemes can be implemented in conjunction with parking reform and other TDM measures.

3.8.6.4 <u>Travel blending</u>

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 personalised process, and then facilitating changes in travel behaviour. While the focus to date has been in developed countries, a recent success in Santiago (Chile) indicates that it may be applicable to developing cities as well.

The technique involves phone contact with all households in the area, and then identifying the proportion of respondents who would be interested in making some changes in travel behaviour. These households are then supplied with pertinent information (e.g., public transport timetables, maps of cycling routes, etc.). For a proportion of respondents there are follow-ups with household visits. In some cases, the interpersonal exchange with customers will alert transport planners to potential changes in the transport system. For example, feedback from customers can highlight the need for better access to public transport stations, new bus stops, provision of new timetables, and the extension of service hours.

The information programme may also involve residents completing seven-day travel diaries. The assisting facilitators will then analyse the diaries to devise suggestions on alternatives for the participant.

In the first trial in Perth (Australia), approximately US$ 61,500 was expended in consulting costs to conduct the surveys and information provision activities. Of the 380 households targeted, the program produced a six percent decrease in auto use immediately and an additional one percent decrease after 12 months. Public transport trips rose from six percent of all trips to seven percent, and cycling trips doubled from two percent to four percent. The results have been maintained even two years later. The technique is now being applied throughout Australia and in some cities in Europe. Similarly impressive results are being achieved at extremely low costs.

A trial of travel blending in Santiago produced a 17 percent reduction in private vehicle trips (as a proportion of participating and non-participating households combined). This experiment also reduced kilometres travelled by 23 percent and travel times by 17 percent.

The social marketing techniques utilised in travel blending can help achieve reductions in private vehicle use as well as provide an information platform for promoting a BRT system. The low-cost and voluntary nature of the programme should make it attractive to most cities.

### 3.8.7 Integration with land use planning

Public transport planning and land-use planning should be undertaken in an integrated fashion to capture mutually-beneficial synergies. Land-use patterns that promote commercial and residential densification around transit stations will both promote public transport and add to customer convenience. This type of

development strategy, known as transit-oriented development (TOD), is increasingly being undertaken in conjunction with new transit systems.

Development around BRT stations in Curitiba represents one of the best-known examples of TOD. The tubed stations in Curitiba have acted as development nodes for commercial shops, housing, and public service centres. The five exclusive busways in Curitiba are lined with high-rise development, reflecting the higher land values near the BRT system. Zoning regulations in Curitiba supported this type of development by restricting high-rise construction to areas near the busways .

The end result in Curitiba has been a land-use planning scheme and a BRT system that have worked to be mutually supportive. The municipality has also benefited in another way, as the cost of public service delivery has been reduced along the corridors.

## 3.9 Planning Stage IX: Impacts

The true impact of BRT is not simply the physical system but rather the improvements that it creates in people's lives. Evaluating the expected impacts on traffic levels, economic development, environmental quality, social interactions, and urban form all help determine whether the BRT system will add real value. The projection of system impacts is thus a crucial step in cost justifying the final development and the cost of construction. Further, by examining the system's expected impacts, it is possible to determine what types of improvements or modifications are required from the design.



### 3.9.1 Traffic impacts

At the outset of the project, the initial modelling work helped to select the appropriate corridors and the likely ridership numbers. Once the initial design and planning work has been completed, it is appropriate to re-examine how the new system will function in the city's transport matrix. Motorists, taxi operators, and others currently using the road network will likely want to be reassured that the development of the BRT system will not lead to gridlock. A traffic impact analysis can help provide the political reassurance that the system will deliver its promise (Figure 204).

Thus, at this stage, a traffic modelling exercise should be conducted to project how the designed system will affect traffic levels as well as improve conditions for current transit passengers. The design information from the operations and infrastructure plans (sections 3.4 and 3.6) can provide the input into the model. A similar modelling process as outlined at the outset (section 3.2) can be followed. However, at this stage, the planning team will have more precise and focussed data to input.

### 3.9.2 Economic impacts

An efficient public transport system can be an effective catalyst for stimulating local economic development. The provision of access and mobility is closely tied to development objectives. This relationship is especially the case in developing cities where private vehicle ownership is relatively low. A BRT system can affect the local economy through the following impacts:

- Employment generation;
- Economic efficiency in moving people and goods;
- Property values; and,
- Technology transfer.

3.9.2.1 Employment generation

*a. System construction*

The new BRT system will likely represent a dramatic transformation of the proposed corridors. As with any project of this magnitude, the system will generate a considerable amount of employment through the construction process. Based upon similar projects from the past, it is possible to project the amount of employment and the duration of the employment from the construction phase (Figure 205). An additional measure of interest, particularly in the developing city context, can be the number of persons being supported by each construction job. Further, construction jobs can sometimes be an important area of employment for unskilled labour groups. Employment generated for these individuals can be especially important since there may otherwise be limited opportunities.

*b. Operations*

The consolidation of informal transport services into a coherent BRT system brings with it concerns over the loss of employment. The small mini-buses that normally precede the introduction of the BRT system typically employ a driver and a conductor. By contrast, a single articulated BRT vehicle may replace four to five small buses. Thus, it would appear that a single driver is replacing as many as ten persons employed by the mini-buses.

However, the reality is actually quite different. The standard mini-bus will generally operate with its single set of employees for as much as 16 hours in a day. The BRT vehicle will actually involve three to four different shifts of employees operating the same vehicle. Thus, the number of drivers will not appreciably change. When the

feeder service drivers are included, BRT may actually increase the number of drivers (Figure 206). However, the big employment boost from operations stems from the myriad of positions created from fare collection, security, information services, and management and operations (Figure 207). Most of these functions did not exist in the previous informal sector.

The development of an employment matrix comparing jobs in the before and after scenarios will likely produce a beneficial comparison for the new BRT system. Additionally, since the existing operators will have the opportunity to bid on serving the new system, the spectre of maintaining existing employment while also expanding new opportunities can be quite strong.

c. Other employment

Additional employment is also likely to be generated due to indirect impacts from the BRT system. The boost in shop turnovers near transit stations can lead to additional employment. Likewise, the construction of new commercial centres next to stations and terminals will have significant employment benefits. Also, if the new system encourages local manufacturing of buses, then more employment can be expected.

Of course, employment generated in one location could mean the loss of employment in another part of the city. If transit customers are now purchasing their groceries near a transit station, then these same customers may not be frequenting their previous shops. However, consumption of this type is not always a zero-sum game. The economic efficiencies of the new transit system can have an economic upliftment effect that increases overall incomes and consumption. Further, the access gained by the transit system may open up the reach of customers to new products and services.

3.9.2.2 Economic efficiency

Traffic congestion can be a significant drain on a developing city economy. As goods and people are held in gridlock, little production (other than petrol consumption) is being achieved. The World Bank estimates that traffic congestion in Bangkok reduces the Gross Domestic Product (GDP) of Thailand by six percent (Willoughby, 2000).

The smooth movement of goods and people is indicative of a more efficient economy. The time saved from both more rapid public transport and from the related reduction in private vehicle congestion can be quite substantial. A baseline economic analysis of the current costs of congestion in the city along with projections of reduced congestion following the BRT system can help derive estimations of the efficiency increases.

3.9.2.3 Property values

BRT busways and the associated stations and terminals will tend to provide a new economies-of-scale along a particular corridor. A concentration of passengers and development will tend to increase the value of being located near the transit corridor. Property values, shop turnovers, and property vacancy rates will all be positively affected by the introduction of the system.

As noted in section 2.2.4.1, property values have been shown to increase on busways in Brisbane (Australia) and Bogotá. This evidence is also supported by previous research on property value increases near urban rail stations. Bogotá has already seen considerable activity in the development of commercial centres along the BRT corridor (Figure 208). The increase in property values mirrors the expected increases in customer numbers at stations and terminals. For this reason, there is evidence to suggest that shop vacancies decrease in the area, leading to employment opportunities.

3.9.2.4 Technology transfer

As noted in section 3.7, the new BRT system will bring with it the introduction of many new technologies to the city's transport sector. These technologies include advanced transit vehicles, fare collection and fare verification devices, and intelligent transportation systems (ITS). The introduction of new technologies presents several opportunities for overall economic benefits. First, as noted with bus manufacturing, there is the potential for new investment and job creation through local production. Second, technology transfer can lead to establishing a local advantage in a particular technology that can lead to export opportunities. Third, the new technology can lead to spin-off opportunities with other applications for new businesses.

### 3.9.3 Environmental impacts

Public transport projects typically bring positive environmental impacts through the reduction of private vehicle use and subsequent associated emissions. Quantifying the expected environmental benefits of the BRT project can help to justify the

project as well as strengthen the image of the initiative with the public. As a major project, an Environmental Impact Assessment (EIA) is likely to be required.

The expected reduction in vehicle emissions will likely be the principal benefit. However, the system will also likely reduce overall noise levels as well as the release of both liquid and solid waste products. The construction process itself can be disruptive and lead temporarily to some increases in emissions. However, by calculating emission reduction benefits across the life of the BRT project, the overwhelming evidence to date suggests that BRT can markedly improve the state of the urban environment.

#### 3.9.3.1 Environmental Impact Assessments (EIAs)

Impact analyses are often mandatory by law in terms of measuring the expected economic, environmental and social ramifications of the project. Completing an Environmental Impact Assessment (EIA) is typically required by international lending agencies. The form of the EIA is generally well known but the practice of such assessments is still in its infancy in some nations.

While mass transit does bring with it many environmental benefits, the design and specifications of the system will determine expected emission and noise levels. Also, the construction process can entail some environmental impacts that must be mitigated to the greatest degree possible.

An EIA analysis will typically involve comparing the baseline scenario (city without the transit project) and the project scenario (city with project). Additionally, the EIA process may require the consideration of alternative options, such as road widening or other types of mass transit systems.

The EIA should be completed by an independent organisation with no relationship to the project or other input services to the project. Specialist consultants are thus frequently utilised to give an objective and independent analysis as well as to lend experience to the effort. An effective EIA can greatly aid the BRT development process by highlighting possible areas of concern and by suggesting design alternatives that will mitigate environmental impacts.

#### 3.9.3.2 Local air emissions

*a. Emission impacts*


Vehicle emissions are the predominant source of pollutants in urban centres and are directly linked to severe health and environmental problems (Figure 209). In city centres, motorised vehicle emissions account for 95 percent of the ambient carbon monoxide (CO) and 70 percent of nitrogen oxides (NOx) (WHO, 2000). The poor air quality in most developing cities limits economic growth and dramatically

curtails quality of life.

The principal impacts from motorised vehicle emissions are:

- Health impacts, including respiratory illness, cardiovascular illness, and cancer.
- Economic impacts, including absenteeism and reduced productivity
- Impacts on the built environment (e.g., damage to buildings)
- Impacts on the natural environment (e.g., harm to trees and vegetation)

Emission levels are set by national and international environmental agencies such as the US Environmental Protection Agency (US EPA), the European Commission, and the World Health Organisation (WHO). Emission standards include both ambient emission levels and tailpipe emission levels.

