CHAPTER 3

METRO, LIGHT RAIL AND BRT

This chapter reviews the global conditions, trends and challenges for the main high-capacity transport options: metro, light rail and BRT. Such public transport modes offer solutions for improving urban mobility, quality of life and the environment in both developed and developing countries, providing a competitive alternative to private motor vehicles. An efficient system facilitates seamless movement within and between cities, which in turn is essential for urban functionality and prosperity.[1] Metros, light rail and BRTs are suitable for key corridors in cities and as part of larger, integrated public transport systems.

High-capacity public transport systems are strategic in shaping urban form, promoting higher densities as well as mixed and accessible land use. Such modes reduce the need for trips by private motorized travel, and may thus reduce the total kilometres travelled in cars and motorcycles, mitigating negative externalities such as air pollution, road traffic accidents, lack of physical activity, noise and greenhouse gas emissions. They are also important in providing inclusive access for vulnerable and low-income groups, and in creating jobs.

In the urban planning dialogue, opinions regarding metro, light rail and BRT are diversified, with arguments in favour of and against each mode.[2] In this chapter, these three modes are explored, demonstrating the importance of undertaking comprehensive evaluations that consider all significant benefits and costs of high-capacity public transport systems, prior to implementation. The chapter also presents an overview of current global conditions and trends, including some challenges: service quality, integration, finance and institutions. The chapter concludes with key policy recommendations.

MAIN CHARACTERISTICS OF METRO, LIGHT RAIL AND BRT SYSTEMS

Metro, light rail and BRT are all intended to provide fast, comfortable and cost-effective urban mobility in medium- to high-demand corridors. These modes of public transport, which use specific fixed or exclusive and separated tracks, have superior operating capacity and performance compared to unsegregated road-based transport such as buses, taxis and paratransit.[3] In principle, the introduction of metro, light rail and/or BRT can produce important benefits to a city: it can improve the efficiency of the urban economy by reducing travel cost and time; it can increase the level of city-centre activity, thereby enhancing agglomeration economies that are crucial for the prosperity of urban areas; and it can reduce road congestion, which would then provide various other economic and environmental benefits. In cities where these modes are dominant, they improve the access to opportunities and services, and may be beneficial to the urban poor in a number of ways.[4]

Metro

Metro is an urban electric transport system using rail tracks, exhibiting high capacity and a high frequency of service.[5] Independent from other vehicles, roads or pedestrian traffic, metros are designed for operations using tunnels, viaducts or at surface levels, but with physically separated infrastructure. In some parts of the world, the metro system is also known as underground, tube, subway, rapid rail or metropolitan railway.[6] With metros, carrying capacity of more than 30,000 passengers per hour per direction is possible.[7] Globally, metros have evolved as a major form of public transport, since the first underground railway opened in London in 1863.[8] Although metro systems are the most expensive urban public transport option, their high capacity and best performance (in terms of speed and number of passengers conveyed), make them invaluable parts of highly developed transport systems. Accordingly, metro systems require huge investments and are often implemented as the preferred option of large cities where demand justifies that high capital cost.[9]

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Light rail

The general term 'light rail' covers those systems whose role and performance lie between a conventional bus service and a metro

Light rail can be described as an electric rail-borne transport, and can be developed in stages to increase capacity and speed.[10] Through the provision of exclusive right-of-way lanes, light rail systems typically operate at the surface level with overhead electrical connectors, and may have high or low platform loading and multi- or single-car trains.[11] Often, segregation is introduced, or priority given to light rail at road junctions, in order to increase speed and service reliability. The general term 'light rail' covers those systems whose role and performance lie between a conventional bus service and a metro.[12] Light rail systems are therefore flexible and expandable. Historically, light rail systems evolved from the 'streetcars', 'trolleycars' or 'tramways' that started in the second half of the nineteenth century as horse-driven carts. With the advent of electricity, tramways became very popular around 1900 and most large cities in developed countries, as well as a few cities in developing countries, had tram systems. After the Second World War, many trams were removed from cities, although many were later modernized and reintroduced in the last part of the twentieth century, as an intermediate, flexible, lower cost public transport mode. Given the relatively high cost of light rail systems, they are often found in wealthy cities and in proximity to high-income developments.[13]

Bus rapid transit

BRT is a bus-based mode of public transport operating on exclusive right-of-way lanes at the surface level, although, in some cases, underpasses or tunnels are utilized to provide grade separation at intersections in dense city centres.[14] The term 'BRT' was initially coined in the US[15] and the first wide-scale development of BRT was implemented in Curitiba, Brazil, in 1982.[16] Other names for BRT are 'high-capacity bus system', 'high-quality bus system', 'metro-bus', 'surface metro', 'express bus system' and 'busway system'.[17] While the terms may vary from country to country, the basic premise is followed: a high-quality customer-oriented public transport that is fast, safe, comfortable, reliable and cost-effective. The best BRT systems flexibly combine stations, bus services, busways and information technologies into an integrated system with a strong identity.[18] Depending on the specific system design, BRT capital costs are 4–20 times lower than light rail systems, and 10–100 times lower than metro systems, with similar capacity and service level.[19]

Main physical characteristics, outputs and requirements

The main physical characteristics of metro, light rail and BRT systems are outlined in Table 3.1, while their outputs and requirements are presented in Table 3.2.

Table 3.1

Main physical characteristics of metro, light rail and BRT

Component	Metro	Light rail	BRT
Running ways	Rail tracks	Rail tracks	Roadway
Type of right of way	Underground/elevated/at-grade	Usually at-grade – some applications elevated or underground (tunnel)	Usually at-grade – some applications elevated or underground (tunnel)
Segregation from the rest of the traffic	Total segregation (no interference)	Usually longitudinal segregation (at grade intersections) – some applications with full segregation	Usually longitudinal segregation (at grade intersections) – some applications with full segregation
Type of vehicles	Trains (multi-car)	Trains (two to three cars) or single cars	Buses
Type of propulsion	Electric	Electric (few applications diesel)	Usually internal combustion engine (diesel, CNG) – some applications with hybrid transmission (diesel/CNG-electric) or electric trolleybuses
Stations	Level boarding	Level boarding or stairs	Level boarding
Payment collection	Off-board	Usually off-board	Off-board
Information technology systems	Signalling, control, user information, advanced ticketing (magnetic/ electronic cards)	Signalling, control, user information, advanced ticketing (magnetic/ electronic cards)	Control, user information, advanced ticketing (electronic cards)
Service plan	Simple; trains stopping at every station between terminals; few applications with express services or short loops	Simple; trains stopping at every station between terminals	From simple to very complex; combined services to multiple lines; express, local – some combined with direct services outside the corridor
User information	Very clear signage, static maps and dynamic systems	Very clear signage, static maps and dynamic systems	Very clear signage, static maps and dynamic systems
Image	Modern and attractive	Modern and attractive	Advanced as compared with standard buses

Notes: Characteristics for high performance metro, light rail and BRT; CNG = compressed natural gas.

Sources: Fouracre et al, 2003; Vuchic, 2007; Federal Transit Administration, 2009.

Table 3.2

Outputs and requirements for metro, light rail and BRT

	Metro	Light rail	BRT
Required roadway space	Low impact on existing roads	Two lanes (narrow 5–8 metres)	Two to four lanes of existing roads (7–15 metres)
Required station space	Large reservation space, especially during construction	Medium reservation space (3–6 metres wide platforms)	Medium reservation space (4–8 metres wide platforms)
Distance between stations	Medium to high (1 kilometre or more)	Short to medium (400 metres or more)	Short to medium (400 metres or more)
Flexibility	Low (trains operate on fixed tracks)	Low (trains operate on fixed tracks)	High (buses can be used inside and outside the busways)
Traffic impacts during operation	Reduce congestion (does not interfere with surface travel)	Variable (takes some space from traffic)	Variable (takes space, reduces traffic interference from buses)
Construction impacts	High (tunnel digging, elevated structures; longer time)	Low to medium (depending on type of construction)	Low to medium (depending on type of construction)
Potential to integrate with existing transport providers	Limited potential	Limited potential	Good potential
Maximum frequency	High (20–30 trains per hour)	High (20–30 trains per hour)	Very high (40–60 buses per hour per platform)
Reliability	High (no interference from other traffic, but could be affected by bunching)	Medium to high (depending on traffic interference)	Medium to high (depending on traffic interference and manual control)
Human safety	Fully segregated from road users, low risk of accidents	Segregated from traffic only, some risk to other road users	Largely segregated from traffic, some risk to other road users
Air pollution	No tailpipe emissions, power generation pollutants dependent on energy source and technologies used	No tailpipe emissions, power generation pollutants dependent on energy source and technologies used	Tailpipe emissions for internal combustion engine, depends on the engine, fuel and emission control technology
Noise	Low (depending on insulation)	Low to medium (depending on tracks)	High (internal combustion engine and rubber-roadway)
Greenhouse gas emissions	68–38 grams per passenger-kilometre	100–38 grams per passenger-kilometre	204–28 grams per passenger-kilometre
Passenger experience	Smooth ride, high comfort (depending on occupancy)	Smooth ride, high comfort (depending on occupancy)	Irregular ride (sudden acceleration and braking), medium comfort (depending on occupancy)

Sources: World Bank, 2002a; Halcrow Fox, 2000; Wright and Fjellstrom, 2003; Fouracre et al, 2003; ADB, 2010b; Demographia, 2005.

