Division 44
Environment and Infrastructure
Sector project "Transport Policy Advice"

Sustainable Transport:
A Sourcebook for Policy-makers in Developing Cities
Module 3a

Mass Transit Options

– revised July 2005 –

Deutsche Gesellschaft für
Technische Zusammenarbeit (GTZ) GmbH

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OVERVIEW OF THE SOURCEBOOK

Sustainable Transport: A Sourcebook for Policy-Makers in Developing Cities

What is the Sourcebook?

This *Sourcebook* on Sustainable Urban Transport addresses the key areas of a sustainable transport policy framework for a developing city. The *Sourcebook* consists of more than 20 modules.

Who is it for?

The *Sourcebook* is intended for policy-makers in developing cities, and their advisors. This target audience is reflected in the content, which provides policy tools appropriate for application in a range of developing cities.

How is it supposed to be used?

The *Sourcebook* can be used in a number of ways. It should be kept in one location, and the different modules provided to officials involved in urban transport. The *Sourcebook* can be easily adapted to fit a formal short course training event, or can serve as a guide for developing a curriculum or other training program in the area of urban transport. GTZ is elaborating training packages for selected modules, being available since October 2004.

What are some of the key features?

The key features of the *Sourcebook* include:

- A practical orientation, focusing on best practices in planning and regulation and, where possible, successful experience in developing cities.
- Contributors are leading experts in their fields.
- An attractive and easy-to-read, color layout.
- Non-technical language (to the extent possible), with technical terms explained.
- Updates via the Internet.

How do I get a copy?

Please visit http://www.sutp.org or http://www.gtz.de/transport for details on how to order a copy. The *Sourcebook* is not sold for profit. Any charges imposed are only to cover the cost of printing and distribution. You may also order via transport@gtz.de.

Comments or feedback?

We would welcome any of your comments or suggestions, on any aspect of the *Sourcebook*, by e-mail to transport@gtz.de, or by surface mail to:

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Further modules and resources

Further modules are anticipated in the areas of *Financing Urban Transport*; *Benchmarking*; and *Car Free Development*. Additional resources are being developed, and an Urban Transport Photo CD-ROM is available.

Modules and contributors

Sourcebook Overview and Cross-cutting Issues of Urban Transport (GTZ)

Institutional and policy orientation

1a. *The Role of Transport in Urban Development Policy* (Enrique Peñalosa)
1b. *Urban Transport Institutions* (Richard Meakin)
1c. *Private Sector Participation in Transport Infrastructure Provision* (Christopher Zegras, MIT)
1d. *Economic Instruments* (Manfred Breithaupt, GTZ)
1e. *Raising Public Awareness about Sustainable Urban Transport* (Karl Fjellstrom, GTZ)

Land use planning and demand management

2a. *Land Use Planning and Urban Transport* (Rudolf Petersen, Wuppertal Institute)
2b. *Mobility Management* (Todd Litman, VTPI)

Transit, walking and cycling

3a. *Mass Transit Options* (Lloyd Wright, University College London; Karl Fjellstrom, GTZ)
3b. *Bus Rapid Transit* (Lloyd Wright, University College London)
3c. *Bus Regulation & Planning* (Richard Meakin)
3d. *Preserving and Expanding the Role of Non-motorised Transport* (Walter Hook, ITDP)
3e. *Car-Free Development* (Lloyd Wright, University College London)

Vehicles and fuels

4a. *Cleaner Fuels and Vehicle Technologies* (Michael Walsh; Reinhard Kolke, Umweltbundesamt – UBA)
4b. *Inspection & Maintenance and Roadworthiness* (Reinhard Kolke, UBA)
4c. *Two- and Three-Wheelers* (Jitendra Shah, World Bank; N.V. Iyer, Bajaj Auto)
4d. *Natural Gas Vehicles* (MVV InnoTec)
4e. *Intelligent Transport Systems* (Phil Sayeg, TRA; Phil Charles, University of Queensland)
4f. *EcoDriving* (VTL; Manfred Breithaupt, Oliver Eberz, GTZ)

Environmental and health impacts

5a. *Air Quality Management* (Dietrich Schwela, World Health Organisation)
5b. *Urban Road Safety* (Jacqueline Lacroix, DVR; David Silcock, GRSP)
5c. *Noise and its Abatement* (Civic Exchange Hong Kong; GTZ; UBA)

Resources

6. *Resources for Policy-makers* (GTZ)

Module 3a

Mass Transit Options

About the contributors

The **Institute for Transportation and Development Policy (ITDP)** was established in 1985 to promote transport options that are environmentally, economically, and socially sustainable. ITDP is an international non-governmental organisation that particularly focuses upon the promotion of public transport, non-motorised transport, travel demand management, and improved land-use planning. ITDP works exclusively in developing countries and economies in transition, where the consequences of inadequate basic mobility are the most keenly felt, and where the adverse social and environmental effects of rapid motorisation are causing the greatest economic and environmental problems. To fulfil its mission, ITDP has three core activities:

(I) Catalysing demonstration projects with progressive municipalities;

(II) Communicating successful options and technical information; and

(III) Encouraging better policy making at the local, national, and multi-lateral levels.