*b. Types of emissions*

"Local" or "criteria" pollutants refer to the types of air emissions that are most directly linked to impacts on human health. These pollutants include nitrogen oxides (NOx), sulphur oxides (SOx), carbon monoxide (CO), and particulate matter (PM). Additionally, vehicles emit air toxics, including benzene, formaldehyde, acetaldehyde, 1,3-butadiene, and acrolein. While emitted in relatively small concentrations, air toxics are highly dangerous carcinogens. Also, the combination of NOx and volatile organic compounds (VOCs) from vehicle emissions will combine in the atmosphere to form ground-level ozone (O3). Ground level ozone is also commonly known as photochemical "smog" and is associated with a host of pulmonary illnesses and the brown haze that permeates cities with excessive automobile emissions. Further, many developing countries still permit leaded fuels. Lead emissions are closely associated with several diseases including cancer and inhibiting the mental development of children. Although international efforts are under way to eliminate the use of lead, the majority African nations still utilise leaded fuels.

While cleaner engine technologies have somewhat mitigated these emissions in developed nations, the age and maintenance of developing-nation vehicles means that even relatively low vehicle numbers can create health and air quality problems.

*c. Emissions model*

Equation 5 is the general equation for determining overall emission levels. Each of the three principal elements, behaviour, land-use, and technology, has a basic role to play in minimising emissions. In reality, the emission profile of each pollutant type is fairly complex. The ambient emission levels will likely vary by time of day, day of the week, and the season of the year. Climate, topography, vehicle use patterns, maintenance practices, and driving behaviour will all play a role. Additionally, interactions between different pollutants will also change the composition and level of pollutants.

**Equation 5 Calculation of transport emissions for an individual mode**

| Mode share | Distance | Fuel efficiency |
|---|---|---|

| | | (behaviour) | | travelled (land-use/design) | | (technology) |
|---|---|---|---|---|---|---|
| **Transport emissions per mode** | **=** | **Number of vehicles** | **x** | **Distance travelled** | **x** | **Emissions per vehicle distance travelled** |

These three broadly-defined variables each consist of several different components. For the case of public transport, the "mode share" or the "number of vehicles" is affected by at least three component categories:

1. Customer utility – This component includes system attributes such as cost, comfort, convenience, travel time, and security that encourage people to use a particular mode;
2. Load factor – The number of occupants per vehicle as a percentage of the total maximum capacity; and,
3. System capacity – The total capacity of the system effectively acts as the ceiling to the amount of mode share that is possible to achieve.

The "distance travelled" is affected by at least three component categories:

1. Land use changes – Transit-oriented-development (TOD) and complementary land-use policies can ultimately produce changes in travel distances by bringing destinations closer to trip origins and by allowing for a single trip to replace what was previously several separate journeys;
2. System design - The routing structure and the location of stations and terminals will directly affect the distance travelled;
3. System management – Efficiently managing the number of vehicles operating at peak and non-peak times will produce savings.

The "fuel efficiency" is affected by at least three component categories:

1. Operational efficiency – The "smoothness" of the vehicle operations (number of stops, amount time idling, use of dedicated busways, etc.) will impact the fuel usage;
2. Fuel type – The type of fuel utilised to propel the vehicle will have inherent characteristics that determine likely emissions; and,
3. Vehicle efficiency – The type of propulsion technology, the materials and design of the vehicle, and the quality of the vehicle maintenance all directly impact the fuel usage rate.

It is worth noting that "fuel type" is just one of many constituent parts in this emissions framework. However, too often this category is the only one pursued by both local and international groups seeking to reduce emissions and improve efficiency. Table 43 provides an overview of each of the component categories to public transport emissions.

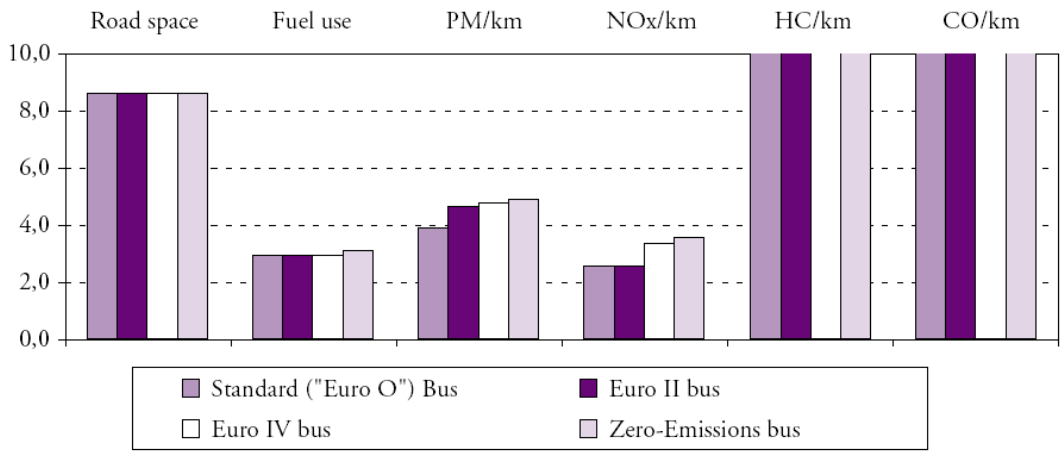
**Table 43 Overview of components affecting public transport emissions**

| Equation variable | Component Category | Components |
|---|---|---|
| **1. Mode Share** | 1.1 Customer utility | ✍ Customer service attributes that affect customer satisfaction including: affordability, appearance, awareness, clarity, comfort, convenience, integration with other modes, reliability, safety and security, vehicle type<br>✍ Operational efficiencies that affect travel time (dedicated busways, route structure, service frequency, dwell times, station location) |
| | 1.2 Load factor | ✍ Vehicle occupancy as a percentage of the maximum capacity |
| | 1.3 Total system capacity | ✍ Vehicle capacity<br>✍ Infrastructure capacity (stations, terminals, fare collection systems) |
| **2. Distance Travelled** | 2.1 Land use | ✍ Transit-oriented development<br>✍ Reinforcing land-use policies |
| | 2.2 System design | ✍ Dedicated busways<br>✍ Route structure<br>✍ Terminal and depot locations |
| | 2.3 System management | ✍ Management of number of vehicles at peak and non-peak times |
| **3. Fuel Efficiency** | 3.1 Operational efficiency | ✍ Dedicated busways (impact on both transit vehicles and mixed traffic vehicles)<br>✍ Route structure<br>✍ Dwell times<br>✍ Distance between stops<br>✍ Driver behaviour<br>✍ Vehicle control systems |
| | 3.2 Fuel type | ✍ Carbon, sulpur, particulate content of fuel<br>✍ Purity of fuel<br>✍ Energy intensity of fuel |
| | 3.3 Vehicle efficiency | ✍ Propulsion system efficiency<br>✍ Vehicle design and materials (weight, aerodynamics, etc.)<br>✍ Vehicle mechanical maintenance |

*d. Emission reduction potential of mode shifting*

The International Energy Agency (IEA) has conducted research to determine the relative impacts of mode share in comparison to different fuel and propulsion options. The IEA examined the emission impacts of shifting mode share by the capacity equivalent of one bus with a total capacity of 120 passengers. Even with the rather modest assumption of only a 50 per cent load factor for the bus and only eight per cent of the passengers having switched from private vehicles, the resulting emission reductions were substantial. The projected reductions in hydrocarbon and carbon monoxide emissions per kilometre were over ten times the emissions of a single bus (IEA, 2002). The reduction per kilometre of particulate matter, nitrogen oxides, and carbon dioxide (fuel use) ranged from two times to four times the emissions of a single bus (Figure 210).

**Figure 210 Impacts of mode shifting to public transport**




Remarkably, the level of emissions reduced did not change significantly with buses of strikingly different emission standards. Buses with Euro 0, Euro II, Euro IV, and fuel-cell technology all produced roughly the same results. This result occurred because the relative impact of the tailpipe standard (and thus the fuel and propulsion choice) was overwhelmed by the impact from mode switching. The IEA study notes that:

> "Regardless of whether a bus is 'clean' or 'dirty', if it is reasonably full it can displace anywhere from 5 to 50 other motorised vehicles..." (IEA, 2002, p. 12)

> "Certainly, a cleaner bus will yield lower emissions, but in this scenario the emission reductions from technology choice are overshadowed by reductions from mode switching (and the resulting 'subtraction' of other vehicles)...Dramatic reductions in road space, fuel use, and most emissions can be achieved through displacing other vehicles with any bus, even the 'Euro 0' buses typically sold in the developing world." (IEA, 2002, p. 48)

The IEA results do not imply that fuel and propulsion technology should be ignored in achieving lower emissions. However, the results do suggest that these technologies alone only address a relatively small portion of the total emission reduction potential. Improving the efficiency of the transport sector and reducing

emissions revolves around a full set of factors, including the many factors that are most important to customers such as cost, comfort, convenience, and security.

*e. The example of Bogotá's TransMilenio*

As a system-based approach to public transport, the TransMilenio system is able to address virtually all the possible components in an emissions reduction effort, as outlined earlier in Table 37. Specifically, TransMilenio is achieving emission reductions through the following mechanisms:

- Increasing the share of public transport ridership by dramatically improving the quality of service (in terms of travel time, comfort, security, cleanliness, etc.);
- Replacing 4 to 5 smaller buses with a larger articulated vehicle;
- Requiring the destruction of 4 to 8 older buses for every new articulated vehicle introduced into the system;
- GPS controlled management of the fleet allowing the optimisation of demand and supply during peak and non-peak periods;
- Encouraging transit-oriented development around stations and along corridors; and,
- Emission standards currently requiring a minimum of Euro II emission levels with a future schedule requiring eventual Euro III and Euro IV compliance.

Bogotá is one of the few cities in the world that is registering a significant increase in public transport ridership. According to a study by Steer Davies Gleave (2003), ten per cent of ridership on Bogotá's BRT system comes from persons who previously drove a private vehicle to work. The quality of TransMilenio is such that even middle- and higher-income travellers are utilising the system. The older mini-buses that dominated Bogotá prior to TransMilenio were largely not an option that discretionary transit users would frequent.

Prior to TransMilenio, as many as 35,000 public transport vehicles of various shapes and sizes plied the streets of Bogotá. In order to rationalise the system, companies bidding to participate in TransMilenio were required to scrap older transit vehicles. During the first phase of TransMilenio, the winning bids agreed to scrap approximately four older vehicles for each articulated vehicle introduced. In the second phase, the successful bids committed to scrapping between 7.0 and 8.9 older buses for each new articulated vehicle. The destruction of older vehicles prevents the "leakage" of these vehicles to other cities.

Each articulated vehicle in TransMilenio has a capacity of 160 passengers. The vehicles are currently achieving a load factor of approximately 80 to 90 per cent. The older public transport vehicles in Bogotá come in a variety of sizes, from micro-buses to full-sized conventional buses. Table 44 summarises recent data collected on characteristics of public transit vehicles in Bogotá.