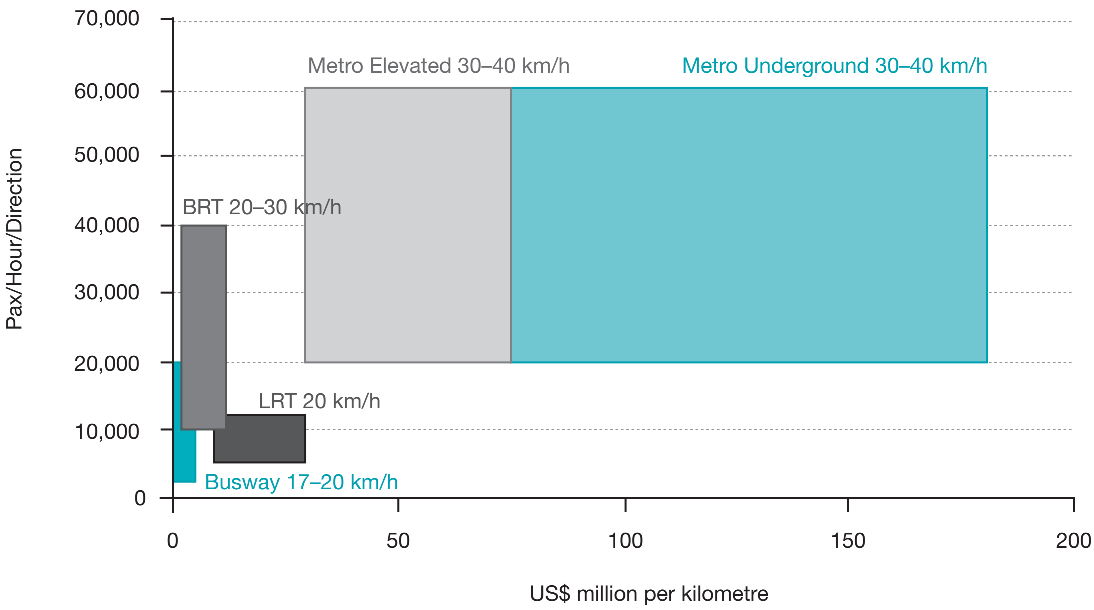

Figure 3.1

Initial cost versus capacity and speed

Note: LRT = light rail.

Source: Hidalgo, 2007.

Metro and light rail systems produce little noise, have low emissions of air pollutants (including greenhouse gases) and have high reliability. In addition, metro systems do not use limited road space on the surface, thus ensuring a consistently reliable and high-quality service. Nevertheless, metro and light rail systems have limited flexibility and require bus or intermediate public transport feeder services for last-kilometre connectivity. Furthermore, the distance between stations is usually higher in metros than in light rail and BRT in order to enable higher travel speeds. While this speeds up long distance commutes, it also requires longer distances for passengers to access stations.

The key variables for evaluating high-capacity public transport systems include capacity, commercial speed and cost

The key variables for evaluating high-capacity public transport systems include capacity, commercial speed and cost. Figure 3.1 indicates that BRT can provide high-capacity services – similar to that of metros and higher than that of light rail systems – at a fraction of their capital costs.[20] While commercial speeds delivered by BRT and light rail systems are usually lower than metros, some BRT systems reach significantly higher speeds than light rail (when using express services or fully separated facilities in expressways). It is also important to note that while elevated and underground metro systems average similar capacities, their initial costs of construction vary greatly (Figure 3.1). A more detailed discussion of construction and operating costs for the various transport modes can be found in Chapter 8.

EXAMPLES OF NATIONAL POLICIES TOWARD HIGH-CAPACITY PUBLIC TRANSPORT IN DEVELOPING COUNTRIES

In the last 15 years, several developing-country cities have started implementing BRT systems, and some have initiated or expanded light rail and metros

Rail-based public transport systems have been a natural part of the development of urban infrastructure in developed countries' cities. However, cities in developing countries have struggled in this respect due to financial and institutional limitations. Nevertheless, in the last 15 years, several developing-country cities have started implementing BRT systems, and some have initiated or expanded light rail and metros. Furthermore, national governments are co-financing public transport infrastructure in order to support the large proportion of the population now living in urban areas, including considerations of energy security, economic efficiency and climate change. This section provides examples from selected developing countries that have introduced national policies to support high-capacity urban public transport systems.

China

In 2011, the Government of China, through the Ministry of Transport, introduced the 'public transport city' project to improve the service level of urban public transport and alleviate traffic congestion in Chinese cities. Supported by the Ministry of Transport, the demonstration projects (in 30 selected cities) will include the construction of public transport hubs, implementation of 'intelligent transport systems', energy conservation and emission reduction practices in public transport. Additional financial support for the demonstration projects will be provided at the national level and co-financed by provincial governments.

As a result of the national support, several Chinese cities have started the construction or expanded their public transport networks in the form of metro, light rail and BRT systems. Beijing, for instance, is implementing a very ambitious rail expansion programme. In 2012, the Beijing metro had 16 lines, with 442 kilometres of track length and 251 stations, becoming the longest metro network in the world.[21] Expansion plans call for 708 kilometres of track in operation by 2015 and 1050 kilometres by 2020.

A number of other Chinese cities are also expanding their metro systems, namely: Hong Kong, Tianjin, Shanghai, Guangzhou, Dalian, Wuhan, Shenzhen, Chongqing, Nanjing, Shenyang, Chengdu, Guangfo, Xi'an, Suzhou, Kunming and Hangzhou. In addition, there are currently 18 cities with metro and light rail systems under construction, and a further 22 cities where construction is either being planned or pending approval. With respect to BRT, a total of 15 Chinese cities had operational systems, while another 11 systems were either under construction or at the planning stage by 2012.

India

In 2005, the Government of India created the US$20 billion Jawaharlal Nehru National Urban Renewal Mission (JnNURM) to fund urban infrastructure improvements and basic services to the urban poor in 65 cities for the 2005–2011 period.[22] It is expected that the programme will be renewed in 2013, as part of the sixth five-year plan.

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With financial and technical assistance from the national, state and local governments, the cities of Kolkata, Chennai, Delhi and Bangalore currently have operational metro systems. Encouraged by Delhi's success, six other Indian cities have metro systems under construction, while metro systems in another eleven cities are in various planning stages. In Delhi, where metro operations commenced in 2002, there are currently 193 kilometres of metro tracks (with 145 stations). Expansion plans include another 140 kilometres (approved) and 139 kilometres (proposed) for a total network of 472 kilometres to be completed by 2021.[23]

In addition to the various metro systems under construction, busways exist in Delhi, Pune and Jaipur, while Ahmedabad has a fully operational BRT system (75 kilometres long, with additional 80 kilometres under construction or being planned). Furthermore, BRT systems are currently being introduced in the cities of Rajkot, Surat, Indore, Hyderabad, Pimpri-Chinchwad, Visakapatnam and Bhopal. Another eight cities are planning the introduction of BRT systems.

Brazil

The Government of Brazil is responsible for promoting improvements in public urban transport. As a result, every city with more than 20,000 inhabitants (i.e. some 1600 cities) is required to develop a mobility master plan linked to its urban development plans. The National Policy on Urban Mobility gives priority to non-motorized transport and public transportation, over private motorized transport. It also seeks to limit or restrict motor vehicle use in a given geographic area or during a specific time period. Other measures sought by the policy to reduce traffic congestion and air pollution include establishing congestion and pollution tolls, as well as emission standards for air pollutants.

To support investment in public transport, the federal government created two programmes 'Pro-transporte' and 'Growth Acceleration Programme', in preparation for the 2014 FIFA World Cup and the 2016 Summer Olympic Games. Projects include BRT lanes in 9 of the 12 cities that will host World Cup matches, including Rio de Janeiro and Belo Horizonte. In four cities, including São Paulo and Brasília, light rail systems such as monorails and trams are being built, with another five cities planning the adoption of the same. Currently, there are eight cities with metro: Belo Horizonte, Brasília, Porto Alegre, Fortaleza, Recife, Rio de Janeiro, São Paulo and Teresina.

Inspired by the bus lanes implemented in Curitiba in the 1970s, 31 cities in Brazil currently have BRT systems or bus ways, totalling 696 kilometres. Most of the already existing busway corridors in Brazil need renovation and the BRT systems offer the opportunity of increasing public transport productivity, while overcoming the problems generated by the multiple superimposed radial routes, converging to terminals located at city centres. Several cities – including Belo Horizonte, Porto Alegre, Salvador, Brasília and Belém – are currently upgrading some sections of existing busways to BRT standards.

Mexico

In 2008, the Government of Mexico created the PROTRAM (Federal Support Programme for Public Transport), to improve urban transport efficiency and to reduce urban greenhouse gas emissions. To date, PROTRAM has given financial support to 11 BRT systems and 1 suburban rail system. Other pipeline projects in 34 cities are earmarked for funding from this programme, which provides both grants and credits.

Mexico has a metro system in its capital Mexico City; light rail systems in Guadalajara and Monterrey; and BRT systems in León, Mexico City, Guadalajara, Ecatepec and Monterrey.