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Bangkok’s Victory Monument, Dec. 2001

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1. Introduction

Choices on public transit options are choices about a city's future. Will there be congestion? Will there be high levels of air and noise pollution? Will transport be affordable? Will services be available to all? The type of public transit system will have a big impact on the answers to these questions (Figure 1).

This module aims to provide policy-makers in developing cities—and those advising them—with guidance on choosing appropriate Mass Rapid Transit (MRT) systems. The module begins by briefly describing some basic concepts and defining features of MRT in developing cities. Current applications of each of the main MRT options are then described, focusing on applications in developing cities. Since Metros and Light Rail Transit are still relatively uncommon in low income developing cities, most of this discussion focuses on the recent development of Bus Rapid Transit systems throughout the world.

The main section of the module then compares each of these MRT options in the light of key parameters for developing cities. Naturally, a leading consideration is cost (including cost of construction, rolling stock, and operation); others include planning & construction time, flexibility in implementation, passenger capacity, speed, and institutional issues. Longer term effects on poverty, city form, and the environment are also assessed. In terms of maintaining a transit-friendly city form and ensuring the urban poor have access to employment, contacts and services, a crucial factor when comparing systems is the potential for a Mass Rapid Transit system to secure long term advances—or at least stabilisation—in the share of people travelling by public rather than private transport.

> *"Choices on transit options are choices about a city's future."*

The module ends with a discussion of what the comparison of the different options reveals. It is seen that although there is no single MRT solution fitting all cities, for all but the major corridors of relatively wealthy and dense developing cities which are planning to develop a MRT system, the best option will often be a form of Bus Rapid Transit.

Fig. 1

Which future? Choices about Mass Rapid Transit concern the kind of city we want to live in.

Lloyd Wright, 2002

2. Mass Rapid Transit concepts

2.1 Terminology

The distinction between many MRT concepts is fluid, and many different approaches are commonly used to distinguish the different modes and features of various MRT systems. Apart from basic defining features such as cost, capacity, and technology, other features used to delineate MRT systems might include distance between stops, extent of right-of-way, operational regimes, and guidance systems. For the purposes of this module we have distinguished between four general forms of Mass Rapid Transit: Bus Rapid Transit, Metros, Commuter Rail, and Light Rail Transit.

Mass rapid transit

Mass rapid transit, also referred to as *public transit*, is a passenger transportation service, usually local in scope, that is available to any person who pays a prescribed fare. It usually operates on specific fixed tracks or with separated and exclusive use of potential common track, according to established schedules along designated routes or lines with specific stops, although Bus Rapid Transit and trams sometimes operate in mixed traffic. It is designed to move large numbers of people at one time. Examples include heavy rail transit, light rail transit, and Bus Rapid Transit.

Heavy rail transit

A *heavy rail transit* system is "a transit system using trains of high-performance, electrically powered rail cars operating in exclusive rights-of-way, usually without grade crossings, with high platform stations" (TCRP, 1998).

Metro

Metro is the most common international term for subway, heavy rail transit, though it is also commonly applied to elevated heavy rail systems. In this module we use "metro" to refer to urban grade-separated heavy rail systems. They are the most expensive form of MRT per kilometre, but have the highest theoretical capacity.

Commuter rail systems

Commuter rail or suburban rail is the portion of passenger railroad operations that carries passengers within urban areas, or between urban areas and their suburbs, but differs from Metros and LRT in that the passenger cars generally are heavier, the average trip lengths are usually longer, and the operations are carried out over tracks that are part of the railroad system in the area.

Light Rail Transit

A *light rail transit* (LRT) system is a metropolitan electric railway system characterised by its ability to operate single cars or short trains along ***exclusive rights-of-way*** at ground level, aerial structures, in subways, or occasionally in streets, and to board and discharge passengers at track or car floor level (TCRP, 1998). LRT systems include tramways, though a major difference is that trams often operate ***without an exclusive right-of-way***, in mixed traffic.

Bus Rapid Transit

Many cities have developed variations on the theme of better bus services and the concept resides in a collection of best practices rather than a strict definition. Bus Rapid Transit is a form of customer-oriented transit combining stations, vehicles, planning, and intelligent transport system elements into an integrated system with a unique identity.

Bus Rapid Transit typically involves busway corridors on segregated lanes—either at-grade or grade separated—and modernised bus technology. However, apart from segregated busways BRT systems also commonly include:

- Rapid boarding and alighting;
- Efficient fare collection;
- Comfortable shelters and stations;
- Clean bus technologies;
- Modal integration;
- Sophisticated marketing identity;
- Excellence in customer service.