**Table 44 Characteristics of public transit vehicles in Bogotá**

| Vehicle type | Passenger capacity | Fuel consumption (km / litre) | Passengers per vehicle-kilometre travelled (IPK) |
|---|---|---|---|

| | | | |
|---|---|---|---|
| TransMilenio articulated bus, Euro II diesel | 160 | 1.56 | 5.20 |
| Conventional bus, diesel | 70 – 80 | 2.14 | 1.00 – 2.27 |
| Conventional bus, Gasoline | 70 – 80 | 1.53 | 1.00 – 2.27 |
| Medium-sized bus, diesel, models 1995-2004 | 27 – 45 | 5.02 | 0.90 – 2.24 |
| Medium-sized bus, diesel, 1980 model | 27 – 45 | 3.96 | 0.90 – 2.24 |
| Medium-sized bus, gasoline, 1980 model | 27 – 45 | 2.64 | 0.90 – 2.24 |
| Micro-bus, diesel | 13 – 19 | 5.54 | 0.60 – 1.44 |
| Micro-bus, gasoline | 13 – 19 | 3.43 | 0.60 – 1.44 |

Source: Martínez, 2004

The differences in "passengers per vehicle-kilometre travelled" are quite telling. The relative efficiency of operating a coordinated system in larger vehicles translates into economic advantages for the operators. By closely controlling the supply of vehicles during peak and non-peak periods, TransMilenio avoids wasteful trips. By contrast, the existing informal operators drive as much as 16 hours each day regardless of passenger flows. As long as the operator's marginal costs (mostly fuel costs) are covered, it makes sense to continue operating. However, this approach leads to the inefficiencies associated with congestion and an oversupply of vehicles.

3.9.3.3 Greenhouse gas emissions

*a. Global trends*

Vehicle emissions are the fastest growing source of greenhouse gas emissions worldwide. Representing 24 percent of greenhouse gas emissions from fossil sources, vehicle emissions have emerged as one of the most significant challenges in mitigating the effects of global climate change. Greenhouse gas emissions from motorised vehicles are predominantly carbon dioxide ($CO_2$) but also include some emissions of methane ($CH_4$) and nitrous oxide ($N_2O$).

From 1995 to 2030, worldwide vehicle ownership is expected to grow by 228% to over 1.6 billion vehicles (OECD and EMCT, 1995). The bulk of this growth is projected to take place in the developing world. Growth in motorised vehicle ownership is due to several factors with per capita income being a decisive influence. Vehicle purchases tend to jump sharply as per capita incomes enter a range of US$ 2,000 to US$ 5,000 (Dargaya and Gately, 1999). Other factors affecting vehicle ownership growth are population growth, urbanisation levels, importation regulations, and the quality of alternative transport services.

*b. Calculation of emission reduction potential*

Calculating the impact of the proposed BRT system on greenhouse gas emissions follows from the same general emissions equation as outlined in Equation 6. Overall emissions are calculated both for the baseline scenario (city with no new BRT system) and the project scenario (city with new BRT system). Key data inputs in this analysis will be the projections for mode shares after the system is in place, the passenger capacity of the new BRT vehicles, the load factor of the vehicles, projections for land-use changes, and the relative fuel efficiency of the new BRT vehicles in comparison to the previous transit fleet and to private vehicles.

As noted earlier, ten percent of Bogotá's BRT ridership previously utilised private vehicles for commuting. This type of mode shift will have a substantial impact on greenhouse gas emissions. Likewise, mode shifts from less efficient mini-bus operations will also produce an emission benefit. However, the new BRT system will also stimulate some mode shifting that actually produces higher emissions. For example, if persons who previously walked or rode a bicycle to work switch to the BRT system, then emissions associated with those individuals will increase. Thus, the calculation of the project's greenhouse gas impacts necessitates a fairly wide collection of input data. The best solution is to integrate the emissions calculation with the transport demand model being utilised to project other characteristics of the system.

Other sources of greenhouse gas emissions include emissions that occur during the construction process. The production of cement is a fairly significant source of greenhouse gas emissions. Thus, the emissions generated from the construction of concrete busways should also be considered in the analysis.

*c. Emissions calculations from Bogotá*

The Bogotá TransMilenio system is one of the first transport initiatives to be brought forward for consideration of international emission credits. Under the Kyoto Protocol, several mechanisms have been created to permit participation by developing countries in climate change mitigation projects. The Bogotá proposal has been developed under the Clean Development Mechanism (CDM), which could ultimately award the system developers with Certified Emission Credits (CERs).

TransMilenio in conjunction with the Andean Development Corporation (a regional development organisation) have estimated the system's projected greenhouse gas emission reductions. The emission analysis includes impacts from mode shifting and fuel efficiency improvements. The analysis also accounts for expected emission increases due to industrial emissions from the construction of concrete busways and the added energy process emissions from the scrapping of older transit vehicles. However, the analysis has not developed any projections from emission reductions stemming from land-use changes. This omission is in part due to the difficulty in modelling land-use changes.

Table 45 summarises the study's results for the period of 2001 through 2016. The annual reductions increase significantly over the period due to the continued expansion of the TransMilenio system.

**Table 45 Projections for greenhouse gas emission reductions from Bogotá's TransMilenio system (tons of $CO_2$-equivalents)**

| Year | Baseline scenario (tons of $CO_2$-eq.) | Project scenario (tons of $CO_2$-equivalents) | | | | | Total annual reductions (tons of $CO_2$-eq.) |
|---|---|---|---|---|---|---|---|
| | | Private buses | Trans-Milenio | Cement production | Vehicle scrapping | Project scenario total | |
| 2001 | 1,580,925 | 1,450,471 | 74,510 | 27,355 | 12,646 | 1,564,982 | 15,943 |
| 2002 | 1,567,044 | 1,440,392 | 85,256 | 0 | 11,476 | 1,537,124 | 29,920 |
| 2003 | 1,557,493 | 1,387,571 | 95,236 | 7,339 | 15,587 | 1,505,733 | 51,760 |
| 2004 | 1,558,716 | 1,357,836 | 99,840 | 20,683 | 17,792 | 1,496,150 | 62,566 |
| 2005 | 1,562,152 | 1,212,356 | 145,198 | 0 | 29,732 | 1,387,286 | 174,866 |
| 2006 | 1,556,963 | 1,199,327 | 147,550 | 0 | 30,864 | 1,377,741 | 179,222 |
| 2007 | 1,551,663 | 1,184,314 | 149,898 | 0 | 31,902 | 1,366,113 | 185,550 |
| 2008 | 1,552,519 | 1,173,484 | 152,260 | 0 | 33,060 | 1,358,804 | 193,715 |
| 2009 | 1,556,270 | 1,165,207 | 154,597 | 13,010 | 34,300 | 1,367,115 | 189,155 |
| 2010 | 1,586,795 | 1,034,346 | 177,373 | 12,543 | 45,606 | 1,269,868 | 316,927 |
| 2011 | 1,616,032 | 854,166 | 210,317 | 5,671 | 57,902 | 1,128,056 | 487,976 |
| 2012 | 1,612,589 | 823,534 | 217,029 | 0 | 63,387 | 1,103,950 | 508,639 |
| 2013 | 1,608,863 | 815,339 | 217,048 | 7,072 | 65,309 | 1,104,768 | 504,095 |
| 2014 | 1,662,188 | 713,824 | 249,013 | 0 | 76,639 | 1,039,476 | 622,712 |
| 2015 | 1,661,548 | 688,882 | 252,482 | 0 | 78,240 | 1,019,604 | 641,944 |
| 2016 | 1,666,696 | 639,111 | 253,477 | 0 | 76,203 | 968,791 | 697,905 |
| *Totals* | 25,458,456 | 17,140,160 | 2,681,084 | 93,673 | 680,645 | 20,595,562 | 4,862,894 |

Source: CAF, 2004

Thus, for just the period of 2001 through 2016, the TransMilenio system is expected to reduce greenhouse gas emissions by a total of 4.86 million metric tons of $CO_2$ equivalents. The period of 2001 through 2016 represents the period over which the construction of the entire system will take place. By 2016, there will be 388 kilometres of exclusive busways constructed in Bogotá. These projections are most likely to be conservative values given that the impacts from land-use changes are not included. Further, the life of the project can be extended significantly as much of the infrastructure will have a duration of 20 to 30 years before requiring complete renovation and/or reconstruction. Thus, the relative amount of emission reductions realised in the year 2016 can be expected to continue for many additional years. Based on this assumption, an extrapolation of the project through the year 2030 yields a total emission reduction of 14.6 million metric tons of $CO_2$ -equivalents.

The estimated emission reductions for TransMilenio show that BRT holds significant potential to reduce greenhouse gas emissions. This finding helps to open up additional opportunities with international funders involved in climate change mitigation. Integrating the demand modelling process with the emission calculations will help ensure higher-quality emission estimations.

### 3.9.3.4 Noise

The existing older vehicles in most developing cities not only produce high levels of contaminant emissions but also generate considerable noise pollution. The inefficient engine technologies in conjunction with poor noise dampening devices means that noise levels can exceed safe levels. Further, the large number of smaller transit vehicles means that existing systems have high numbers of noise generating mini-buses. BRT helps reduce vehicle noise by:

- Replacing 4 to 5 mini-buses with a larger transit vehicle;
- Using quieter engine technologies;
- Managing the system to produce “smoother” vehicle operations;
- Employing noise dampening devices; and,
- Encouraging mode shifting from private vehicles to public transport.

Projecting the potential reduction in noise levels can be difficult since there may be no baseline noise levels collected for the city. Thus, baseline decibel measurements may be a recommended part of a pre-project evaluation of the existing environment. The projected external noise levels of new vehicles are typically specified by the vehicle manufacturers. This information in conjunction with the average noise level of an existing transit vehicle can produce an initial estimation of the projected benefits.

3.9.3.5 Liquid and solid wastes

Transit operations will also generate a variety of liquid and solid waste products. Waste oil, other lubricants, and industrial solvents should be recycled or disposed in an approved manner. Liquid wastes that are not properly treated can endanger water supplies. These wastes can be a particular danger to residents living near transit depots and other repair shops. Solid waste products such as worn tires and failed components should also be disposed in a safe manner.

A formal transit system, such as a BRT system, can help to reduce and control these emissions by providing standard procedures and a more controlled environment. While informal operators may dispose of waste products in an uncontrolled fashion, concessioned BRT operators must follow procedures stipulated in the contractual agreements. The TransMilenio depots in Bogotá include infrastructure to facilitate the recycling and proper disposal of wastes (Figure 211).

### 3.9.4 Social impacts

3.9.4.1 Types of social impacts

Social impacts are also generally positive as BRT systems give lower-income groups more access to public services and economic opportunities. Social impacts refer to the ability of a new transit system to help create more social equity within a city. Thus, this factor is related to previous discussions on affordability and employment creation, as well as social changes due to the new urban environment.

The lower unsubsidised fare levels of BRT in developing cities can help make the transit system accessible to a wider social audience. Of course, with subsidisation, fares on LRT and metro systems can likewise be made affordable to the majority of

the population. The metro systems in Mexico City and Delhi, for example, employ significant fare subsidies in order to ensure accessibility.