Kenya

In 2009, the Government of Kenya launched the Integrated National Transport Policy, which seeks to establish appropriate institutional and regulatory frameworks to coordinate and harmonize the management and provision of passenger transport services. Among the policy recommendations is the establishment of independent institutions to manage urban passenger transport services and operations.[24]

The policy further envisions increasing use of high-capacity public transport through the provision of railway infrastructure for Nairobi and its environs. Consequently, the government opened the Syokimau Railway station in the suburbs of Nairobi in 2012. The railway service from this station to the city centre has reduced travel time by half over the 18-kilometre journey. Furthermore, authorities have also ensured that the railway is integrated with other modes, as *last-mile* link buses have been introduced to boost the city commuter train service.[25]

The transport policy also envisages the provision of infrastructure to support public transport services, i.e. bus lanes, promotion (through fiscal incentives) of high-occupancy public transport vehicles and discouraging private motor vehicle use once the public transport system is efficient.[26] In 2012, the Government of Kenya, supported by the World Bank, launched the National Urban Transport Improvement Project (NUTRIP) to support the development of selected high-capacity public transport corridors.[27]

Inspired by the bus lanes implemented in Curitiba in the 1970s, 31 cities in Brazil currently have BRT systems or bus ways, totalling 696 kilometres

Morocco

The Government of Morocco has embarked on reforming the transport sector along three main pillars: improving the sector's governance; improving the efficiency and developing the supply of urban transport services and infrastructure; and improving the environmental and social sustainability of urban transport.[28] Significant investments have been made towards light rail systems in the cities of Casablanca and Rabat-Salé. Commissioned in 2011, the tramway line between Rabat and Salé consists of 44 trams, with an expected daily ridership of 180,000 passengers. The total length of the dual-line tramway network is 19.5 kilometres and consists of 31 stations that are spaced a half kilometre apart.[29]

In Casablanca, the tramway development company acquired 74 trams for the 31 kilometres Y-shaped network, which commenced operations in 2012. The line has 48 stops and has an expected daily ridership of 255,000 passengers.[30]

Nigeria

Nigeria's 2010 National Transport Policy seeks to develop an efficient, self-sustaining and reliable public transport system, and to improve the infrastructure and institutional framework for public transport service delivery. It also aims to enhance the capacity of the existing infrastructure through proper maintenance of roadways and efficient traffic management. Furthermore, it calls for the substantial expansion of urban infrastructure, with emphasis on public transport infrastructure – railway, dedicated bus routes, etc.[31]

The rapid increase in the number of rail-based systems is an indication of the importance of metros in facilitating mobility, particularly in large urban areas that are beyond city limits

The policy envisions the introduction of a high-capacity bus-based transport system that can be accommodated by the existing infrastructure. Already there are dedicated bus routes in Lagos, where a BRT is being implemented. The policy also aims to promote private sector participation in urban public transport services and in the long-term introduce rapid rail systems into the country's major cities.

To advance the efficiency of urban transport system operations and management, an autonomous body – the Municipal Transportation Agency – will be established in each major city. The task of these agencies will be, *inter alia*, the regulation, planning, designing and maintenance of urban transport infrastructure facilities.

South Africa

Asian cities account for the largest share of metro ridership, totalling more than 51 million riders a day

In South Africa, the Public Transport Strategy aims to improve public transport by establishing an integrated rapid public transport network that comprises of an integrated package of rapid rail and road corridors. Through BRT, the government aims to link different parts of a city into a network and ensure that by 2020, most city residents are no more than 500 metres away from a BRT station.[32] The BRT systems are being implemented through public–private partnerships, whereby cities build and maintain the infrastructure for the operation of the buses, stations, depots, control centres and a fare collection system. Private operators, by contrast, own and manage the buses, hire staff and provide services on a long-term contract.

In Johannesburg, the Rea Vaya BRT is being implemented in phases across in the city since 2009. Notably, the first trunk route running between Ellis Park in Doornfontein and Thokoza Park in Soweto has been completed. The long-term plan is for the Rea Vaya route to cover 330 kilometres, allowing more than 80 per cent of Johannesburg's residents to catch a bus within 500 metres from a BRT station.[33] In addition to Johannesburg's BRT system, Cape Town also has a BRT system known as MyCiTi,[34] while Tshwane is implementing Tshwane BRT that will cover some 80 kilometres of bus lines.[35]

The Gauteng Provincial Government has implemented Gautrain, which is South Africa's first high-speed passenger railway line, connecting OR Tambo International Airport with the cities of Johannesburg and Pretoria. The 80-kilometre high-speed passenger railway network comprises of two routes: the north–south line connecting Pretoria and Hatfield Johannesburg; and an east–west line from Sandton to the airport, which is supported by a network of feeder buses serving most of its ten stations.

METRO SYSTEMS AROUND THE WORLD: TRENDS AND CONDITIONS

Due to government stimulus programmes in the wake of the global financial crisis, the world market for railway infrastructure and equipment has been growing at 3.2 per cent a year, and is set to grow at around 2.7 per cent annually until 2017. Spending on metro rail systems should grow faster still, at perhaps 6–8 per cent.[36] Figure 3.2 shows the growth of metro rail systems around the world in terms of the number of cities with operational systems.[37] By 1970, there were a total of 40 cities worldwide with metro systems, followed by a rapid increase during the next four decades. Currently, there are 187 cities with a metro system as part of their public transport system.[38] Box 3.1 provides an overview of the growth of metros across the world. The rapid increase in the number of rail-based systems is an indication of the importance of metros in facilitating mobility, particularly in large urban areas that are beyond city limits. Notably, metros are less prone to congestion than roadways and are important to those residing in peripheral locations, as they commute long distances to employment centres and other activity nodes.[39]

The global distribution of metro systems in Figure 3.3 shows a concentration of metros in Europe, Eastern Asia and the eastern part of the US. The regional distribution in terms of number of cities and ridership is presented in Table 3.3. Asian cities account for the largest share of metro ridership, totalling more than 51 million riders a day. In terms of total track length of metros, Asian cities account

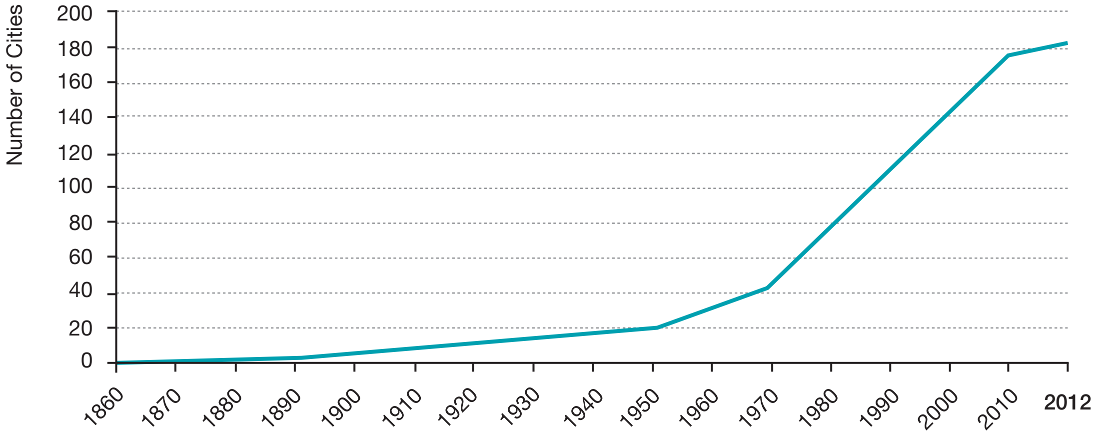


Figure 3.2

Growth of metro systems worldwide

Source: Based on Metrobits, 2012.

Box 3.1 The growth of metros around the world

The building of metro systems accelerated from the 1960s, mainly in reaction to the growth of sprawling mega-metropolises around the world. Currently, 187 cities have metros, with more to come amid a fresh spurt of construction in developing countries. In 2012, the Chinese cities of Suzhou, Kunming and Hangzhou opened their metros, as did the city of Lima in Peru. In 2011, Algiers (Algeria) was the second African capital to launch a metro system.

Whereas China's investment in high-speed intercity railways is tailing off, evidence suggests that it is still pumping money into metros. So is India: Bangalore's metro was launched in 2011, which will soon be followed by Mumbai. Smaller cities, such as Bhopal and Jaipur, have plans on the drawing-board. Brazil is expanding metro systems in its two main cities, Rio de Janeiro and São Paulo, while building new ones in smaller cities such as Salvador and Cuiabá.

Metros are being built in various smaller cities, such as in Dubai, where the world's longest driverless metro (75 kilometres) became operational in 2009; followed by Mecca's in 2010. Abu Dhabi, Doha, Bahrain, Riyadh and Kuwait City have plans in progress. Other cities planning to build metros include Asunción in Paraguay and Kathmandu in Nepal.

Many congested cities in developing countries have spent years planning metro systems. However, very little progress has been made towards implementation. A prime example is Algeria's 1991–2002 civil war that accounts for the long gestation period of its capital's metro. In other cases, sluggish (and sometimes corrupt) bureaucracies are the main obstacle. In 2008, Indonesia's traffic-choked capital, Jakarta, abandoned its attempt to build a monorail and built a successful busway as a stopgap instead. Since then, the city's governor has promised to commence work on an underground metro.

Source: Economist, 2013.

for 41 per cent. European cities also depend heavily on metro systems for urban mobility, accounting for more than 38 million daily riders or 34 per cent of global ridership, and 35 per cent of global track length. This is followed by Latin America and the Caribbean, as well as North American cities that account for 11.5 per cent and 8.6 per cent of the world's metro ridership, respectively. The two African cities that have metros – Algiers and Cairo – have a daily ridership of 2.2 million passengers or 2 per cent of global ridership.