Bus Rapid Transit is more than simply operation over exclusive bus lanes or busways. According to a recent study of at-grade busways (Shen *et al.*, 1998), only half of the cities that have busways have developed them as part of a systematic and comprehensive package of measures as part of the city mass transit network that we would identify as a BRT system.

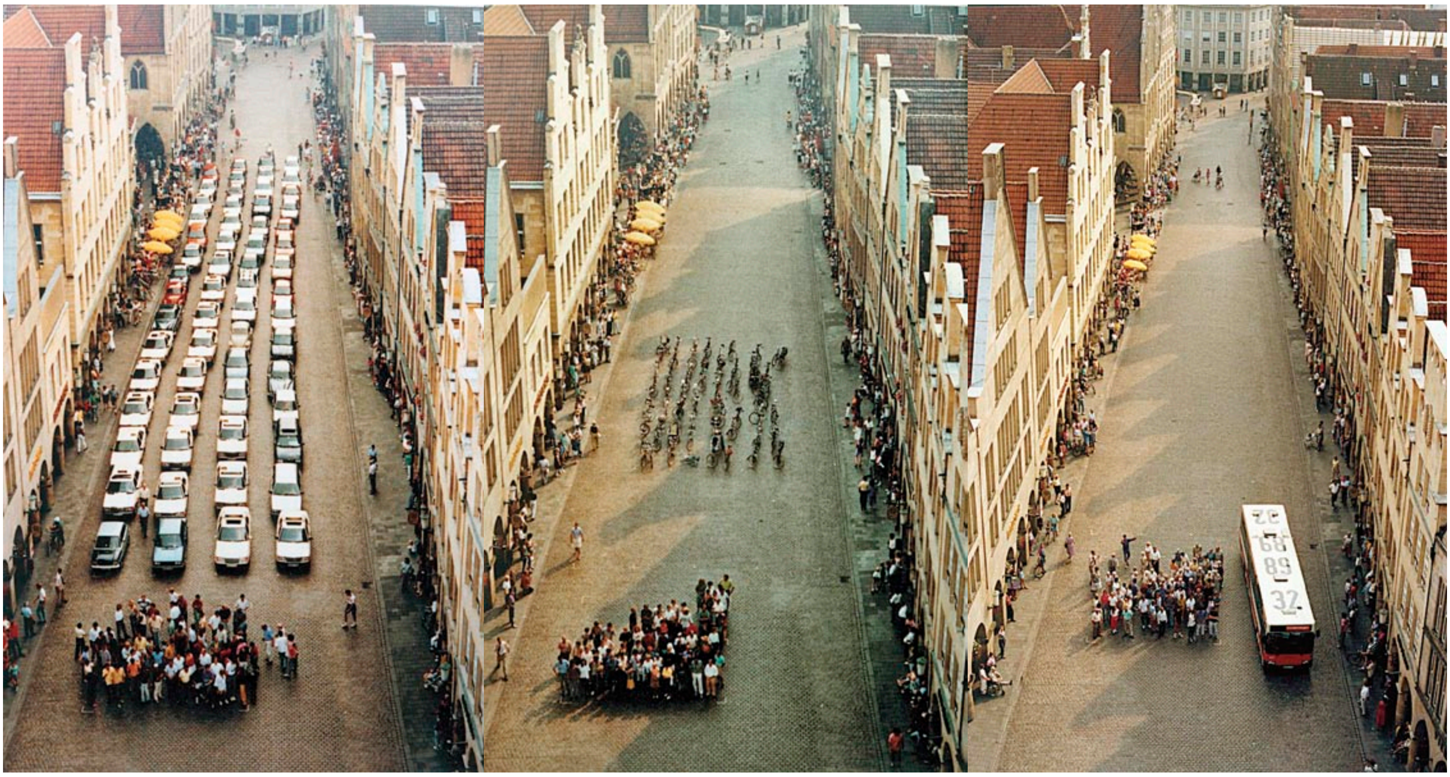


Fig. 2

The amount of space required to transport the same number of passengers: car, bicycle, and bus.

Poster displayed at the City of Muenster Planning Office, August 2001

While Bus Rapid Transit systems always include some form of exclusive right-of-way for buses, the applications we consider in this module are mostly at-grade, street-level busways. Elevated busways or tunnels may be needed for traversing some city centres, but in many developing cities funds will not be available for extensive grade separation.

Bus lane (or priority bus lane)

A bus lane is a highway or street reserved primarily for buses, either all day or during specified periods. It may be used by other traffic under certain circumstances, such as while making a turn, or by taxis, bicycles, or high occupancy vehicles.

Bus lanes, widely used in Europe even in small cities, are increasingly applied in developing cities such as Bangkok, where counter-flow buses can move rapidly through peak period congestion.

Busway

A busway is a special roadway designed for exclusive use by buses. It may be constructed at, above, or below grade and may be located in separate right-of-way or within highway corridors. Some form of busway system is a feature of many Bus Rapid Transit systems.