Transit systems can also provide one of the few places in a city where all social groups are able to meet and interact. An affordable and high-quality system can attract customers from low-income, middle-income, and high-income sectors (Figure 212). This role as a common public good can be quite healthy in creating understanding and easing tensions between social groups.

The regeneration of an urban area due to public transit improvements can have multiple social benefits. As noted, the upliftment of an area creates employment and economic growth. Additionally, evidence suggests that public transit improvements can also reduce crime.

The development of the Bogotá BRT system contributed to an environment that experienced dramatic reductions in crime. In 1999, the year prior to the introduction of TransMilenio, 2,058 robberies were recorded in the city. By 2002, this figure had dropped to 1,370, a reduction of 33 percent. The city also experienced a 32 percent reduction in personal assaults and a 19 percent reduction in homicides over the same period. These impressive reductions were achieved through a combination of innovative measures, of which the BRT system and accompanying improvements in public space were just one component. Thus, the credit cannot be directly given to the BRT system, but it is likely that the system has contributed to creating a safer and more pleasant environment in the city.

#### 3.9.4.2 Estimating social impacts

Predicting some of these types of effects can be quite difficult. The affordability of the system and the expected patronage from lower-income groups can be predicted from the demand modelling process. The expected impact on social class interactions is probably not possible to determine with any significant accuracy. However, if the demand modelling process produces estimates of the amount of middle and higher-income ridership, then some conclusions can perhaps be made. Projecting the impacts on crime levels is probably not feasible, but establishing a baseline of crime levels near the BRT corridor can be useful for future evaluation exercises.

### 3.9.5 Urban impacts

#### 3.9.5.1 Types of urban impacts

The relationship between BRT and land use can have long-lasting impacts on the form of the city. Busways can play a catalysing role towards sustained economic development. For example, the BRT stations in Curitiba are development nodes, which act to attract commercial and residential development. In fact, the busways and development nodes are mutually beneficial. The strategic siting of BRT stations improves customer access to shopping, employment, and services while the high-density centres ensure sufficient passenger traffic to maintain cost-effective busway operations. Curitiba has also coordinated new residential construction around bus arteries. The end result is that the municipality can deliver basic infrastructure such as water, sewage, and electricity at a significant cost savings to areas with concentrated development. While mixed use, high density planning does not always guarantee a sustainable urban environment, integrated planning efforts between land use and transport can provide a win-win situation for municipal officials, commercial developers, and residents.

#### 3.9.5.2 Predicting changes in urban form

To estimate the projected changes in urban form, a land-use model can be useful. However, such models are not yet entirely well-established. Thus, a city may also wish to base projections on the experiences to date in cities such as Bogotá and Curitiba. Qualitative projections of likely commercial and residential developments may be possible with the assistance of property professionals. Further, if the BRT project has already been announced, then some land-use changes may be occurring even before the system is developed. For example, property values along mass transit corridors will likely change as soon as the project is announced.

## 3.10 Planning Stage X: Implementation Plan

The production of a BRT plan is not the end objective of this process. Without implementation, the planning process is a rather meaningless exercise. And yet, too often significant municipal efforts and expenditures on plans end in idle reports lining office walls, with little more to show for the investment. However, the planning process can provide a confidence boost to leaders and ensure that sufficient considerations have been taken to ensure a successful implementation. Thus, this final stage of the BRT planning process is the critical point to ensure that the spirit and form of the plans can be brought to completion in an efficient and economic manner.



### 3.10.1 Timeline and workplan

A BRT project entails the management of a disparate group of activities to deliver a coordinated final product. The timing and order of each piece must be carefully scheduled and delivered. A full set of construction and implementation plans with timelines can be a useful managerial tool to oversee and control the progress and direction of the overall project.

Just as a strict timeline and workplan was developed for the BRT planning process, similar management tools will be required for the implementation plan. Construction of an initial set of corridors can be reasonably completed within 12 months to 18 months after the BRT plan is developed, provided financing is available and contractual agreements with construction firms and suppliers are readily achievable. However, the actual construction time depends upon many local factors, including the size and complexity of the initial corridors, the availability of financing, and the legal clearance to proceed.

In the implementation phase, events can be more difficult to control than during the planning process. Accidents, strikes, legal challenges, and technical problems are just a few occurrences that can delay the construction process. Thus, additional contingency time for unforeseen events should be factored into any timeline. A

conservative timeline should be particularly considered when announcing expected start dates to the press and public. A missed launch date can create a negative image of the system even before the public has had an opportunity to experience the system for themselves. By contrast, an earlier than expected start will be heralded as a sign of a highly-efficient development process.

Some of the elements in the implementation timeline and workplan include:

- Finalisation of financing
- Finalisation of construction contracts
- Ground-breaking ceremony
- Finalisation of operating company bidding and awarding of concessions
- Hiring of all public company staff
- Continued expansion of pre-launch marketing programme and public education programme
- Periodic reviews of construction progress and completion of contract milestones
- Construction completion
- Testing phase
- System launch

Each of these elements should be included in the implementation timeline and workplan.

### 3.10.2 Financing plan

Financing does not need to represent an insurmountable barrier to BRT implementation. In comparison to other mass transit options, BRT's relatively low capital and operational costs puts the systems within the reach of most cities, even relatively low-income developing cities. Some developing-nation cities have actually found that loans and outside financing are unnecessary. Internal municipal and national funding may be sufficient to fully finance all construction costs. Further, since most BRT systems operate without operational subsidies, no public financing will likely be necessary beyond the provision of infrastructure.

However, developing a complete financing package will require much effort and persistence. Ideally, an effort on financing should begin at the earliest stages of the planning process. The financing plan should also be developed on an iterative basis with the operational and infrastructure design process since the available financing will be a determinant factor in the design possibilities. The expected financing that will be available to private operators should also be a consideration as the technology plan is developed. If the cost of the specified transit vehicle exceeds the likely financing reach of the private operators, then the implementation of the envisioned plan will be compromised.

The planning team, though, must be careful not to be overly pessimistic on the finance possibilities and subsequently under-design the system. BRT's success in cities such as Bogotá and Curitiba has raised the profile of this mass transit option with many public, private, and international financing organisations. Finance should

not become an obstacle to delivering a high-quality system that meets the city's mobility needs.

3.10.2.1 Financing strategy

At the outset, the planning team should develop an overall strategy and approach to system financing. Some common characteristics of a successful financing strategy are:

- Diversity
- Competition
- Sustainability
- Clarity and transparency
- Realism
- Cost-effectiveness.

A diverse portfolio of financing options can be a healthy strategy to hedge against difficulties with a single financing organisation. All relevant local, regional, and international financing sources should be investigated as options. Ideally, the planning team will create such a strong financial case for the new system that a degree of competition will occur between potential financing groups. When multiple lenders are competing to participate in a project, the city will likely be able to negotiate more favourable terms.

Sustainability refers to whether the proposed financing package places an undue amount of pressure on future administrations. If the financing stream 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, the financing process and the financing obligations should be discussed in a wholly transparent manner to allow all parties (including civil society) to provide input. Finally, the total financing package must be cost-effective. The package should strive to achieve an optimum interest rate and a reasonable debt level.

The long-term vision of the financing strategy will likely vary from the financing applied to the system's initial corridors. Bogotá relied upon local funding sources in its first phase, but is now able to tap a greater amount of international financing sources for its subsequent phases. Table 46 outlines the funding sources for TransMilenio's Phase I.

**Table 46 Financing for Phase I of TransMilenio**

| Source | Percent of contribution to infrastructure costs |
|---|---|
| Municipality* | 48% |
| Revenue from petrol tax | 23% |
| National government | 19% |
| World Bank loan | 10% |

* Revenues from the sale of the municipal electricity company
Source: Sustainable Transport, 2003

If an initial project phase is successful, as was the case with TransMilenio, then the number of financing sources for subsequent phases will tend to increase. This tendency is largely due to financial organisations gaining confidence in a project once the city successfully delivers initial phases.

3.10.2.2 Financing options

Financing for BRT can be divided into three groups of activities: planning, infrastructure and equipment (such as buses). Each of these activity areas typically involves different sorts of financing organisations. Table 47 summarises the potential financing sources for these activity areas. Section 3.1.5 has already discussed financing options for planning activities.

**Table 47 Potential Financing Sources for BRT**

| Activity Area | Financing Source |
|---|---|
| System Planning | Local and national Sources<br>Bi-Lateral assistance agencies (e.g. GTZ, USAID)<br>United Nations Development Programme (UNDP)<br>Global Environment Facility (GEF)<br>Private foundations |
| Infrastructure | Local and national general tax revenues<br>Petrol taxes<br>Road pricing / congestion charging<br>Parking fees<br>Improved enforcement of traffic regulations<br>Land value taxation<br>Sales or leasing of commercial space near stations<br>Advertising<br>Merchandising<br>Commercial banks<br>Municipal bonds<br>World Bank<br>Regional Development Banks (e.g., ADB, IDB)<br>Emissions trading |
| Equipment (e.g. buses) | Private sector bus operators<br>Bus manufacturers<br>Bi-Lateral export banks<br>International Finance Corporation<br>Commercial banks |

For the most part, the financing plan will concentrate on financing infrastructure. The business model developed in section 3.5 should have ensured that the equipment costs (e.g., buses) will be financed by the private sector. The private operators themselves will need to develop their own financing plans so that the focus of the public financing will likely remain on infrastructure.

3.10.2.3 Local and national sources

The most stable and low-cost financing options are likely to found quite close to home. Local revenue sources are generally the base financing source for realising BRT initiatives, especially during the initial project phases. As was the case for Bogotá, local and national sources may well be sufficient to finance much of the system's initial infrastructure. Cities and national governments also exert more control over their own resources, and thus in many instances, can ascertain the long-term reliability of the revenue flow. Further, many potential local sources for BRT also carry the benefit of discouraging private vehicle use, which will only further strengthen the soundness of the BRT system.

*a. Existing transport budgets*

The logical starting point for any financing plan is to examine existing budgets for public transport and roadway development. Often the price of a single flyover project is equivalent to launching much of the BRT system. Re-directing local and national roadway projects to transit priority projects can be justified on both cost and equity grounds. In many instances, the BRT investments will serve the dual purpose of improving both public transport and private vehicle infrastructure. The construction of the TransMilenio corridors in Bogotá also included upgrades to the nearby mixed traffic lanes.

*b. Fees and taxes*

Dedicated revenue streams from special fees and taxes can help establish a long-term sustainable basis for financing BRT development and expansion. Such fees and taxes include:

- Local and national general tax revenues
- Petrol taxes
- Road or congestion pricing
- Parking fees
- Enforcement of traffic regulations
- Land-valuation taxation

Most of these fees and taxes will also act as disincentives to private vehicle use. Petrol taxes, parking fees, and congestion pricing will all help to encourage public transport use.


Bogotá made use of a dedicated tax stream from the taxation of petrol. Twenty eight percent of Colombia's petrol tax is hypothecated directly to eligible public transport projects such as TransMilenio. In a similar manner, the State of North Carolina in the United States has delivered an innovative scheme to ensure public transit projects receive the necessary funding. One-half of one percent of the State sales tax is set aside for municipal transit projects. This revenue source generates approximately US$ 50 million each

year. The State then uses these funds to provide a 50 percent match for municipal transit projects.