Table 3.4 lists the world's major metro systems – i.e. those with an average daily ridership of more than 2 million passengers per day. Six of these 16 systems are in cities in developing countries, while the rest are in developed countries. The world's largest or most used metro systems are Tokyo (Japan), Seoul (Republic of Korea) and Beijing (China) with

Table 3.3

Metro systems by region

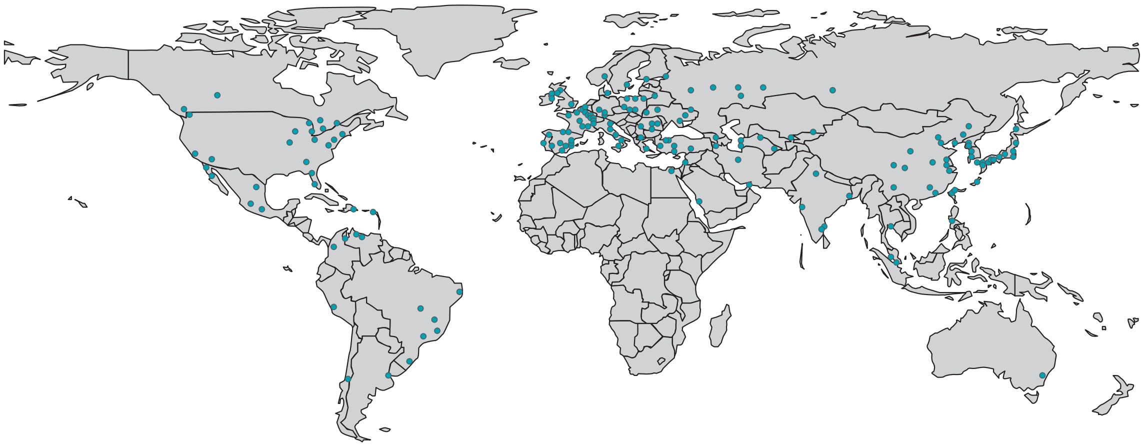
Region	Cities	Length (km)	Average daily ridership (millions)	Share of global daily ridership (%)
Africa	2	75	2.2	2.0
Asia	58	4279	51.0	45.7
Europe	80	3638	38.2	34.3
Latin America and the Caribbean	17	828	11.5	10.3
North America	24	1601	8.6	7.7
Total	**181**	**10,421**	**111.5**	**100.0**

Source: Metrobits, 2012.

Figure 3.3

Metro systems around the world

Source: Based on data from http://mic-ro.com/metro/table.html, last accessed 5 June 2013.



The world's largest or most used metro systems are Tokyo (Japan), Seoul (Republic of Korea) and Beijing (China) with 8.5 million, 6.9 million and 6.7 million passengers per day, respectively

8.5 million, 6.9 million and 6.7 million passengers per day, respectively. In Tokyo, Japan, the modal share of public transport is nearly 80 per cent of all motorized trips, with the metro accounting for a significant proportion.[40] In Shanghai, China, top priority has been given to the extension of the city's subway with the opening of six additional lines in 2010, and a planned four-fold increase of the current 423 kilometres of track length by 2020.[41] In 2007, the city's metro accounted for 13 per cent of its total public transport; and with further investment this was expected to increase to 45 per cent by 2012, thus reducing the dependence on private cars.

Several developing-country cities, particularly in China, have been able to expand their metro networks in a short time. For instance, Beijing, which has one of the two most developed subway systems in China, has the highest use of public transport in the country.[42] Since 2005, Beijing has allocated 30 per cent of its public construction budget to its public transport system, including its metro. Whereas Beijing's public transport system is strong by Chinese standards, its citizens do not utilize public transportation as much as the residents of other cities, such as Seoul (Republic of Korea) and Tokyo (Japan). As a result, the emission of air pollutants from mobile sources remains one of the government's most urgent challenges.

Since its launch in 1987, the metro system in Cairo, Egypt, has gradually been expanded and the total track length now measures 90 kilometres.[43] Likewise, the metro's modal share of all trips has increased steadily from 6 per cent just after the launch to 17 per cent in 2001. The total number of passengers using the metro has continued to increase, from 2 million per day in 2001 to more than 3 million in 2012, partly due to its relatively affordable fares.[44]

A comparison between metro systems worldwide reveals certain trends. First, a majority of these cities have very large populations. For instance, Tokyo's

Table 3.4

Metro systems with average daily ridership of more than 2 million passengers per day

Rank	City, Country	Initial year	Length (km)	Stations	Average daily ridership (millions)
1	Tokyo, Japan	1927	305	290	8.50
2	Seoul, Republic of Korea	1974	327	303	6.90
3	Beijing, China	1969	442	252	6.74
4	Moscow, Russia	1935	309	187	6.55
5	Shanghai, China	1995	437	279	6.24
6	Guangzhou, China	1999	232	146	5.00
7	New York, US	1904	368	468	4.53
8	Mexico City, Mexico	1969	180	175	4.41
9	Paris, France	1900	218	383	4.18
10	Hong Kong, China	1979	175	95	3.96
11	London, UK	1863	402	270	3.21
12	Cairo, Egypt	1987	90	55	3.00
13	São Paulo, Brazil	1974	74	67	2.40
14	Osaka, Japan	1933	138	133	2.29
15	Singapore	1987	147	100	2.18
16	Saint Petersburg, Russia	1955	110	65	2.15

Sources: Metrobits, 2012; Huzayyin and Salem, 2013 (Cairo).

Box 3.2 Metros, urban structure and land use

The integration of metro systems within the urban fabric makes some important demands on the planning system. Rights-of-way must be established and protected. Space must be released for depots and terminals. In addition, where high-density ancillary developments are intended, the land must be assembled into lots suitable for development and the appropriate densities of development sanctioned.

The most indisputable structuring effect of metros is that they allow central business districts in large dynamic cities to continue growing, where service by road, either by car or bus, would be increasingly frustrated by congestion. Without the high-capacity links, activities would begin to be decentralized. This has implications both for city planning and for project evaluation. A conscious attempt to maintain the growth of the city centre will save on public infrastructure costs in other areas; avoiding these extra costs is an important part of the long-term benefit of metro investments.

Unfortunately, the magnitude of those savings is little researched, particularly in developing countries, and the economic evaluation of metro investments is usually based on the more conventional user cost–benefit appraisal. While that may still be justifiable, in the interest of avoiding the worst kind of 'white elephants', a more wide-ranging multi-criteria analysis may be the most suitable way of ensuring that those unmeasured effects are taken into consideration. An integrated land use, urban transport and air quality strategy, such as the Integrated Urban Transport Plan in São Paulo, is needed to ensure that the metro system is adequately inserted in the urban structure.

Obtaining desirable structuring effects outside the city centre is more difficult. Clustered multi-nuclear development associated with station locations sometimes occurs spontaneously, but normally requires either some planning by government (as in the cases of Singapore and Hong Kong, China) or close links between private ownership of the metro system and contiguous developments (as is common in Japan). In both cases, this requires land to be assembled for development in relatively large lots. This has been achieved by comprehensive public ownership of land in Hong Kong, by compulsory public purchase in Singapore and through market mechanisms in some Japanese private railway developments.

Source: World Bank, 2002a.

metro has the largest ridership in the world, and is located in the world's most populous urban agglomeration (with some 37 million inhabitants[45]). Similarly, major urban agglomerations such as New York and Mexico City, each with an estimated population of more than 20 million have metro systems that carry 4.5 million passengers daily. Being large also implies that metro cities are often the most fiscally sound, while small municipalities lack economies of scale necessary to construct and operate metros. Some of the links between metro systems and urban structure are highlighted in Box 3.2, and further explored in Chapter 5.

Second, urban areas with metro systems have often extended or grown beyond their established boundaries, engulfing surrounding areas, adjacent towns and sometimes into different provinces. For instance, Mexico City has encroached upon municipalities in two states. Tokyo (Japan), which has the world's largest metro system, has 75 per cent of its estimated 37.2 million population living in suburban areas.[46] In China, Shanghai encompasses a mega-urban region occupying an area of over 6340 square kilometres, with the Beijing mega-urban region extending over 16,870 square kilometres.[47] This implies that the governance of metro systems has to go beyond the traditional city limits. The metropolitization of neighbouring districts, municipalities and cities through cross-boundary institutions offers significant benefits in terms of efficiency, construction and operation costs, including creating economic synergies among newly connected areas. This is discussed in more detail in Chapter 9.

Third, many of the cities with metro systems are either capital cities or large cities in their respective countries. Capital cities account for 9 of the 16 cities with the world's largest metro systems (Table 3.4), and 27 per cent of all cities with metros. The rest are major cities. For instance, in China, Japan and Germany, besides the capital cities, 15, 12 and 18 cities in these countries respectively have metros. Being the national capital or major city can determine the extent to which countries invest in metro systems. This is because apart from generating more revenue, capital or large cities dominate the system of settlements and perform major administrative, commercial, diplomatic, financial and industrial functions. In order to perform these functions effectively, capitals and other large cities need an efficient and integrated public transport system that includes metros.

Urban areas with metro systems have often extended or grown beyond their established boundaries, engulfing surrounding areas, adjacent towns and sometimes into different provinces

LIGHT RAIL SYSTEMS AROUND THE WORLD: TRENDS AND CONDITIONS

Light rail is a flexible concept that evolved from the nineteenth century horse-driven rail carts.[48] The re-emergence as an alternative means of transport to cars or buses was due to its potential to mitigate congestion and support mobility in urban centres.

In 2013, there are approximately 400 light rail and tram systems in operation worldwide

The last two decades have seen several European cities either overhauling or implementing new light rail and tram systems as a cornerstone of their redevelopment efforts

As of mid-2013, there were 156 cities worldwide with BRT and bus corridors

Light rail systems have proliferated in both developed and developing countries in the last decades. Among European countries, light rail systems have been particularly evident in the UK, France, Spain, Portugal and Italy. These countries have successfully improved the quality of service and the image of the light rail system at affordable costs. Consequently, the last 20 years have seen many cities in Asia, Africa and Latin America reintroduce light rail systems.