2.2 Defining features of MRT

Use of space

Similar space-efficiency considerations (see Figure 2) apply to all the MRT modes, although in practice it arises as a policy issue only with regard to buses and some versions of LRT, since rail systems are already fully segregated from other traffic. BRT and LRT often involve re-allocation of existing road space in favour of more efficient modes, whereas Metros are normally fully grade separated and have no impact on road capacity, unless they are elevated in which case there may be a small reduction in road capacity.

Speed and passenger capacity

All forms of MRT operate with relatively high speed and passenger capacities, and the basic requirement of MRT in a developing city is that it carries large amounts of passengers, rapidly. Where Metros are applied in developing cities they are often by far the fastest mode of MRT, with an average speed of up to 40–50 km/h, while LRT and BRT systems typically operate at average speeds of between 20 and 30 km/h.

Integration

All MRT systems require interchanges with other elements of the public transport system, and integration with other modes of transport such as cars, walking, and cycling. Shanghai, for example, provides excellent Metro/bicycle and Metro/pedestrian interchanges, and good Metro/bus interchanges at some major stations. Mexico City's Metro is physically integrated with the international airport and major bus stations. Curitiba's BRT system includes excellent integration with pedestrian streets and taxi stands. Sao Paulo's BRT integrates well with the Metro system. Poor integration is a feature of some under-performing rail-based MRT systems, such as in Kuala Lumpur and Manila.

Level of service

MRT systems usually offer a superior level of service compared to unsegregated road-based modes such as regular buses, taxis, and paratransit.

Superior service is evident for example with:

- Terminals & interchanges;
- Cleanliness;
- Sophisticated marketing image;
- Passenger information;
- Climate control;
- Modal integration;
- Integration with major trip attractors.

Rail-based systems have historically performed better on 'level of service' indicators, although recent Bus Rapid Transit successes are challenging these traditional conceptions.

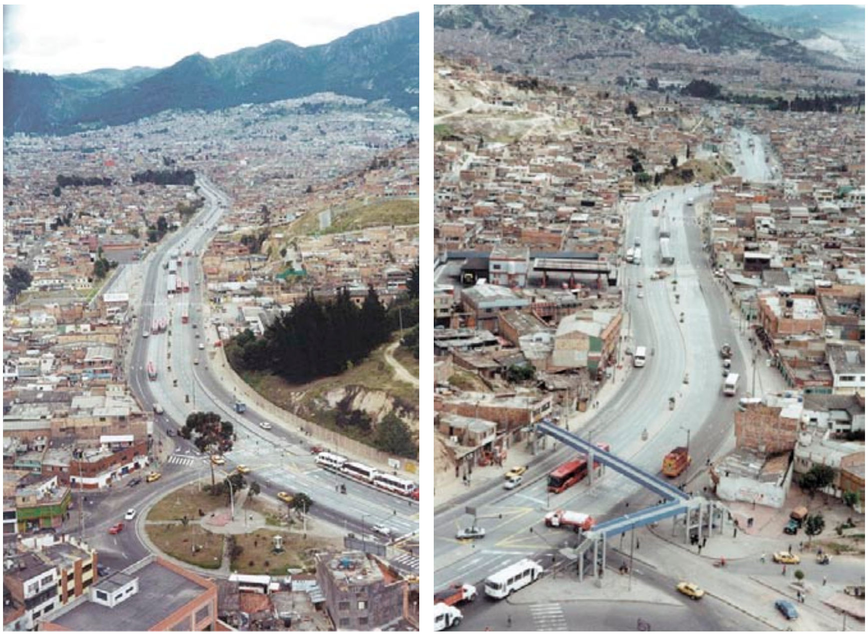


Fig. 3

Corridors in Bogotá where the TransMilenio system operates: Many developing cities, even though increasingly traffic-saturated, retain a corridor orientation which is conducive to Mass Rapid Transit.

Enrique Penalosa, 2001

2.3 The strategic importance of MRT systems

Developing cities are experiencing rapidly worsening traffic and related environmental conditions. As a first step, political commitment to give priority to efficient modes of transport (transit, walking, cycling) is needed.

Experience in developed cities shows that MRT systems tend to have little impact on land use patterns. This leads many experts to recommend that 'adaptive' MRT systems should be used, not to attempt to influence land use patterns, but rather to adapt to the existing land use patterns (e.g., Cervero, 1998). In many developing cities, however, the influence of MRT on land use patterns is likely to be much stronger, since such cities are often undergoing rapid spatial expansion. Current trends—e.g., geared toward gated communities and greenfield housing estates in many Southeast Asian cities—often favour car-dependent urban forms, but a quality MRT system can help counteract such trends by maintaining growth along main corridors and in city centres (Figure 3).