As noted previously, congestion charging and electronic road pricing has served as a highly effective revenue stream for public transport projects in London and Singapore (Figure 213). These measures have also been credited with substantially reducing vehicle congestion levels. However, road pricing schemes can be complex to implement. Further, given the technology involved and significant start-up costs, a separate initial financing plan may be necessary just to implement a road pricing scheme. The municipality may have to wait several years before the initial investment delivers a net return.



Parking fees can be equally as effective in discouraging vehicle use as road pricing, but the relative ease of implementation of parking restrictions makes parking control a more viable short- and medium-term option (Figure 214). However, changes in parking fees and regulations will likely require local council approval. In the case of applying fees to parking at commercial sites, special legislation is also a likely requirement. Many developing cities may currently have few parking restrictions and poor parking enforcement. While a parking fee regime will produce a dramatic increase in city revenues in such cases, the political challenge of introducing an entirely new charging scheme can be difficult.

However, the operating cost of a parking fee programme will be significantly less than a road pricing programme. Relatively little physical set-up is required and the administrative structure may already be in place through existing parking regulations. Thus, a parking fee programme can begin providing BRT revenues relatively quickly. The city of Cuenca (Ecuador) has utilised a parking control initiative as a highly-effective mechanism for helping to finance new bus priority measures (Figure 215).

As with a lack of parking regulations, traffic enforcement in general is an area that many developing cities have not entirely controlled. The development of the BRT system provides a reason to improve overall traffic control and enforcement.

Enforcement of laws on speeding, stopping, and obeying lane markings will help ensure smoother traffic patterns as the new street configurations are introduced. Improved traffic enforcement can also generate revenues from fines and penalties. While enforcement of previously ignored traffic laws requires a tremendous change of street culture, the promise of the new transit system can help mitigate some of the public criticism. If the fines and penalties are dedicated towards the new public transit system, then there may be greater public acceptance of tighter enforcement of traffic regulations. Clearly, though, coordination with the local and national police agencies will be required to implement a new enforcement ethic (Figures 216 and 217).


Land-value taxation is a new financing opportunity that holds much promise to revolutionise the manner in which mass transit projects are financed. The arrival of a high-quality transit system along a corridor can dramatically increase the value of properties in the area. The proximity to the transit network means greater convenience for residents and greater customer flows for commercial enterprises. The idea is being pursued in the United Kingdom where land values around several high-profile transit projects have increased significantly. Property values within one kilometre of stations on the Jubilee Line extension (London Underground system) increased by approximately £ 13 billion (US$ 23.4 billion) as the project developed (Riley, 2001). The cost of the entire extension was only £ 3.5 billion (US$ 6.3 billion). Unfortunately, none of the windfall increases in property values were captured by the government. A tax on the property value increases could have paid for the Jubilee Line extension. Thus, many groups are devising property valuation mechanisms to help capture revenues to pay for the transit infrastructure (Figure 218).

While these fees and taxes have considerable appeal as a basis for BRT financing, there is one significant barrier. Each requires a great deal of political will to implement. Fees and taxes are never politically easy to introduce, especially for political officials viewing re-election. However, the political benefits of delivering a high-quality public transit system can be a strong counter-force to these concerns. Ultimately, the viability of the entire BRT projects rests on the will of elected officials to create a markedly better transit system for the city.


*c. Commercial revenue opportunities*

The inherent attractiveness of the new transit system can open up new commercial opportunities that will produce positive revenue streams. Commercial development of stations, advertising, and merchandising are just a few the creative mechanisms that the city can take advantage of to generate additional revenues.

As strategic nodes for development and commercial enterprise, BRT systems also present many opportunities for commercialisation. The space inside and around stations and terminals holds particular value given the high volumes of persons passing through the system. Land values often skyrocket upon the announcement of a public transit corridor. System developers can take advantage of this situation by controlling and selling commercial space. Mass transit systems in cities such as Manila and Bangkok have used the leasing of commercial space to help fund infrastructure costs (Figure 219).

Likewise, the selling on advertising space at stations and within buses can be an option to consider (Figure 220). However, the commercialisation of the system must be done with a great deal of caution. Commercial signage should be discretely done, if at all, or it will risk degrading the visual and aesthetic quality of the system. When commercial signage overwhelms stations and buses, then customers are less able to distinguish signage relating to system use. The general despoiling of the aesthetic quality of the system can lower the image of the system, which is directly related to customer satisfaction and usage. Visual degradation can also lead to increased incidences of graffiti, vandalism and other criminal activities.

Some BRT systems have achieved such a positive status within their communities that revenue opportunities exist with system merchandising. The sale of system t-

shirts, model stations and buses, and other souvenirs can in fact provide a reliable revenue stream. The marketability of the system relates back to the quality of the initial marketing impression (system name, logo, etc.) as well as the degree of social pride attained through the delivery of a high-quality product.



*d. Local lending institutions*

Local commercial banks and national development banks are both logical targets for financing requests. If the municipality has maintained an acceptable credit rating with lending institutions, then access to these institutions should be reasonably straight forward. National development banks typically have a stated mandate to support major infrastructure initiatives at the local level, and thus these institutions should be particularly targeted for support. Further, development banks may also offer interest rates below the commercially available rates.

The local commercial banks may be particularly relevant to providing capital for the acquisition of transit vehicles by the concessioned private operators. In many instances, the private operators may already have an established relationship with the commercial lending institutions.

However, in both the cases of commercial lenders and national development banks, the relative unfamiliarity with BRT as a concept may create hesitancies. If lenders are unsure of BRT's viability as a successful mass transit option, then they may not be enthusiastic about financing the project. In Phase I of Bogotá's TransMilenio project, the private operators largely were not able to access loans from the commercial banks. The lending institutions were unfamiliar with BRT and did not have confidence in the overall scheme. However, following the great success of Phase I, there is significant competition amongst the commercial lenders to provide capital to the subsequent phases.

*e. Municipal bonds*

Municipal bond issues are quite frequently utilised in North America and Europe to finance major municipal infrastructure projects. This funding mechanism is less widely used in developing cities. However, in some cases, municipal bonds may be an appropriate mechanism to minimise financing costs. The viability of this approach will depend on whether a legal structure exists to issue the bonds and

whether there is sufficient market confidence in the municipality's financial record. In some cases, guarantees from the national or provincial government may be required to bolster market confidence. Such guarantees will also act to reduce the required interest rate of the bond issue.

*f. Public-private partnerships (PPPs)*

A notable omission from the list of infrastructure financing options in Table 47 is private developers. Both private operators and private development firms are sometimes used in what is known as public-private partnerships (PPPs) for infrastructure. A typical PPP arrangement implies that a private firm will construct a mass transit system's infrastructure in return for a concession on operating the network. The infrastructure investment is then recovered by the firm through system revenues (i.e., fares). Thus, in a PPP, both capital and operating costs are recovered through system revenues. PPPs are often used successfully in building toll roads.

While a PPP offers the highly attractive notion of providing a city with a mass transit system at no public cost, the viability and terms of such agreements have a relatively poor history. PPPs with rail-based systems in cities such as Kuala Lumpur and Bangkok have undergone bankruptcy proceedings. The expectation is often that the public sector will intercede with investment if the private system becomes financially unstable. Unfortunately, failed PPPs occur all too often. The demands of recovering both capital and operating costs through the fare system create tensions in terms of tariff levels and service quality. In some cases, the required tariff levels are well outside of the affordable range of the city's lowest income groups. Additionally, to recover their full investment, the private company typically receives a relatively long concession, perhaps as long as 20 to 30 years. With such a long contractual period, the municipality is tied to an agreement that gives little flexibility in addressing future changes in the urban environment.

Further, the resulting system will likely only operate in the most lucrative corridors. Since the PPP will be unrelated to other transport services in the city, there is typically no fare integration with these other services. For example, although different private sector rail systems cross one another in both Bangkok and Manila, passengers have to pay twice to go from one corridor to another. In many instances, physical integration is not provided either, meaning that just walking from one line to another is difficult.

Funding infrastructure through revenues also brings up issues of fairness and equity. Urban road infrastructure for private vehicles is typically financed through the general tax base. Thus, why should public transport users have to pay for their infrastructure by themselves when private vehicle owners do not? A public transport user ends up paying for both the infrastructure of the transit system and the infrastructure of the private vehicle users.

In summary, the expected fare levels and service needs of developing cities are quite difficult to achieve with PPPs. Further, requiring public transport users to exclusively finance their own infrastructure raises serious questions over fairness and equity.

3.10.2.4 International sources

*a. Combining local and international sources*

In some cases, international financing and funding may be an appropriate addition to a locally- and nationally-based financing plan. If outside financing proves to be necessary, commercial, bi-lateral and multi-lateral institutions are increasingly supportive of assisting BRT projects. Unlike other costly mass transit options, BRT presents sufficiently low capital requirements and historically positive operational returns to be considered commercially bankable projects. Likewise, international organisations also tend to support BRT for similar reasons.

If international financing is pursued as an option, such financing should only be considered an augmentation to existing locally- and nationally-based financing. International resources will most likely never fully finance the system. A lack of local and national financing support sends the message that the governmental entities are not really supportive of the project. The lack of financial contributions will also imply that the local and national entities may not take full political ownership of the initiative and will do little to support the future development of the full system.

*b. Bi-lateral support*

Section 3.1.5 outlined the various international organisations that would potentially provide some support to a developing city's BRT planning process. The list of international organisations that would potentially help finance infrastructure development is more limited. Most overseas development agencies will not directly fund infrastructure. Likewise, private foundations more typically lend support to technical capacity and not directly to financing infrastructure.

Developed-nations do offer export-promotion financing that can be utilised within a developing-city mass transit initiative. Some examples of these types of banks include:

- German Kreditanstalt fur Wiederaufbau (KfW)
- Japanese Bank for International Cooperation (JBIC)
- United States Export-Import Bank (EX-IM Bank)
- United States Overseas Private Investment Corporation (OPIC)
- United States Trade & Development Administration (TDA)

While some developed-nation export banks will potentially provide finance, this support is tied to using a particular developed-nation company. This restriction may compromise the intended direction and quality of the project as well as increase the overall capital cost. Further, promoting developed-nation companies at the expense of local suppliers will likely be counter to local development objectives.

*c. International development banks*

Thus, the principal international financing sources will be the World Bank and regional development banks. The World Bank Group actually consists of five

different organisations, each with a different mandate in supporting development. Most loans for BRT will be managed through the International Bank for Reconstruction and Development (IBRD). However, for the lowest-income countries, the International Development Association (IDA) may be the appropriate lending organisation. Additionally, the International Finance Corporation (IFC) focuses on supporting private sector initiatives in developing countries, and thus the IFC could be an appropriate source of finance for concessioned operators.