In 2013, there are approximately 400 light rail and tram systems in operation worldwide, while construction of additional systems is ongoing in a further 60 cities. An additional 200 light rail systems are either being constructed or at various planning stages.[49] There is a strong concentration of light rail systems in Western Europe (170 systems) and in the US (more than 30 systems). Eastern Europe and Central Asian countries also have a fair concentration of light rail systems. The growing popularity of light rail systems can be attributed to their ability to provide significant transport capacity, without the expense and density needed for metro systems.[50] Several African countries have developed light rail systems such as Algeria, Egypt and Tunisia. In Algiers (Algeria), the tramway commenced service in 2010. When fully completed and operational, the tramway is expected to carry between 150,000 and 185,000 passengers per day.[51] In addition, the Oran tramway was launched in May 2013. The Oran tramway is 18.7 km long and can carry 90,000 passengers per day.[52] A number of other African countries have light rail projects in the pipeline. Ethiopia, for instance, is implementing a light rail project in Addis Ababa, covering a distance of 34 kilometres.[53] Furthermore, Mauritius is scheduled to commence work on a light rail system in 2014, covering a 28-kilometre corridor between the cities of Curepipe and St Louis.[54]

Globally, light rail systems are challenged by ageing or obsolete assets, as well as the increasing popularity of the private car. As a result, transport authorities in many cities are rejuvenating their existing light rail infrastructure or constructing completely new systems. Increased environmental consciousness and soaring fuel costs are also motivating more and more people to opt for public transport. As indicated in Table 3.5, the leading light rail systems in the world (in terms of ridership) are in Hong Kong and Manila.

Table 3.5

Top ten light rail and tram systems by ridership

City	Country	Passengers per day
Hong Kong	China	617,000
Manila	Philippines	604,822
Bochum-Gelsenkirchen	Germany	392,877
Dortmund	Germany	356,164
Istanbul	Turkey	315,000
Frankfurt/Main	Germany	310,000
Essen	Germany	306,616
Kuala Lumpur	Malaysia	300,301
Calgary	Canada	276,000
Boston	US	219,084

Source: Compiled from several sources.

The last two decades have seen several European cities either overhauling or implementing new light rail and tram systems as a cornerstone of their redevelopment efforts. For example, trams are part of the transformation of 24 French cities, including Nantes, Grenoble, Bordeaux, Clermont-Ferrand and Marseille. Other cities such as Lille and Lyon, Caen, Brest, Nancy and Toulon are advancing planning efforts. The tram networks in France are expected to reach a total track length of 610 kilometres by 2015.[55] Even cities without light rail, such as Astana, Kazakhstan, have reached advanced stages with plans for the implementation of light rail.[56]

An expansion of tram networks is evident in other European cities. A study shows that 40 cities and municipalities in the 15 EU countries had a total length of 488 kilometres under construction in 2009. A further 55 cities and municipalities had planned 1086 kilometres of network developments: 268 kilometres for new systems and 818 kilometres for expansions.[57]

Light rail systems are beneficial for their technology and low emissions, and are also seen as symbols of national pride. Mayors such as Samuel-Weis from the French city of Mulhouse have indicated: 'We wanted a tram that called attention to itself, as a symbol of economic vitality, environmental awareness and civic improvement – transportation as an integrated cultural concept'.[58]

BRT SYSTEMS AROUND THE WORLD: TRENDS AND CONDITIONS

Compared to metro and light rail systems, BRT is a relatively recent phenomenon, starting with the implementation of the first busway in Curitiba (Brazil) in the early 1970s.[59] However, bus priority measures were in place years before the Curitiba BRT system was implemented. Since then, there has been a worldwide increase in the adoption of BRT systems. As of mid-2013, there were 156 cities worldwide with BRT and bus corridors; most of them implemented in the last decade (Figure 3.4).[60]

Since BRT and metro systems are both rapid public transport systems, a comparison of their growth and performance is inevitable. BRT systems are concentrated in Latin America and the Caribbean (64 per cent of global ridership) and Asia (27 per cent) (Table 3.6 and Figure 3.5). The total ridership for BRT – 25.7 million passengers per day – is only 23 per cent of the ridership of metro systems. In terms of system lengths, however, BRT systems cover a total

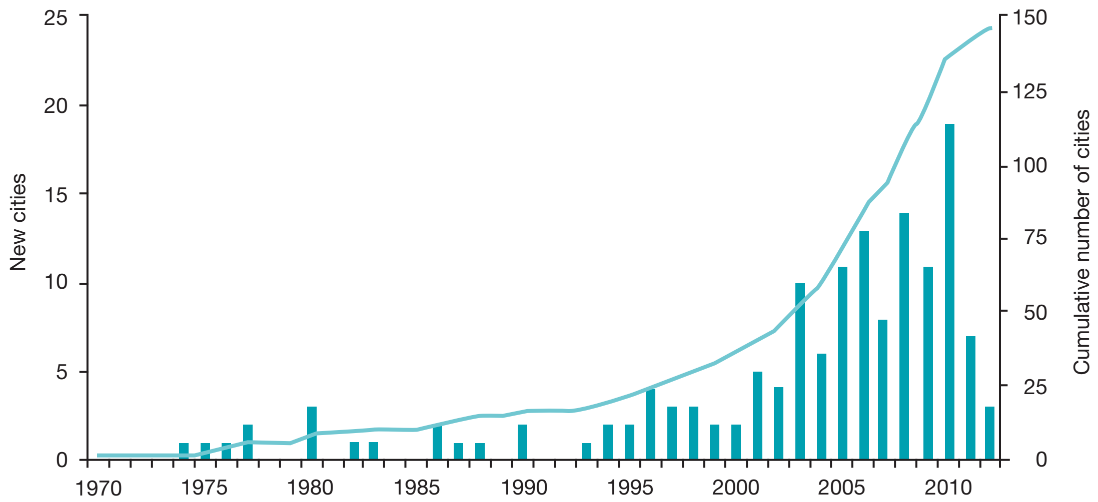


Figure 3.4

Evolution of BRT – Number of new cities each year and cumulative number of cities with operational BRT systems (1970–2012)

Source: Based on Hidalgo, 2012.

of 4072 kilometres,[61] or almost 40 per cent of the total length of all the world's metro systems.

The major BRT systems in the world – i.e. those with a ridership of over 300,000 passengers per day – are listed in Table 3.7. BRT systems are not yet comparable to metro systems in terms of their total track length and daily demand; the longest metro system (Beijing) is 3.3 times longer than the longest BRT system (Jakarta), while the most popular (in terms of daily ridership) (London) carries four times more passengers than the most used BRT (São Paulo).

In Bogotá, Colombia, the TransMilenio BRT provides fast and reliable transport for over 1.8 million passengers per day and in the process reduces traffic congestion.[62] Travel time has been reduced by 34 per cent and traffic fatalities by 88 per cent. In the case of Curitiba (Brazil), 70 per cent of commuters use the BRT to travel to work, thus resulting in a reduction of 27 million auto trips per year.[63] When compared with eight other Brazilian cities of similar size, Curitiba uses 30 per cent less fuel per capita. This helps achieve air quality and other environmental goals. By making high-capacity public transport more accessible, affordable and customer friendly, BRT has the potential to increase overall public transport ridership. In Curitiba, the BRT serves over 1.3 million passengers daily with commuters spending about 10 per cent of their income on transport – much less than the national average.[64]

In Bogotá, Colombia, the TransMilenio BRT provides fast and reliable transport for over 1.8 million passengers per day and in the process reduces traffic congestion

Recently, African cities have made remarkable strides in developing BRT as part of their public transport systems. In 2008, Lagos (Nigeria) launched a BRT 'lite' corridor (a high-quality system that is affordable in the local context, while retaining as many of the desirable BRT characteristics as possible). This marked the first substantial investment in public transport for the city. The system was launched with a 22-kilometre route, 26 stations and 220 high-capacity buses, and it was designed to carry 60,000 passengers a day. By 2010, it was carrying 220,000 passengers per day, with more than 100 million person-trips being made in the first 21 months of operation. The 'lite' version of BRT halves the costs (about US$2.75 million per kilometre), however, capacity is limited as it uses kerb-aligned busways (not median-aligned busways) and the total route is not on a separated busway. As such, the overall speed (and capacity) of the BRT system is reduced.[65]

The Lagos BRT has brought about many positive changes.[66] Since its implementation, over 200,000 commuters use this bus system daily, with passengers enjoying a 30 per cent decrease in average

Table 3.6

Current state of BRT systems around the world (mid-2013)

Region	Number of cities with BRT	Number of corridors	Total length (km)	Average daily ridership (million)	Share of average global daily ridership (%)
Africa	3	3	62	0.2	0.9
Asia	31	77	1097	7.0	27.2
Europe	42	75	704	0.9	3.6
Latin America and the Caribbean	53	163	1368	16.3	63.6
North America	20	39	584	0.8	3.3
Oceania	7	12	328	0.3	1.3
Total	**156**	**369**	**4143**	**25.7**	**100.0**

Source: Based on data from brtdata.org, last accessed 6 June 2013.

Figure 3.5

BRT systems around the world, number of cities and system lengths (mid-2013)

Source: Based on data from brtdata.org, last accessed 5 June 2013; and Hidalgo, 2012.