While theoretically we are told that cities should follow a 'balanced' approach, using 'complementary' MRT systems appropriate to local circumstances, in practice—especially in developing cities—once a particular MRT system is developed, resources tend to be devoted to that system, while other transit modes are neglected. Developing cities often lack the institutional capacity to simultaneously develop multiple systems. This is apparent in almost all developing cities which have recently pursued rail-based systems, including for example Kuala Lumpur, Bangkok, Cairo, Buenos Aires and Manila. In all these cities, bus transit has been neglected.

3. Current applications in developing cities

We now survey world-wide applications of the different MRT systems, focusing on developing cities.

Rail-based systems in developing country Metros carry about 11 billion journeys each year, surface rail about 5 billion, and light rail about 2.5 billion. While the proportion of public transport trips by rail exceeds 50% in Seoul and Moscow, rail systems dominate only in a very few cities (World Bank, 2001).

Some typical MRT systems in developing cities are outlined in Table 1. Several of the systems in Table 1 are discussed in more detail below, and in Module 3b: *Bus Rapid Transit*.

3.1 Bus Rapid Transit

Various BRT systems operate in cities. An extensive list can be seen in Module 3b: *Bus Rapid Transit,* but here is a list of the most significant projects.

- ***In Asia***: Ankara, Istanbul, Jakarta, Kunming, Nagoya, Taipei.
- ***In Europe***: Besançon, Bradford, Clermont-Ferrand, Dijon, Eindhoven, Essen, Grenoble, Ipswich, Leeds, Limoges, Lyon, Montpellier, Nancy, Rennes, Rouen, Runcorn, Strasbourg, West Sussex.

Table 1: Performance and costs of various MRT systems.

World Bank, Cities on the Move, Urban Transport Strategy Review (Oct. 2001)

EXAMPLE	Caracas (Line 4)	Bangkok (BTS)	México (Line B)	Kuala Lumpur (Putra)	Tunis (SMLT)	Recife (Linha sul)	Quito Busway	Bogotá (TransMilenio, Phase 1)	Porto Alegre Busways
Category	Rail metro	Rail metro	Rail metro	Light rail	Light rail	Suburban rail conversion	Busway	Busway	Busway
Technology	Electric, steel rail	Electric, steel rail	Electric, rubber tyre	Electic, Driverless	Electric, steel rail	Electric, steel rail	AC Electric duo-trolleybus	Articulated diesel bus	Diesel buses
Length (km)	12.3	23.1	23.7	29	29.7 km	14.3	11.2 (+ext 5.0)	41	25
Vertical segregation	100% tunnel	100% elevated	20% elevated 55% at grade 25% tunnel	100% elevated	At grade	95% at grade 5% elevated	At grade, Partial signal priority	At grade, Mainly segregated	At grade, No signal priority
Stop spacing (kms)	1.5	1.0	1.1	1.3	0.9	1.2	0.4	0.7	0.4
Capital cost, ($m) of which:	1,110	1,700	970	1,450	435	166	110.3	213 (inf only)	25
Infrastructure/TA/ Equipment ($m)	833	670	560	n.a.	268	149	20.0	322	25
Vehicles ($m)	277	1,030	410	n.a.	167	18	80 (113 vehs.)	Not included (private operation)	Not included (private operation)
Capital cost/route km ($m)	90.25	73.59	40.92	50.0	13.3	11.6	10.3	5.2	1.0
Initial (ultimate) vehicles or trains / hour / direction	20 (30)	20 (30)	13 (26)	30	n.a.	8	40 (convoy operation planned)	160	n.a.
Initial maximum pass capacitys	21,600	25,000	19,500	10,000	12,000	9,600	9,000		20,000
Maximum pass. carrying capacity	32,400	50,000	39,300	30,000	12,000	36,000	15,000	35,000	20,000
Ave operating speed (kph)	50	45	45	50	13/20	39	20	20+ (stopping) 30+ (express)	20
Rev/operating cost ratio	n.a.	100	20	>100	115% in 1998	n.a.	100	100	100
Ownership	Public	Privat (BOT)	Public	Private (BOT)	Public	Public	Public (BOT) under consideration	Public infrastructure, private vehicles	Public infrastructure, private vehicles
Year completed	2004	1999	2000	1998	1998	2002	1995 (ext 2000)	2000 (1998 prices)	Mostly 1990s

Source: James Urban Transport System; BB&J Consult, 2000; J. Rebelo, and G. Menckhoff.