Regional development banks operate in a similar manner as the World Bank but with a more focused geographical mandate. The list of regional development banks include:

- African Development Bank (AfDB)
- Andean Development Corporation (CAF)
- Asia Development Bank (ADB)
- Central American Bank for Economic Integration (CABEI)
- Council of Europe Development Bank (CEDB)
- Development Bank of Southern Africa (DBSA)
- Eastern and Southern African Trade and Development Bank (PTA)
- European Bank for Reconstruction and Development (EBRD)
- Inter-American Development Bank (IDB)
- Islamic Development Bank (ISDB)

*d. Emissions trading*

While the global market for emissions trading is still in a very nascent stage, there is future potential for financing mass transit initiatives through emission reduction credits. The most prominent opportunities are related to reductions in greenhouse gas emissions. In 1997, under the auspices of the United Nations, member nations drafted the Kyoto Protocol. The protocol calls for developed nations to reduce emissions by an average of 5.2 per cent from a 1990 baseline.

While ratification of the Kyoto Protocol remains stalled, several nations and organisations are proceeding with mechanisms that involve projects in developing nations as well as in economies-in-transition. The initiatives inspired by the Kyoto mechanisms are being developed under the framework of the "Clean Development Mechanism" (CDM) and "Joint Implementation" (JI). These new mechanisms permit investors to gain Certified Emission Reductions (CERs) by investing in emission reducing projects in developing nations and economies-in-transition. The following programmes are underway:

- ERUPT Programme (Netherlands)
- Finnish CDM/JI Programme (Finland)
- Japanese CDM Programme (Japan)
- Prototype Carbon Fund (World Bank)

TransMilenio SA of Bogotá and the Andean Development Corporation have submitted a calculation methodology for BRT to the United Nations Framework Convention on Climate Change (UNFCCC). With approval of this methodology,

Bogotá hopes to claim "Certified Emission Reduction" credits to help finance future extensions to the system.

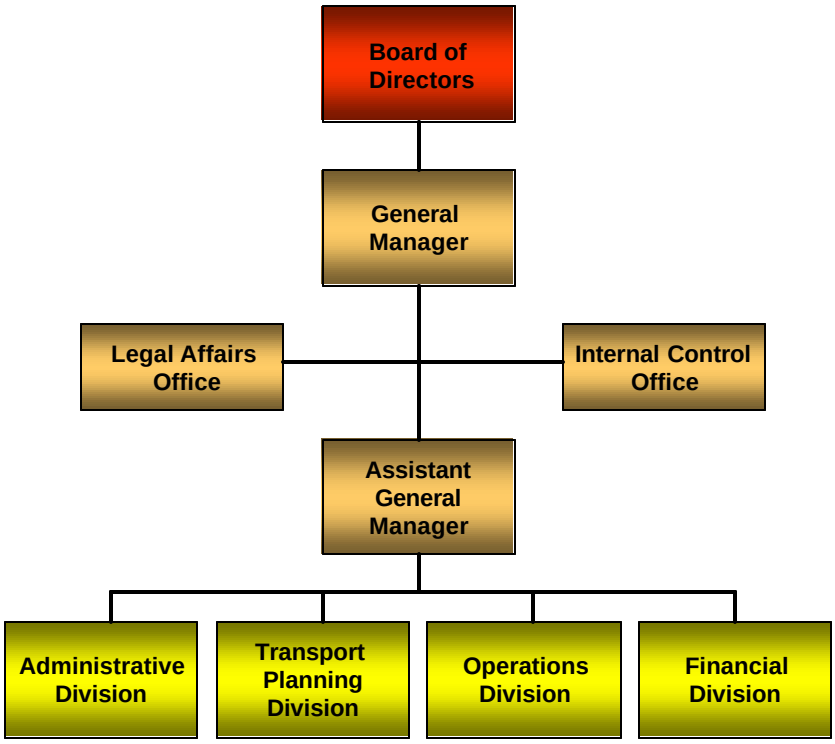
### 3.10.3 Staffing and management plans

As the project moves closer to implementation, the full establishment and staffing of the BRT management agency will be required. Section 3.1.3 outlined some of the positions required to develop the BRT plan. While a staff of three to ten persons may be sufficient at the planning stage, to develop the full management organisation a wider range of positions and skills will be needed. The build-up of staff will likely occur in a phased manner with certain key positions being filled initially.

The formal establishment of the public management company for the BRT system should follow from the structures detailed in section 3.5 (Business and Regulatory Structure). This structure has the BRT management entity reporting to the mayor's office either directly or through a representative board of directors. The legal process to form the management entity should be completed well before the system is launched. TransMilenio SA was legally formed in October 1999, over a year prior to the system launch in December 2000.

The organisational structure of the management entity should promote clear lines of responsibility and should provide logical sub-units pertaining to the major functions of the organisation. Such units may include administration, financial control, legal affairs, operations, and planning. Figure 221 outlines the internal organisational structure utilised by TransMilenio SA.

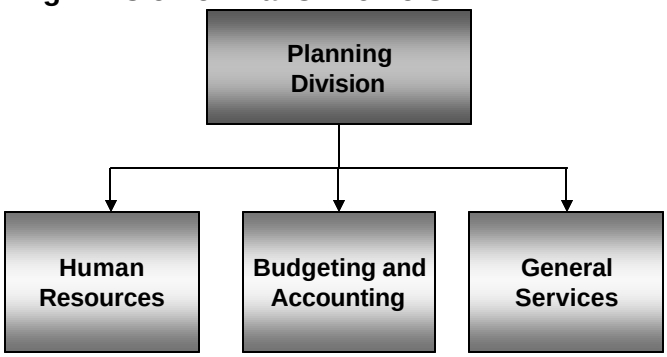
**Figure 221 Organisational structure of TransMilenio SA**



The General Manager position has overall responsibility for developing and implementing the organisation's strategy. The General Manager reports directly to the Board of Directors, and is the organisation's principal interface with other governmental agencies and with private entities. The Assistant General Manager directly manages the day-to-day activities of TransMilenio's four divisions: Administration, Planning, Operations, and Finance. The Internal Control Officer ensures that TransMilenio's internal financial operations are conducted in a proper manner in accordance with the regulations established by the Board of Directors and the municipality. This position also oversees the fulfilment of the internal financial audit. The Legal Affairs Officer ensures that legal documents and contracts are in compliance with all local and national laws.

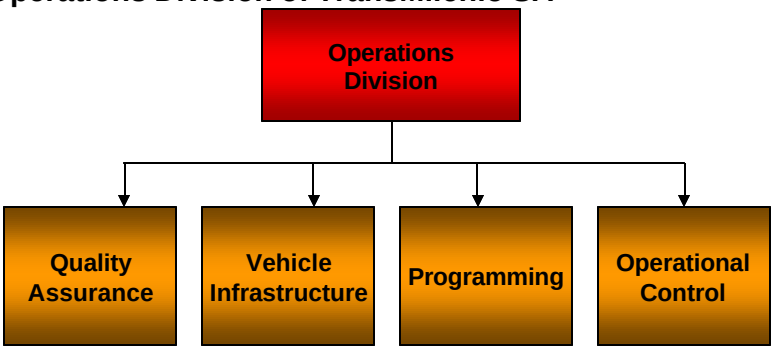
The Planning Division of TransMilenio is focused upon the planning activities required for the expansion of the system. The Planning Division thus takes the lead on new corridor projects. Figure 222 indicates the structure of the Planning Division.

**Figure 222 Planning Division of TransMilenio SA**



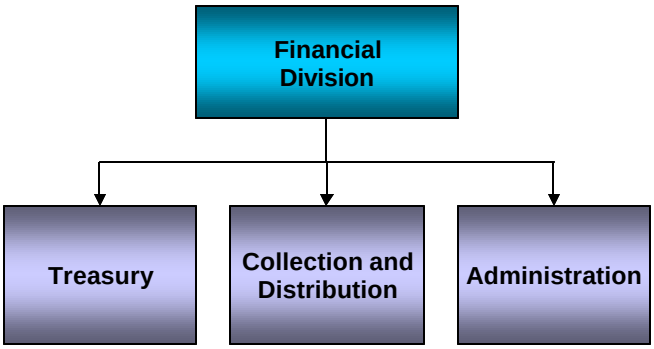

The Operations Division of TransMilenio ensures that the system functions in an efficient manner. The Operations team monitors the performance of the private bus operators, the functioning of the control centre, and the overall service quality of the system. Figure 223 provides an outline of the structure of the Operations Division.

**Figure 223 Operations Division of TransMilenio SA**



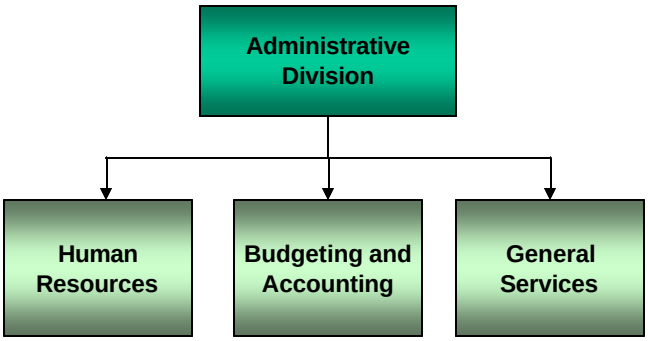

The Financial Division of TransMilenio monitors the system's cost structure to ensure the proper levels of technical tariffs and customer tariffs. This division also oversees the private operator with the fare collection concession. Figure 224 gives the structure for the Financial Division.

**Figure 224 Financial Division of TransMilenio SA**




The Administrative Division provides support services to TransMilenio SA in terms of human resources, budgeting, and general services. The structure of the Administrative Division is given in Figure 225.

**Figure 225 Administrative Division of TransMilenio SA**




TransMilenio manages to fulfil its mandate with a staff of approximately 80 persons. The simplicity of BRT systems along with the increasing prominence of information technology have permitted large transit systems to be administered by relatively lean management agencies. Table 48 lists the number of employees at TransMilenio SA by functional area.

**Table 48 Employees by functional area in TransMilenio SA**

| Functional area | Number of employees |
|---|---|
| General Manager's Office | 5 |
| Assistant Manager's Office | 5 |
| Legal Affairs Office | 5 |
| Internal Control Office | 3 |
| Administrative Division | 17 |
| Planning Division | 11 |
| Operations Division | 27 |
| Financial Division | 7 |
| *Total* | 80 |

Source: TransMilenio SA

Each position should be competitively advertised and processed through a formal interview process. The long-term success of the system will very much depend on the skills and creativity of the management agency's staff.

### 3.10.4 Contracting plan

Leveraging the competitiveness and efficiency of the private sector allows cities to deliver more cost-effective transit systems. However, to ensure that the private sector performs in the manner intended, clear and precise contractual arrangements must be established. These contracts will specify the activities to be undertaken, the expected final products, the duration of the activity, and the means for receiving compensation. As noted in section 3.5, "quality incentive contracts" are an effective mechanism for linking contractual performance to the amount of the eventual payment. A set of fines and penalties may also be appropriate in order to discourage underperformance and errors.