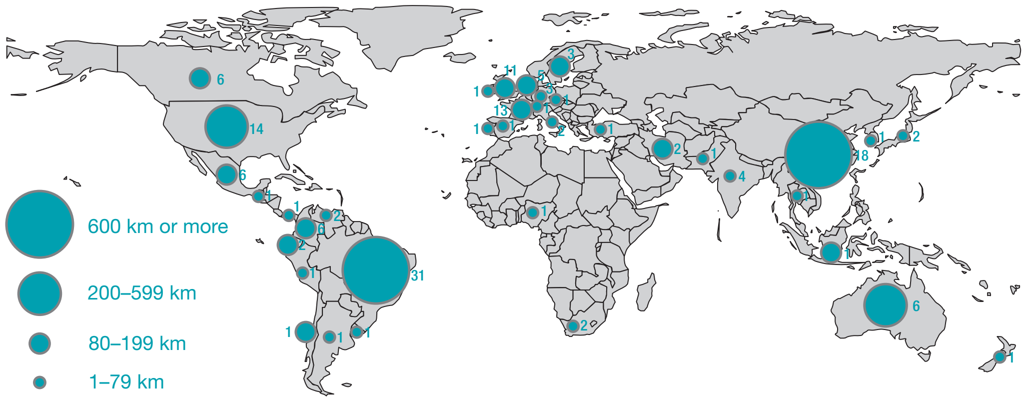


Table 3.7

The world's major BRT systems

City, country	Length (km)	Stations	Average daily ridership (million)	Type
São Paulo, Brazil	122	205	2.1	Open
Bogotá, Colombia	106	135	1.8	Closed
Rio de Janeiro, Brazil	63	70	1.6	Open
Tehran, Iran	91	114	1.4	Closed
Belo Horizonte, Brazil	24	16	1.3	Open
Taipei, China	60	150	1.2	Open
Recife, Brazil	11	25	0.9	Open
Guangzhou, China	22	26	0.8	Open
Mexico DF, Mexico	95	147	0.8	Closed
Istanbul, Turkey	42	32	0.6	Closed
Curitiba, Brazil	81	113	0.5	Closed
Jakarta, Indonesia	134	145	0.3	Closed

Note: In open systems the buses come from outside and continue in the busway, in closed systems the buses stay only in the busway (connection through feeder services). The Jakarta system uses central closed busways in arterials that also carry bus routes in the general traffic; as a result the demand for BRT services is lower than in other systems where the service is exclusive.

Source: Hidalgo, 2012.

fares. Furthermore, commuters have been able to reduce their travel time by 40 per cent and waiting time by 35 per cent, and experience safe, clean and reliable transport. Other significant socioeconomic benefits include the creation of direct employment for 1000 people and indirect employment for over 500,000 people. The Lagos BRT has demonstrated that local operators can run successful public transport systems.[67]

The success of the Lagos BRT can be attributed to the leadership and political commitment at all levels of government; and a capable, strategic public transport authority (LAMATA), a focus on user needs and deliverability within a budget and programme. Also core to the Lagos BRT success was a community engagement programme, which assured citizens that the BRT 'lite' system is a project created, owned and used by them.[68] This type of engagement was crucial, as Lagos residents had little experience with organized public transport. Due to a history of poor delivery of transport improvements – and with prior systems that sought to ensure that profit was directed to the already well-to-do – the community engagement sought to rid the residents of scepticism and suspicion of motives and intentions regarding the project.[69]

With the impetus from the 2010 World Cup, three South African cities (Johannesburg, Cape Town and Port Elizabeth) all initiated BRT lines. The Johannesburg Rea Vaya system was the first full BRT line in Africa (2009), operating on a 22-kilometre route, costing US$5.5 million per kilometre, travelling at 25 kilometres per hour and carrying 16,000 passengers daily. In 2011, the completed Phase 1 included 122 kilometres of busways and carried 434,000 passengers daily.[70]

In Johannesburg, the Rea Vaya BRT links the central business district with Braamfontein and Soweto, providing fast, reliable and affordable transport for 80,000 passengers per day, and in the process, reduces traffic congestion on that route.[71] In terms of employment, the Rea Vaya has created more than 800 permanent jobs and about 6840 temporary construction jobs.[72] Approximately 350 of these employees are recruited among taxi drivers who were affected by the launch and subsequent operation of the BRT system.[73] Transport authorities in Johannesburg paid special attention to ensuring that the Rea Vaya BRT was functional and attractive. This included pre-paid tickets; level boarding for full accessibility; multiple stopping bays; and weather-protected stations. Furthermore, the stations have been designed with the local urban environment in mind and local artists have been commissioned.[74]

Additional BRT schemes are being developed in Lagos, Nigeria, as well as the aforementioned South African cities. Similarly, other African cities are also investing in high-quality, efficient and environmentally clean transport. These include Accra (Ghana), Kampala (Uganda), Dar es Salaam (Tanzania), Nairobi (Kenya) and several other South African cities (Bloemfontein, Durban, East London, Pretoria, Ekurhuleni, Polokwane and Rustenburg). This demonstrates the increasing shift from informal public transport systems to high-technology BRT systems.[75]

MAIN CHALLENGES FACING HIGH-CAPACITY PUBLIC TRANSPORT SYSTEMS

Despite their growth, high-capacity public transport systems still face a number of challenges, especially in developing countries. This section discusses some of the main challenges, which include: integration (within the public transport system, with other modes and with the urban form); quality of service; finance; and institutions.

Integration within the public transport system

Integration occurs at three levels: physical, operational and fare. Physical integration allows for direct connections from one service to another, usually including transfer facilities and terminals. Operational integration consists of coordination of schedules and frequencies so that the service is guaranteed and wait times are not excessive. Fare integration involves free or reduced cost transfers, usually through advanced ticketing systems. Adequate integration requires the development of information systems to coordinate services and provide information to the users.

Most cities in developed countries have advanced integration at all three levels, either through the consolidation of a single public transport authority (e.g. Transport for London, UK, or the Land Transport Authority of Singapore), or the coordination of multiple agencies (Consórcio de Transportes de Madrid, Spain, or STIF in Paris, France). In contrast, most metro, light rail and BRT systems in developing countries are still evolving into integrated systems with the rest of the public transport system. In some cases, such as Bangkok's metro, Manila's light rail and Quito's BRT, different lines are not integrated with one another, requiring passengers to incur additional fares and walk long distances in order to connect between stations. This has proved to be a major disincentive to using the system. Some major cities have successfully integrated high-capacity public transport systems with the rest of the public transport systems in their cities. A descriptive list of these is presented in Table 3.8.

Despite their growth, high-capacity public transport systems still face a number of challenges, especially in developing countries

Integration with other elements of the transport system

Besides the integration between components of the public transport system, it is important to provide adequate connectivity with other components of the urban transport system, such as walking, biking, taxis, informal transport services, cars and motorcycles. These types of connections complement public transport systems, as feeder services, to provide door-to-door connectivity and allow for expanded coverage of the public transport system.

Most metro, light rail and BRT systems in developing countries are still evolving into integrated systems with the rest of the public transport system

Walking is usually the most common access mode to public transport and requires an adequate environment, with protected, well-lit, signalized and surfaced sidewalks. Design should consider the needs of the most vulnerable users: children, the elderly and people with disabilities. It is important to build these spaces according to good practices, but perhaps even more important is to keep such spaces clean and free of encroachments. Whereas the management of sidewalks is often outside the jurisdiction of public transport agencies, adequate coordination with the responsible agencies is important to ensure safe and pleasant travel for public transport passengers who are walking to and from the stations.

In Singapore for instance, adequate facilities are provided for pedestrians. An inventory of pedestrian facilities in Singapore shows that there are: 491 overhead bridges; 54 pedestrian underpasses; 26 footbridges; 24 kilometres of covered linkways; and 98,400 street lightings.[76] All these provide a safe and comfortable walking environment, which is unsurpassed in other Asian cities. Cyclists require two integration elements: infrastructure and safe parking. As discussed in Chapter 2, bike travel should be separated from the walking and the motor vehicle environment as much as possible – to protect pedestrians as well as cyclists. Furthermore, bike lanes should be wide enough to accommodate bike travel, with strong segregation from the car traffic.

It is important to provide adequate connectivity with other components of the urban transport system, such as walking, biking, taxis, informal transport services, cars and motorcycles

To ensure usability by cyclists, public transport vehicles should accommodate bikes inside the trains

Table 3.8

Examples of cities with infrastructure, information systems and payment elements that promote multi-modal connectivity

City	Authority/operator	Multi-modal infrastructure elements	Information systems	Integrated payment solution
London	Transport for London (TfL)	Metro; bus; bike-sharing; taxis; light rail; trams	iBus; Web and Mobile information systems	Oyster smart card
Paris	RATP; JCDecaux (bike-sharing)	Metro; tram; bus; bike-sharing	IMAGE project (real time traffic information)	Navigo pass
Singapore	Land Transport Authority	Metro; light rail; bus; taxis	Web-based and mobile (How2Go) information systems	EZ-Link; NETS FlashPay
Hong Kong	MTR Corporation (metro); private operators (bus services)	Metro; bus	Next Train mobile app; Passenger information display systems	Octopus smart card
Los Angeles	Los Angeles County Metropolitan Transportation Authority (LAMTA)	Metro; light rail; city bus; and BRT	NEXTRIP (NextBus technology)	Transit Access Pass (TAP) card
New York City	New York City MTA	Metro; BRT; local and express bus	MTA Bus Time	MetroCard
Mexico City	Metro: Mexico City Metro; BRT: Metrobus (buses run by private operators); Bike-sharing: Ecobici (operated by Clear Channel)	Metro; BRT; bike-sharing	Web-based passenger information system (mexicometro.org) for all modes	Metrobus Card
Guangzhou	Metro: Guangzhou Metro Corporation; BRT: Guangzhou Bus Rapid Transit Operation and Management Co.; Bike-sharing: Guangzhou Public Bicycle Operation and Management Co.	Metro; BRT; bike-sharing	Web-based and station-based passenger information systems	Yang Cheng Tong
Budapest	Budapesti Közlekedési Központ (Centre for Budapest Transport)	All public transport modes, roads and traffic management and parking	Centrally coordinated ticketing system with special cards and passes	Travel card 24h, Monthly/Annual pass, Students, Pensioners
Chicago	Chicago Transit Authority	Bus; metro; bike-sharing; car-sharing	BusTracker (real time bus information); TrainTracker (real time train information)	Chicago Card, Chicago Card Plus/I-Go card for integration of car-sharing with public transport

Note: Brand names mentioned for illustration purposes only.