Bogotá's TransMilenio: initial results

Results of the first few years of operation of TransMilenio have met the high expectations of the system's developers:

- The system is moving 900,000 passengers each day (June 2005)
- Most users of TransMilenio have gained more than 300 hours per year to themselves
- 11% of TransMilenio's riders are former private car drivers
- Average speed is higher than 25 km per hour
- With the 72% of the total number of buses the system moves about 60,000 passengers in peak hours
- Noise and air pollution have been reduced by 30% where TransMilenio runs
- 627 buses in operation
- Ticket fare of US$0.40
- 55 km in operation
- 67 stations in operation
- 421 km feeder routes
- 362 feeder buses
- 927 million trips since the beginning (as of July 1, 2005)

- ***In Latin America***: Belo Horizonte, Bogotá, Campinas, Curitiba, Goiania, Leon, Porto Alegre, Port of Spain, Quito, Recife, Sao Paulo.
- ***In North America***: Alameda and Contra Country, Boston, Chicago, Honolulu, Las Vegas, Los Angeles, Miami, Orlando, Ottawa, Philadelphia, Pittsburgh, Seattle, Vancouver.
- ***In Oceania***: Adelaide, Brisbane, Sydney.
- ***In Africa***: Abidjan, Saint-Denis.

BRT systems are under planning or construction in the following cities:

- ***In Asia***: Bangalore, Beijing, Chengdu, Delhi, Dhaka, Hangzhou, Shejiazhuang.
- ***In Latin America***: Barranquilla, Bogotá (expansion), Bucaramanga, Cali, Cartagena, Cuenca, Guatemala City, Guayaquil, Lima, Medellín, Mexico City, Panama City, Pereira, Puebla, Quito (expansion), San José, San Juan, San Salvador.
- ***In North America***: Albany, Charlotte, Cleveland, Eugene, Hartford, Louisville, Montomery County, Reno, Salt Lake City, San Francisco, Toronto.
- ***In Oceania***: Auckland, Perth.
- ***In Africa***: Accra, Cape Town, Dakar, Dar-Es-Salaam.

Latin American experience

Curitiba, Brazil

It was in Curitiba in the early 1970s that the Bus Rapid Transit idea first evolved. The city has implemented many other measures such as car-free zones and large green spaces to become one of the world's urban success stories.

Curitiba is one of the best examples of integrated transport and urban planning. It has a population of 1.5 million and about 655,000 motor vehicles. Public transport is managed by a public company, URBS, and is operated by 10 private companies under concession contracts. The public transport system runs 1,677 buses—many of which are 270-passenger bi-articulated buses—which carry on average 976,000 passengers per day. The 57 km of busways along five main routes are "fed" by 340 km of feeder routes that concentrate passenger demand on strategically placed interchange terminals. These terminals are linked in turn by 185 km of circular interdistrict routes. Acting in support of this network are 250 km of "Speedy Bus" routes that stop only at special tube stations generally set at every 3 km. For the same flat fare, the passenger can thus transfer from one bus to another at any of the terminals, extending public transport access to 90% of the city (Meirelles, 2000).

Fig. 4

In Curitiba, boarding tubes support 5-door boardings on locally manufactured buses. Doors open outwards, and ramps drop down to allow same-level boarding.

Manfred Breithaupt, 1999

Curitiba has inspired improvements elsewhere. Even Los Angeles, perhaps the most car-dependent city in the world, has developed Bus Rapid Transit after a recent visit of a delegation of leading city officials to Curitiba.

Bogotá, Colombia

With over 6 million inhabitants, Bogotá has proven that Bus Rapid Transit is suitable even for the largest cities. Bogotá's new TransMilenio system went into operation in January 2001. The existing two lines already by December 2001 served over 600,000 passenger trips per day, greatly exceeding initial projections (see margin note). When the full system is completed in 2015, TransMilenio will serve 5 million passengers each day with 388 km of busways.

Bogotá's TransMilenio system was briefly described in Module 1a of this *Sourcebook*, and is discussed in more detail in Module 3b: *Bus Rapid Transit*.

Sao Paulo, Brazil

Sao Paulo operates probably the largest Bus Rapid Transit system in the world in terms of kilometres covered. Sao Paulo, the most important financial and industrial centre in Brazil, has 9.9 million inhabitants and 4.8 million vehicles. Bus public transport is managed by a public company, SPTRANS, and is operated by 53 private companies. The public transport system runs 12,000 buses, which carry an

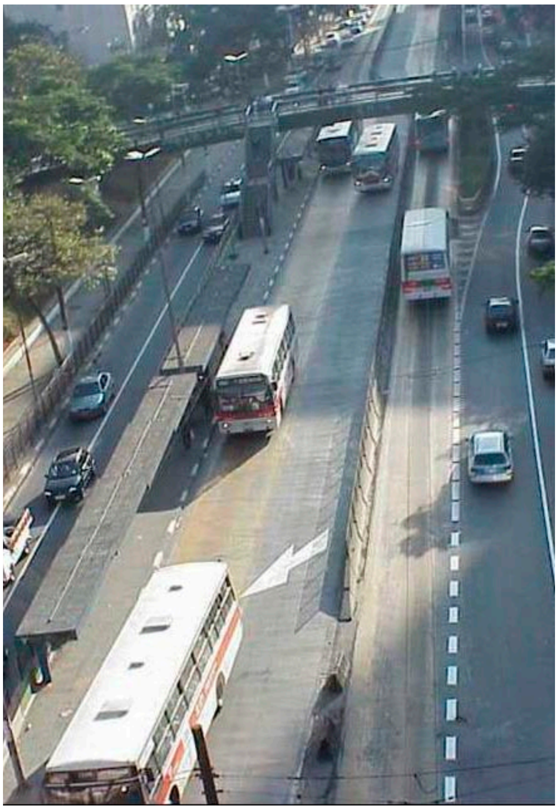


Fig. 5

Sao Paulo has the world's most extensive bus lane network, with 28 km of median busways and 137 km of bus lanes.