#### 3.10.4.1 Types and characteristics of contracts

This planning guide has already outlined many of the types of contracts that will be required to plan and implement the BRT system. These contracts include:

- Consultant contracts
- Trunk-line operator concession
- Feeder concession
- Fare collection concession
- Fiduciary contract
- Construction contracts

While the terms and nature of each contract will vary by the intent and circumstances, each will share some general characteristics. The awarding of contracts should all be based upon a competitive framework in which firms bid to pre-determined criteria. A well-defined scoring system is then utilised to select the bidding firm offering the greatest potential to deliver a high-quality and cost-effective product. The entire process will need to be open and transparent so that the public's confidence in system development remains strong. Financial incentives should be built into contracts in order to encourage superior performance. The timely delivery of each product should be well-specified with defined penalties for failure to perform.

#### 3.10.4.2 Construction contracts

Previous sections have outlined issues related to the concession agreements with private operators. The construction work will likely be awarded by way of traditional contracts rather than through concession agreements. However, well-designed construction contracts will also encompass many of the same long-term incentives found in concession agreements.

Specifically, incentives are required to ensure that construction companies provide a high-quality and long-lasting product. If construction firms have no responsibilities beyond the initial delivery of their assigned infrastructure component (e.g., busway,

stations, terminals, depots, etc.), then the financial reward will only be based upon the initial product rather than long-term quality and durability. Thus, contractors will have an incentive to only worry about a rapid and low-cost delivery and not whether the product is still functional in a few years.

The best mechanism to ensure a higher-quality and more durable product is to encompass long-term maintenance responsibilities within the construction contract. The firm that builds the busway or station will be contractually required to maintain it to specific standards. If the firm has a five to ten year maintenance contract, then automatically the company will want to build the infrastructure to endure. If the construction is delivered in poor quality, then the firm will have higher costs maintaining the infrastructure over the entire period of the contract.

In Phase I of TransMilenio, the construction firms were not responsible for long-term maintenance. Thus, when severe road construction faults occurred after only three years of operation, the city had no legal recourse to hold the private companies as the responsible party. Instead, the costly, crumbling concrete busway became an exercise in finger-pointing in which no entity wished to admit fault. With this lesson in mind, TransMilenio restructured the Phase II contracts in order to link construction and maintenance together. If a construction problem appears in the future, it will clearly be the responsibility of the construction firm to correct it.

A sense of competition can also be achieved within the construction contracting by developing many different tender opportunities. Rather than rely upon a single firm to construct all corridors, stations, terminals, and depots, contracting distinct elements to different firms can be quite advantageous. The municipality will be able to judge the performance of each company, and thus make decisions about the best performing firms for future contracts. This comparative analysis will likely spur a better performance from each of the participating firms. Further, dividing distinct elements between different competitors will avoid overburdening the capacity of a few firms. If the construction process only uses one or two firms, then there may be a greater risk of serious delays or problems since a problem with a single firm will affect the entire project.

3.10.4.3 Legal structure of contracts

All contractual agreements should be rigorously vetted by legal staff to ensure compliance with relevant laws and regulations. The exact structure of a contract will vary according to each country's own legal system.

### 3.10.5 Construction plan

The construction process represents a great risk to the image and future of the new transit system. The closing of roadways, the construction noise, and the blowing dust can all give the new system a negative first impression to the population (Figure 226). Thus, organising the construction work in a city-friendly manner should be a top consideration.

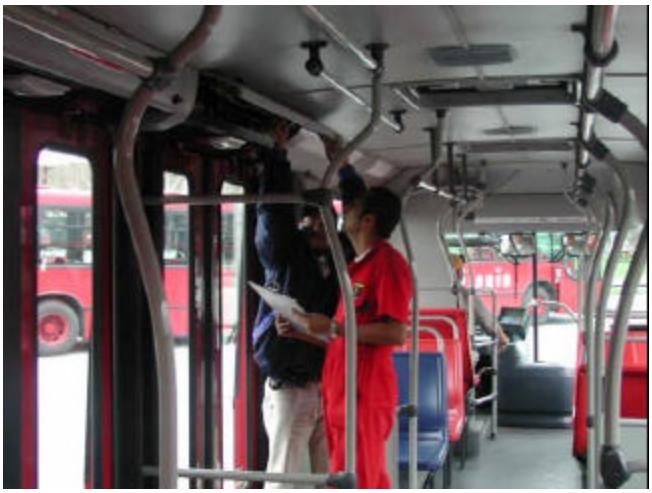
A construction plan should be delivered in conjunction with the contracted firms. Each step of the process should be mapped out to minimise the negative impacts.

In some cases, construction at nights, weekends, and holidays may be the best options for avoiding the prolonged closure of key connecting roads. A public education plan can also help to warn residents of the work and to offer suggestions on commuting alternatives. It may also be best to work on a segment by segment basis rather than closing the entire length of a particular corridor. However, the particular strategy will depend much upon local circumstances. The management of traffic re-routing and traffic control during the construction should be coordinated between the construction firm, the police, and the public transit agency.

The manner of the construction process should also be noted in the construction contract. It is also possible to include financial incentives to construction firms that successfully minimise negative impacts of road closings and construction dust and noise.

**3.10.6 Maintenance plan**

Start-up problems aside, most systems operate well and project a highly-positive image through its initial years. As systems age, though, the question arises as to whether it will maintain its initial quality and performance. Bus systems are notoriously left with little investment and civic care over the long term. Thus, developing a maintenance plan and dedicated funding stream to upkeep the system is fundamental to its long-term performance.



The maintenance of some equipment items such as buses will be the responsibility of private sector operators (Figure 227). Thus, maintenance and quality standards must be explicitly stated in the original contractual agreements. The maintenance of system infrastructure components (busways, stations, terminals, depots, and control centre) will depend on the nature of the original construction contracts. As noted in section 3.10.4, linking the original construction contracts to maintenance responsibilities can produce the right incentives for quality construction. However, there are trade-offs between this approach and the cost of the construction contract. Thus, responsibility for maintenance may be held by either private firms or the municipality.

Maintenance practices should ensure that any problems are addressed as they occur. A damaged roadbed will not only create discomfort for passengers but also increase maintenance costs for transit vehicles. Maintenance teams should be constantly on the watch for graffiti and other types of system vandalism. If vandalism is not repaired immediately, it can create an impression that such actions are tolerated and will thus encourage even more acts of vandalism.

If certain infrastructure components are requiring frequent maintenance actions, then this information should be incorporated into decisions on future extensions of the system. A maintenance logbook should thus be kept by all maintenance contractors with copies submitted to the transit agency or the public works department. Vehicle doorways and station doorways are particularly prone to degradation over time. Analysing maintenance actions and the nature of the problems can possibly help in devising future solutions.

At a certain point, each infrastructure component will likely require a major overhaul. The expected lifetimes of roadways, stations and other infrastructure will depend upon such factors as use patterns, topography, and climate. Roadways may require reconstruction every five to ten years, depending on the materials utilised in the original construction. Stations, terminals, and depots should last for several decades before major reconstruction is required. Estimating the lifespan of the infrastructure components will also allow financial planners to determine later re-capitalisation needs of the system.

### 3.10.7 Monitoring and evaluation plan

#### 3.10.7.1 Fundamentals of monitoring and evaluation

In many respects, the success or failure of a system can be apparent from public reactions to the system. The customer's opinion is perhaps the single most important measure. However, to obtain an objective and quantifiable indication of a system's overall performance, a defined monitoring and evaluation plan is fundamental. The feedback from such a plan can help identify system strengths as well as weaknesses requiring corrective action.

The identification of a full set of system targets and indicators is a first basic step in the development of a monitoring and evaluation plan. A baseline value should be created for the relevant indicators. Thus, the evaluation work will begin prior to the development of the system. By noting such factors as average vehicle speeds, travel times, and public transport usage prior to the system's development, it will be possible to quantify the benefits gained by the new system. Most indicators will be quantitative in nature, but qualitative assessments can also be accommodated through survey work.

A strict monitoring and evaluation schedule should be established. Many of the system performance indicators, such as passenger numbers, will be collected automatically through the management control system and the fare collection data system. Other indicators will require direct periodic measurement. The initial period of system operation will likely be a period of more frequent measurement since

there will be great interest to evaluate the original design and operational assumptions. Feedback from the initial monitoring may shape the design and operational adjustments that frequently occur in the first year of operation. After the initial months of operation, though, a regular pattern of data collection should be established.

Baseline data may also need to be collected across several different points of time. Some baseline factors will likely vary by time of day, day of the week, and months of the year. The original modelling process is another rich source of potential baseline data. Evaluating the projections from the demand modelling process will also be helpful in determining the accuracy of the model for future applications.

3.10.7.2 System performance indicators

The potential indicators for evaluating system performance include:

- Mode shares (public transport, private vehicles, walking, cycling, taxis, motorcycles, etc.)
- Average travel times
- Average public transport vehicle speeds
- Average private vehicle speeds
- Passenger capacity of roadway
- Peak capacity of public transport system
- Average wait times
- Total travel cost
- Transit subsidy levels
- Number of positive media reports on system / number of negative media reports on system
- Customer satisfaction.


3.10.7.3 Economic indicators

The potential indicators for evaluating economic impacts include:

- Employment created during the construction phase
- Employment created in the operational phase
- Economic value of travel time savings
- Economic value from the reduction of congestion
- Property values near stations and corridor
- Shop sales near stations and corridor
- Vacancy rates of properties near stations and corridor
- Creation of private firms producing BRT technologies (e.g., vehicles, fare collection technology, etc.)
- Employment generated from local production of BRT techologies.

3.10.7.4 Environmental indicators

The potential indicators for evaluating the environmental impact of the system include:

- Levels of local air pollutants (CO, NOx, SOx, PM, toxics, $O_3$)
- Emissions of greenhouse gases ($CO_2$, $CH_4$, $N_2O$)
- Noise levels
- Number of older buses retired from service.

3.10.7.5 Social indicators

The potential social indicators for evaluating the system include:

- Percentage of public transport passengers from each socio-economic grouping
- Percentage of household incomes required for transport
- Crime levels along corridor
- Crime levels within public transport vehicles.

3.10.7.6 Urban indicators

The potential indicators for evaluating impacts on urban form include:

- Number of new property developments along corridor
- Opinion surveys on quality of public space along corridor.

3.10.7.7 Political indicators

The potential indicators for evaluating political impacts include:

- Change in number of political officials supporting project over time
- Re-election success rate of officials supporting system.