Several cities . . . have been able to implement efficient public transport services and develop urban forms that are highly conducive to public transport ridership

or buses and/or provide adequate bike parking at stations. In high-capacity public transport systems, safe parking at the integration point is recommended.

Other mechanisms to provide last-kilometre connectivity are taxis, informal transport services and motor vehicle parking and pick-up or drop-off areas. In Nairobi, the Kenya Railways Corporation introduced *last-mile* link buses to convey passengers to and from the railway station in 2013.[77] The *last-mile* link shuttle services pick passengers from the surrounding areas and feed them into the Syokimau Railway Station, and thereafter drop them off at various points within the city centre. For this purpose, the Corporation has contracted a private firm to provide bus connections for rail transport users within the city centre.

At important integration points, especially in the periphery of cities, adequate space is needed for these mechanisms. This is to ensure that different types of users are able to connect to the public transport system and avoid using cars to go to the city centre.

Integration with the built environment

Accompanied by complementary land-use and zoning policies, high-capacity public transport systems can encourage compact, pedestrian and public-transport friendly environments that are integrated into the surrounding area. Several cities, such as Copenhagen (Denmark), Singapore and Curitiba (Brazil), have been able to implement efficient public transport services and develop urban forms that are highly conducive to public transport ridership.[78] In these cities, public transport and urban form function in harmony: either through mixed-use, compact and accessible development suited for public transport (also known as transit-oriented development), or through flexible public transport options suited to low-density urban development.

Singapore is planned as a public-transport-oriented compact city, with high-density residential and commercial developments around transport nodes. This improves accessibility to public transport. Although public bus and train services are provided on a commercial basis, all forms of public transport are generally affordable to the public – thus contributing to increased use of public transport and a reduction in the use of private vehicles. The adequate integration between public transport and the built environment makes both the public transport system and the city successful. High density (combined with disincentives to private car ownership and use) increases ridership, while public transport provides access to dense, accessible, mixed-use urban environments. Consequently, shorter trips can be completed on foot or bicycle. The result is less vehicle kilometres travelled and thus lower transport emissions and fewer traffic accidents.

Quality of service

Quality of service involves several elements as perceived by the user involving dimensions such as travel time, reliability, safety and security, comfort and user information. Travel time includes the door-to-door connectivity, walking to the station, waiting for the service, travelling on board, transferring between services and walking to the final destination. Reliability involves the confidence on the arrival of the service, and the travel time on board. Safety implies the buses and trains are well maintained and that passengers would not be exposed to preventable accidents. Security implies that passengers travel with the realization that they would not be victims of crime or terrorist attacks. Comfort deals with several amenities, but mainly with the space available, or occupancy. User information comes in many forms to allow the passenger to navigate the system and be aware of real time information and contingencies.

The most advanced public transport systems in the world include all these dimensions of quality to provide a very attractive alternative to car and motorcycle use. Many advanced systems in developing countries have high-quality services, but may not include the first and last leg of the trip (i.e. walking to and from the station). 'Universal design'[79] – which is an important aspect of inclusive public transport systems – is often overlooked.

Cities in developed countries have incorporated reliability as part of the key performance indicator metrics. Nevertheless, in developing cities, reliability is not commonly measured and hence not managed. Typically, light rail and BRT systems in developing cities observe train or bus 'bunching' (i.e. two or three vehicles arriving simultaneously at the stage and gaps between vehicles). This reduces the systems' capacity and causes high occupancy for some vehicles, while others have excess space. Advanced control systems could be used to provide real-time information to the drivers and thereby reduce bunching.

Occupancy levels are the main aspect when considering comfort. Notably, the occupancy standards in developed and developing countries tend to differ: four to five standees per square metre vs. six to seven standees per square metre, respectively. In general, this is a result of financial considerations, rather than user acceptance or cultural considerations. Higher occupancy standards mean fewer vehicles and drivers, and less infrastructure requirements. It also means that the capacity for peak flows is set artificially high.

As a result, public acceptance of several systems can suffer.[80] For instance, surveys in São Paulo's metro (Brazil), Manila's light rail (the Philippines) and Bogotá's BRT (Colombia) indicate that the main user complaint is overcrowding in trains, buses and stations. These surveys indicate that the occupancy standards adopted are not acceptable by users, irrespective of the public transport mode, and should be revised. This is important when considering public transport as an alternative to private motor vehicle use. In the longer run, the high occupancy standards may result in more people choosing motorcycles or cars as they become more affordable due to economic growth.

The most advanced public transport systems in the world include all . . . dimensions of quality [travel time, reliability, safety and security, comfort and user information] to provide a very attractive alternative to car and motorcycle use

User information systems include static and dynamic information, and are particularly useful for new users, visitors and for frequent users making infrequent trips. Modern systems include real-time information on service arrivals, and voice and visual announcements for the visually and the hearing impaired. With the advent of smart wireless technologies this type of information is gradually becoming available on handheld devices.

Finance

The availability of finance is essential for efficient urban mobility systems. Conversely, the absence of finance can constrain the ability of relevant authorities to implement sustainable high-capacity public transport options. These issues, which are addressed in the paragraphs below, are examined in greater detail with respect to urban mobility systems in Chapter 8.

■ *Financial risks in public transport project development*

The expansion and maintenance of metros, light rail or BRT systems require large amounts of funding. One common issue in developed and developing countries alike is the tendency to underestimate time and cost (leading to costly overruns for both), and overestimate demand during the decision-making process. The average cost escalation of rail, fixed link and road have been estimated at 45, 34 and 21 per cent, respectively;[81] in the case of overestimating demand, 84 per cent of rail projects, and 50 per cent of road projects have been associated with inaccuracies larger than 120 per cent.[82] This issue requires substantially improved procedures during project preparation, with strong institutions

The expansion and maintenance of metros, light rail or BRT systems require large amounts of funding

and evaluation processes to ensure more reliable data to inform decision-making.

■ *Funding sources*

Funding for capital investments in high-capacity public transport requires the participation of local, regional and national governments. Several countries have developed programmes to co-finance capital investments in public transport, often supported by multi-lateral development banks and international technical assistance programmes. It is important to recognize that the major multi-lateral development banks – African Development Bank, Asian Development Bank, Development Bank of Latin America, the European Bank for Reconstruction and Development, the European Investment Bank, the Inter-American Development Bank, the Islamic Development Bank and the World Bank – pledged US$175 billion during the Rio+20 Conference to support sustainable transport between 2012 and 2022.[83] This fund will be used to promote all forms of sustainable transport, including public transport; bicycle and walking infrastructure; energy-efficient vehicles and fuels; railways; inland waterways; and road safety. Additional sources of international funding are the climate change financial mechanisms, but they are usually small, as compared with the funding needs.[84]

Funding for capital investments in high-capacity public transport requires the participation of local, regional and national governments

The national governments' interest in public transport comes from the importance of cities for the productivity of the countries, and national energy security and environmental targets. Other considerations are equity and expanded access, as well as opportunities for low-income and vulnerable populations living in urban areas. It is also important to have adequate evaluation procedures to maximize the benefits of such investments and avoid cost overruns.[85]

In addition to transfers from different levels of government, local authorities require innovative funding mechanisms to support implementation and operation of public transport systems beyond the farebox revenues.[86] Several potential sources for such funding are discussed further in Chapter 8.

■ *Public transport subsidies*

Another important aspect of finance is the issue of subsidies. Transport economics literature has shown that public transport subsidies are efficient and socially worthwhile as public transport involves several positive externalities (air quality, climate change, road safety, physical activity). Thus, the provision of subsidies to encourage operators to lower their existing fares and/or expand their existing frequencies is socially desirable.[87] The majority of the social benefits accrue from the 'Mohring effect',[88] which indicates that subsidies increase ridership, and ridership increase engenders higher service frequencies, and the higher frequencies reduce the average waiting times at public transport stops. Hence, subsidies could be justified because of the scale economies conferred on riders. Nevertheless, subsidies need adequate management for them to be targeted towards service improvements and serving the needs of vulnerable populations (low income, elderly, handicapped). Unmanaged subsidies may result in inefficiencies, such as excessive overheads, large number of operators and drivers, and high maintenance costs.[89]

Institutions

Urban transport involves multiple institutions and levels of government that are not always well coordinated. Lack of coordination results in several issues such as the lack of integration among public transport components, other transport modes and the built environment. Very often, the agencies responsible for metros, light rail or BRTs are only responsible for their respective mode, with minimal (if any) coordination with other components of the urban transport system. A second institutional issue is the lack of technical and managerial capacity. Many agencies in developing countries are not able to retain qualified personnel to plan, implement and manage the complexity of public transport projects. There is an urgent need to upgrade the technical capacity through training and professional development programmes. The institutional and governance dimensions of sustainable urban mobility systems are discussed further in Chapter 9.