US Federal Transit Administration, 2001

average 4.8 million passengers per day. The city has 35 bus transfer terminals, 28 km of median busways and 137 km of bus lanes. New bus corridors are planned to integrate the inter-city bus lines, suburban rail and Metro systems, and the local bus routes (Meirelles 2000).

The system links outlying metropolitan areas to Sao Paulo's successful underground system. Thus, similar to Hong Kong and Singapore where bus services are well integrated with Metro systems, Sao Paulo is an example of bus and Metro systems being mutually beneficial.

Quito, Ecuador

Quito's trolley-bus system and recent *Eco-Via* addition are dramatic examples of BRT cost-effectiveness and the applicability of BRT even under stressed economic conditions. Ecuador has experienced several tumultuous years of political and economic misfortune. In 1998, rains from the El Niño climatic effect destroyed much of the nation's infrastructure. Then, in 1999, on the heels of the emerging global market crisis, Ecuador's banking sector virtually collapsed. Two governmental administrations during the late 1990s only survived a short time in office. However, in the midst of this rather chaotic scene, Quito has developed and expanded an impressive transit system featuring 25 km of exclusive busways. The system covers all operating costs with a fare of only US$0.20.

Fig. 6

The on-line median busway in Quito, Ecuador, covers operating costs at a fare of only US$0.20.

Lloyd Wright, 2001

Quito's existing fleet of privately run buses has taken an environmental and health toll on the city. Until recently, the average bus age of the private sector fleet has been 17 years, with some units as old as 35 years. The electric trolley-bus also delivers additional environmental gains through the substitution of diesel-fuelled buses with units powered by hydro-generated electricity. The overwhelming popularity of the Quito trolley-bus has exceeded expectations and in a sense created an unexpected problem. With over 200,000 commuters now using the system daily, its maximum capacity has been reached, and thus has prompted calls for further expansion. The municipality plans to deliver an additional 73 kilometres of busways in the near future.

For cost reasons, Quito's new *Eco-Via* line utilises Euro II diesel buses rather than continue with electric trolley technology. Likewise, the planned expansion will be utilising clean diesel technology for its buses.

Porto Alegre, Brazil

Porto Alegre, Brazil has shown that BRT can be delivered at a relatively low-cost. In this case, the system was reportedly built for less than US$1 million per km. The city has 17 bus

Buses are the backbone

Even where extensive rail systems have been built

Even cities with several subway and surface rail lines typically serve many more passengers with bus systems than with the rail systems. Mexico City's Metro, for example, is more than 150 km in length and has 11 lines, but serves less than 15% of all motorised trips. Likewise the Buenos Aires Metro has 5 lines but serves only 6% of trips in the metropolitan area. A similar situation applies in Singapore, Sao Paulo, Bangkok and other developing cities with high cost rail-based mass transit systems. In all these cases buses continue to serve the large majority of public transport trips, with rail serving less than 15% of trips.

In nearly all developing cities the majority of public transport is bus based. Exceptions include the 'motorcycle cities' such as Ho Chi Minh and Denpasar, where buses serve less than 5% of trips, as well as rail-dominated Moscow.

Another notable partial exception is Hong Kong, though even there buses still serve a majority of public transport passenger trips. Railways are forecast to handle about 40% to 50% of the total public transport passenger boardings in Hong Kong by 2016, increasing from 33% in 1997 (Env. Protection Dept., Govt. of Hong Kong SAR, 2002).

Shanghai, with its two new subway lines, elevated Pearl LRT line and suburban rail line, combined with the poor and deteriorating traffic conditions for buses, may be following a similar trend, at least in the central city area.

Initial results from Taipei

Initial results from Taipei, China, have also been very positive, including:

- Improved traffic orderliness
- Improved operating efficiency of roadways
- Reduced traffic interference by bus stops
- Savings in travel times
- Reduced frequency and severity of accidents
- Improved bus operation, in terms of both efficiency and reliability
- Increased ridership of public transport (Jason Chang, 2002).

Taipei (China), along with Bogotá and other leading systems, is discussed in more detail in the Module 3b: *Bus Rapid Transit*.

Fig. 7

Porto Alegre, Brazil.