# 4. BRT Resources

The groundswell of interest in BRT in the last few years has meant that new resources are now available to assist interested cities. Governmental and non-governmental organisations have dedicated substantial resources to share knowledge on BRT. This section notes some of these key organisations and technical resources:



## 4.1 BRT support organisations

1. American Public Transportation Association (APTA)

APTA is a national trade association representing transit agencies and operators in the United States. The APTA website includes useful background documentation on BRT concepts.

www.apta.com/info/briefings/brief2.pdf

2. Breakthrough Technologies Institute

The Breakthrough Technologies Institute is a US-based organization that seeks to provide key background information on the BRT option. The web site provides news on BRT developments, links to key BRT reports, and information on different vehicle technologies.

www.gobrt.org

3. Bus Rapid Transit Central

This site is a hub for articles on BRT and links to technical information on various systems. Additionally, the site is home to a BRT discussion board that allows practioners an opportunity to get answers from their peers.

www.busrapidtransit.net

4. GTZ Sustainable Urban Transport Programme (SUTP)

The German Overseas Technical Assistance Agency (GTZ) has developed an information source on a wide range of sustainable transport topics. The SUTP web site hosts this BRT module and other documents on sustainable transport. GTZ also supports sustainable transport projects in a variety of developing-nation cities.

www.sutp.org

5. Institute for Transportation & Development Policy (ITDP)

ITDP is an international non-governmental organisation that provides supports to BRT initiatives and other sustainable transport projects in Africa, Asia, and Latin America. ITDP has assisted BRT projects in such countries as Brazil, Colombia, Ecuador, Panama, Ghana, Senegal, South Africa, Tanzania, Bangladesh, India, and Indonesia. ITDP also publishes a regular newsletter, e-Sustainable Transport, that features frequent articles on BRT projects worldwide.

www.itdp.org

6. International Energy Agency (IEA)

The IEA has compared the environmental performance of different fuel and propulsion options for buses in its publication entitled *Bus Systems for the Future: Achieving Sustainable Transport Worldwide*. This research has also compared the emission impacts of tailpipe technologies to the benefits of mode-shifting strategies.

www.iea.org

7. National Bus Rapid Transit Institute

Based at the University of South Florida in the United States, the National BRT Institute is an information clearinghouse on BRT. The work of the institute receives support from the US FTA. The site includes BRT publications and presentations from US officials, local governments, and consultants.

www.nbrti.org

8. Transit Cooperative Research Program (TCRP)

TCRP is a component of the US Transportation Research Board (TRB). TCRP has produced several key studies on topics related to BRT, including a compendium of BRT case studies and planning guidances.

http://www4.trb.org/trb/crp.nsf

9. Transportation Research Board (TRB)

TRB is a division of the US National Research Council which acts as an independent advisor to the US government. TRB seeks to promote innovation and progress in transport through research. Each year in January, TRB hosts its annual review conference which includes many useful sessions on BRT related themes.

http://gulliver.trb.org

10. Transport Roundtable Australia

This site provides useful information and articles both on general BRT issues as well as specific links to Australian systems in cities such as Brisbane and Adelaide. In October 2000, the Transport Roundtable sponsored a conference related to BRT in Brisbane.

www.transportroundtable.com.au

11. US Federal Transit Administration (USFTA)

This site provides an overview of the USFTA's national BRT programme as well as information on the activities underway in each of the participating cities. The site also provides a number of useful links to technical documents.

www.fta.dot.gov/brt

12. World Bank

The World Bank completed its *Urban Transport Strategy Review* in 2001. This document, *Cities on the Move*, presents the World Bank's strategy for supporting sustainable urban transport options, and also provides a wealth of information on public transit systems, including BRT.

www.worldbank.com/transport

## 4.2 Technical resources

This document has sought to provide an overview of the BRT concept as well as provide insights into the BRT planning process. However, there are several other publications that also provide additional perspectives and information on the topic of BRT. This section lists some of these documents.


Allsop, R. (2000), *Mass rapid transit in developing countries*, London: Halcrow Fox.

Friberg, L. (2000), Innovative solutions for public transport: Curitiba, *Sustainable Development International*, 3: 153-157.

Gwilliam, K., Meakin, R. and Kumar, A. (2000), *Designing competition in urban bus passenger transport: Lessons from Uzbekistan*, World Bank Discussion Paper TWU-41. Washington: World Bank.

Hardy, M., Stevens, W., and Roberts, D. (2001), *Bus rapid transit vehicle characteristics*, USFTA report number FTA-DC-26-7075-2001.1. Washington: Federal Transit Administration.

Litman, T. (2004), Evaluating public transit benefits and costs, Victoria: Victoria Transport Policy Institute (http://www.vtpi.org).

Meakin, R. (2002a), *Bus regulation and planning.* Eschborn: GTZ.

Meakin, R. (2002b), *Urban transport institutions.* Eschborn: GTZ.

Meakin, R. (2001), *Technical guidelines on bus route tendering*. Eschborn: GTZ.

Meirelles, A. (2000), A review of bus priority systems in Brazil: From bus lanes to busway transit. Presented at the Smart Urban Transport Conference, 17-20 October, 2000, Brisbane, Australia.

Menckhoff, G. and Zegras, C. (1999), *Experiences and issues in urban transport infrastructure*. Presented at the International Road Federation Symposium, Hanoi, Vietnam.
(Web document: http://www.worldbank.org/transport/publicat/twu-38/twu-38.pdf)

Ortúzar, J. and Willumsen, L. (2002), *Modelling transport*. Chichester (UK): John Wiley & Sons Ltd.

Robelo, J. (2003), *Basic busway data in Latin America*, Washington: World Bank.
(Web document: (http://www.worldbank.org/transport/urbtrans/pubtrans.htm).

Robelo, J. (1999), *Automated ticketing systems: The state of the art and case studies*, Washington: World Bank.
(Web document: http://www.worldbank.org/transport/urbtrans/pubtrans.htm)

TAS Partnership Ltd. (2000), Quality bus infrastructure: A manual and guide. London: Landor Publishing.

TCRP (2002), A toolkit for self-service, barrier-free fare collection, TCRP Report 80. Washington: National Academy Press.

TCRP (2002), Estimating the benefits and costs of public transit projects: A guidebook for practitioners, TCRP Report 78. Washington: National Academy Press.

TCRP (1999), The role of transit amenities and vehicle characteristics in building transit ridership, TCRP Report 46. Washington: National Academy Press.

TCRP (1997), The role of transit in creating livable metropolitan communities, TCRP Report 22. Washington: National Academy Press.

TransMilenio (2003), Plan marco sistema: TransMilenio. Bogotá: TransMilenio SA.

Transportation Research Laboratory (TRL) (2004), The Demand for Public Transit: A Practical Guide. Report TRL 593, Wokingham, UK: TRL.

US FTA (2001), Proceedings of the bus rapid transit vehicle design meeting. Washington: Federal Transit Administration.

US FTA (2001), Proceedings of the FTA / PRHTA bus rapid transit fare collection workshop. Washington: Federal Transit Administration.

US GAO (United States General Accounting Office) (2001), Bus rapid transit shows promise. Washington: US GAO.

Wright, L. and Fjellstrom, K. (2003), *Mass transit options*. Eschborn, Germany: GTZ.

## 4.3 Links to BRT cities

Adelaide, Australia
www.adelaidemetro.com.au/guides/obahn.htm

Auckland, New Zealand
www.nscc.govt.nz/brt
www.busway.co.nz/brt.html

Bogotá, Colombia
www.transmilenio.gov.co

Boston, USA
www.allaboutsilverline.com

Brisbane, Australia
www.transport.qld.gov.au/busways

Cleveland, USA
www.euclidtransit.org

Curitiba, Brazil
www.curitiba.pr.gov.br/pmc/ingles/solucoes/transporte/index.html

Eugene, USA
www.ltd.org/brt1.html

Hartford, USA
www.ctbusway.com/nbh

Leeds, UK
www.firstleeds.co.uk/superbus/html/

Los Angeles, USA
www.mta.net/metro_transit/rapid_bus/metro_rapid.htm

Miami, USA
www.co.miami-dade.fl.us/transit/future/info.htm

Orlando, USA
www.golynx.com/services/lymmo/index.htm

Phoenix, USA
www.ci.phoenix.az.us/brt

Pittsburgh, USA
www.portauthority.com

Quito, Ecuador
www.quito.gov.ec/trole/trole_1.htm

San Francisco, USA
www.projectexpress.org

San Pablo, USA
www.actransit.org/onthehorizon/sanpablo.wu

Santa Clara, USA
www.vta.org/projects/line22brt.html

Sydney, Australia
www.rta.nsw.gov.au/initiatives/e6_c.htm

## References


Allport, R. (2000), *Urban mass transit in developing countries*. London: Halcrow Fox.

Bruton, M. (1985), *Introduction to Transportation Planning*. London: Hutchinson.

Como Vamos Bogotá, Boletín números 6 y 7, diciembre de 2001.

Doganis, R. (2001), *The airline business in the 21st century*. New York: Routledge.

Flyvbjerg, B., Bruzelius, N., and Rothengatter, W. (2003), *Megaprojects and risk: An anatomy of ambition.* Cambridge: Cambridge University Press.

Garb, Y. (2003), Transit terror: The view from Jerusalem, *Sustainable Transport*, Fall 2003, 15: 12-13, 17.

Goodwin, P., Hass-Klau, C., and Cairns, S. (1998), Evidence on the effects of road capacity reduction on traffic levels, *Traffic Engineering and Control*, June: 348-354.

Hazel, G. and Parry, R. (2003), *Making cities work*. London: Academy Editions.

IplanRio (Prefeitura da Cidade do Rio de Janeiro) (1996), Transportes urbanos: Perfil do usuáio na área metropolitana, Rio de Janeiro. Rio de Janeiro: IplanRio.

Levinson, H., Zimmerman, S., Clinger, J., Rutherford, S., Smith, R., Cracknell, J., and Soberman, R. (2003), Bus rapid transit, Volume 1: Case studies in bus rapid transit, TCRP Report 90. Washington, DC, USA: TCRP (Transit Cooperative Research Program).

Meakin, R. (2003), *Institutional framework for bus regulation and planning*. Presentation at the Sustainable Urban Transport Development conference, Bucharest, Romania, 19 November 2003.

Meakin, R. (2002a), *Bus regulation and planning*, Eschborn: GTZ.

Meakin, R. (2002b), *Urban transport institutions*, Eschborn: GTZ.

Meirelles, A. (2000), A review of bus priority systems in Brazil: From bus lanes to busway transit. Presented at the Smart Urban Transport Conference, 17-20 October, 2000, Brisbane, Australia.

Ortúzar, J. and Willumsen, L. (2002), *Modelling transport*. Chichester (UK): John Wiley & Sons Ltd.

Rodriguez and Targa (forthcoming) (2004), The value of accessibility to Bogotá's bus rapid transit system, *Transport Reviews*, 24(5).

Steer Davies Gleave (2003), Estimation of private vehicle trips replaced by TransMilenio: Phase II report, SDG: Bogotá.

Thomson, I. (2001), UN Economic Commission for Latin America and the Caribbean (UNECLAC), “The Impact of Social, Economic and Environmental Factors on Public Transport in Latin American Cities”, International Seminar on Urban Transport, November 2001, Bogota, Colombia.

US GAO (United States General Accounting Office) (2001), Bus rapid transit shows promise. Washington: US GAO.

Vasconcellos, E. (2001), Urban transport, environment and equity: The case for developing countries. London: Earthscan.

WBCSD (World Business Council for Sustainable Development) (2001), Mobility 2001. Switzerland: Atar Roto Presse.

Wright, L. and Fjellstrom, K. (2003), *Mass transit options*. Eschborn, Germany: GTZ.

Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH

Dag-Hammarskjold-Weg 1-5
Postfac h 51 80
65726 Eschborn
Telefon (0 61 96) 79-1357
Telefax (0 61 96) 79-7194
Internet: www.gtz.de