Many agencies in developing countries are not able to retain qualified personnel to plan, implement and manage the complexity of public transport projects

Significant opportunities exist to enhance technical and managerial capacity, through direct exchanges among peer institutions and benchmarking. Some examples of these efforts include:

- Nova – a programme of international railway benchmarking, made up of a consortium of medium sized metro systems from around the world: Bangkok (Thailand), Barcelona (Spain), Buenos Aires (Argentina), Brussels (Belgium), Delhi (India), Istanbul (Turkey), Lisbon (Portugal), Montréal (Canada), Naples (Italy), Newcastle (UK), Rio de Janeiro (Brazil), Singapore, Toronto (Canada) and Sydney (Australia). The four main objectives of Nova are: to build measures to establish metro best practice; to provide comparative information both for the metro board and the government; to introduce a system of measures for management; and to prioritize areas for improvement.[90]
- CoMET – a programme of international railway benchmarking, made up of a consortium of large metro systems from around the world: Beijing (China), Berlin (Germany), Guangzhou (China), Hong Kong (China), London (UK), Madrid (Spain), Mexico City (Mexico), Moscow (Russia), New York (US), Paris (France), Santiago (Chile), São

Paulo (Brazil), Shanghai (China) and Taipei (China). Just like Nova, the four main objectives of CoMET are: to build measures to establish metro best practice; to provide comparative information both for the metro board and the government; to introduce a system of measures for management; and to prioritize areas for improvement.[91]

- The International Bus Benchmarking Group (IBBG) – a programme of urban bus operations benchmarking, made up of medium and large bus organizations located around the world: Barcelona (Spain), Brussels (Belgium), Dublin (Ireland), Istanbul (Turkey), Lisbon (Portugal), London (UK), Montréal (Canada), New York (US), Paris (France), Seattle (US), Singapore, Sydney (Australia) and Vancouver (Canada). IBBG was established in 2004 to provide a confidential forum to share experiences, compare performance, identify best practices and learn from one another in order for member organizations to improve performance.[92]
- SIBRT – whose mission is to cooperate and create a synergy for the promotion, consolidation and strengthening of BRT and integrated transport systems, so that they become paradigms for the future of mobility in Latin America and the world, and to contribute effectively to improve the quality of urban life.[93]

Additional exchanges are organized through industrial associations such as the International Association of Public Transport (global),[94] the American Public Transportation Association (US),[95] Canadian Urban Transit Association (Canada),[96] and Associação Nacional de Transportes Públicos (Brazil).[97]

CONCLUDING REMARKS AND LESSONS FOR POLICY

This chapter has presented empirical evidence of the trends and conditions as well as challenges with respect to the role of high-capacity public transport systems worldwide. These systems play important social, economic and environmental roles in terms of facilitating more efficient urban mobility systems and sustainable urban development patterns. Such high-capacity public transport systems are primarily appropriate for large and dense urban agglomerations, and serve as important parts of integrated public transport systems. Accordingly, they should be designed to provide a competitive and viable alternative to private cars and motorcycles.

Globally, metro systems have an average of 112 million passengers per day. Asian cities account for 46 per cent of global ridership, followed by European cities with 34 per cent of global ridership. As of 2013, there are only two African cities with metro systems. Ridership on light rail systems is significantly lower, although there are some 400 light rail and tram systems in operation worldwide. Most of these are found in Europe and the US, although the two light rail systems with the highest number of passengers are both located in Asia.

As of mid-2013, there were 156 cities worldwide with BRT system. The total ridership for BRT, which is about 26 million passengers per day, is less than a quarter of that of metro systems. Most BRT systems are located in developing countries, particularly in Latin America and the Caribbean, and Asia.

Integration is important for public transport systems to be efficient and sustainable

Metro, light rail and BRT systems have different characteristics, each with its benefits and drawbacks. This report calls for an advanced evaluation of the costs and benefits of high-capacity public transport systems, prior to their implementation. It is also important to avoid endless discussions about alternatives, as the worst case scenario is 'to-do-nothing'.

The most efficient systems are those that have achieved route integration; integration with other public transport systems; integration with private motorized transport . . .; integration with non-motorized modes . . .; and fare integration

A major issue relating to the successful implementation of high-capacity public transport systems is an accurate understanding of the requirements and perceptions of its potential users. In order to ensure maximum ridership on metro, light rail and BRT systems, these need to be designed and implemented in a manner that meets the aspirations of potential riders.

Integration is important for public transport systems to be efficient and sustainable. The most efficient systems are those that have achieved route integration; integration with other public transport systems; integration with private motorized transport (including through encouraging drivers of private cars to park outside the city centre and use public transport for parts of their daily commute); integration with non-motorized modes (through easy access for pedestrians and/or bicycle parking and allowing bicycles onto public transport vehicles); and fare integration: allowing users to travel throughout the urban public transport system on a single ticket, or at reduced rates when switching between operators and/or lines. Integration also includes the built environment dimension: dense, mixed-use and accessible urban forms enhance ridership and vice versa.

Integration also includes the built environment dimension: dense, mixed-use and accessible urban forms enhance ridership and vice versa

Technical inadequacies in the construction of public transport systems, such as ramps, gaps, steps or waiting areas, represent significant challenges for vulnerable groups. Many high-capacity public transport systems are also characterized by real or perceived security risks. These challenges and risks often lead to reduced ridership and exclusion of many potential users, especially women, children, the elderly, disabled and minorities.

NOTES

1 UN-Habitat, 2013a.
2 See, for example, Fouracre et al, 2003; Wright and Fjellstrom, 2003; Litman, 2007; Hensher, 2007; Vuchic, 2007; Systra, 2008; Salter et al, 2011.
3 World Bank, 2002a.
4 World Bank, 2002a.
5 UITP, undated.
6 APTA, 1994.
7 ERRAC-UITP, 2009.
8 Transport for London, undated a.
9 ERRAC-UITP, 2009.
10 UITP, undated.
11 APTA, 1994.
12 UITP, undated.
13 World Bank, 2002a.
14 ITDP, 2007.
15 Levinson et al, 2003.
16 Lindau et al, 2010.
17 Wright and Hook, 2007.
18 Levinson et al, 2003.
19 ITDP, 2007.
20 It should be noted that it is possible to find systems with higher costs and capacities than those indicated in the table; nevertheless these can be considered as exceptional cases.
21 Economist, 2013.
22 MoUD, 2005; Pai and Hidalgo, 2009. See also Box 8.13.
23 DMRC, undated.
24 Republic of Kenya, 2009.
25 Omwenga, 2013.
26 Republic of Kenya, 2009.
27 World Bank, 2013.
28 Asmaa et al, 2012.
29 Net Resources International, 2012.
30 Railway Gazette International, 2012.
31 Federal Republic of Nigeria, 2010.
32 South African Government Information, 2012.
33 Rea Vaya, undated.
34 City of Cape Town, 2013.
35 City of Tshwane, undated.
36 Economist, 2013.
37 Transport for London, undated a.
38 Metrobits, 2012.
39 World Bank, 2002a.
40 McKinsey Global Institute, 2010.
41 McKinsey Global Institute, 2010; Doi and Asano, 2011.
42 McKinsey Global Institute, 2010.
43 Huzayyin and Salem, 2013.
44 Huzayyin and Salem, 2013.
45 UN, 2011b.
46 Cox, 2012.
47 UN-Habitat, 2004.
48 UITP, undated.
49 UITP, undated.
50 UITP, 2004.
51 Issam, 2011.
52 Trade Arabia, 2013.
53 Ethiopian Railways Corporation, 2011.
54 Republic of Mauritius, 2013.
55 UPI, 2008.
56 ADB, 2012a.
57 ERRAC-UITP, 2009.
58 UPI, 2008.
59 Hidalgo, 2011.
60 See Table 3.6.
61 brtdata.org, last accessed 5 June 2013.
62 Hidalgo, 2008.
63 Goodman et al, 2006.
64 Goodman et al, 2006.
65 Gauthier and Weinstock, 2010.
66 World Bank, 2009a.
67 World Bank, 2009a.
68 Mobereola, 2009.
69 Mobereola, 2009.
70 TRB, 2011; ITDP, 2008.
71 McCaul, 2009.
72 Rea Vaya, 2011a.
73 Rea Vaya, 2011b.
74 McCaul, 2009.
75 Gauthier and Weinstock, 2010.
76 LTA, 2012.
77 Omwenga, 2013.
78 Cervero, 1998.
79 See Chapter 6.
80 Hidalgo and Carrigan, 2008.
81 Flyvbjerg et al, 2003.
82 Flyvbjerg et al, 2008.
83 ADB, 2012b.
84 Dalkmann and Brannigan, 2007.
85 Owen et al, 2012.
86 CODATU, 2009; Scheurer et al, 2000.
87 Savage and Small, 2010.
88 Mohring, 1972.
89 Obeng, 2012.
90 http://www.nova-metros.org, last accessed 21 May 2013.
91 http://www.comet-metros.org, last accessed 21 May 2013.
92 http://www.busbenchmarking.org, last accessed 21 May 2013.
93 http://www.sibrtonline.org, last accessed 21 May 2013.
94 http://www.uitp.org, last accessed 21 May 2013.
95 http://www.apta.com, last accessed 21 May 2013.
96 http://www.cutaactu.ca, last accessed 21 May 2013.
97 http://portal.antp.org.br, last accessed 21 May 2013.