Lloyd Wright, 2001

transfer terminals, 27 km of median busways and 1 km of bus lanes, along 5 radial routes (Meirelles, 2000).

Porto Alegre employs a unique “Convoy” technique in organising its route structure. Platoons of buses operate on main corridors and stop simultaneously at station bays that provide space for three buses. At the end of the main corridors, the same buses continue onto separate community routes. Thus, rather than switching to feeder buses at transfer terminals, customers can complete their entire journey without transfers.

Asian experience

Kunming, China

Through a partnership with the city of Zurich, Switzerland, Kunming has become the first city in China to adopt the BRT concept.

Hong Kong, China

The Hong Kong bus system displays many features of BRT, including bus priority measures, advanced fare collection, comprehensive coverage, clean buses, and passenger information. The system is well integrated with Hong Kong’s Metro, with an extensive bus feeder network comprising more than 140 bus feeder shuttle routes connecting with railway stations including the MTR, KCR and Airport Express.

Fig. 8

Nathan Road, Hong Kong. Franchised bus operators concentrate along major traffic corridors where major commercial centres are located.

Karl Fjellstrom, June 2001

Fig. 9

Nagoya, Japan, marks the bus lanes with a coloured road surface.

Courtesy of John Cracknell, TTC, and the US Transportation Research Board.

Japan

Japan is currently hosting a 16-city Transport Demand Management program in which eight of the cities are developing bus improvement initiatives.

Taipei, Taiwan (China)

Taipei has developed a bus lane network of 57 km since March 1998 (at an average cost of

Fig. 10

Taipei commuters ponder the benefits of bus travel.

Jason Chang, 2002

US$500,000 per kilometre), in the context of a wider policy framework emphasising:

- A network of dedicated bus lanes;
- High quality transfer environments;
- Green buses;
- Intelligent Transport System (ITS) applications, including innovative passenger information systems;
- Transit-oriented development.

Taipei has pursued a number of innovative solutions to finding lane spaces for buses.

Fig. 11

With an initial 17 city program, Bus Rapid Transit is rapidly expanding in the United States.

Courtesy of US Federal Transit Administration

North American experience

Ottawa, Canada

Ottawa has one of the most successful BRT systems in North America with 26 kilometres of exclusive busways and a total system length of over 60 kilometres. Up to 200 articulated buses operate on the system per hour and handle peak capacities of approximately 10,000 passengers per hour per direction. The system is currently handling 200,000 passengers each day for an annual total of over 85 million passenger trips. The system is well integrated with other transport infrastructure including train stations, Park and Ride lots, and cycleways. The system also provides good examples of features such as traffic signal prioritisation and queue jumping for buses (Leech, C., personal communication, OC Transpo, Ottawa, 2002).

Ottawa's visionary system was developed at a time when many other cities were looking to much more expensive rail-based mass transit solutions, and in combination with transit-friendly land use development policies. Faced in the 1980s with anticipated increases in the metropolitan population, employment, and transit ridership, the transit operating agency OC Transpo strove to increase the efficiency and use of the existing bus system in the region.

OC Transpo considered that the region would be best served by an "outside-in" rapid transit development strategy. The downtown segment was the most expensive to construct and was therefore deferred in favour of less costly construction in the corridor leading to the downtown. The near term benefit/cost ratios were much higher for the relatively inexpensive outer segments than for the costly CBD links. Also, forecasts of future transit use indicated that the building of a costly tunnel or any other grade-separated facility in the downtown area could be safely deferred for 20 to 25 years (Shen *et al.*, 1998).

USA

Bus Rapid Transit is a success story of technology transfer from the developing world to the developed. Invented in Curitiba (Brazil) Bus Rapid Transit is quickly being replicated in North America, Europe, and Australia. In the United States, the initial 17-city program is rapidly expanding, and benefiting greatly from a national information sharing program.

Honolulu's successful CityExpress system has now been expanded to connect the system with a unified intercity service called CountyExpress. Pittsburgh initiated its busway program back in 1977 and now has three lines on 26 kilometres of exclusive busways.

Results from the US Bus Rapid Transit program are encouraging, as Table 2 shows. In virtually every case, travel times have been reduced and ridership levels have seen dramatic gains, though from a low base.

Table 2: Positive initial results from the US Bus Rapid Transit program.

City	Travel time reduction	Ridership increase
Pittsburgh	50%	80–100%
Los Angeles	25%	27–41%
Miami	N/A	70%
Honolulu	25–45%	N/A
Chicago	25%	70%

Source: US Federal Transit Administration

Fig. 12

The modern Civis bus on a busway in Rouen.

Courtesy of John Marino (Irisbus) and the US Transportation Research Board

European experience

France

France also has an ambitious Bus Rapid Transit agenda with such cities as Grenoble, Lyon, Nancy, and Clermont Ferrand in France opting for improved bus services.

Fig. 13

Ipswich, England. The unpaved centre strip reduces costs considerably, and also reduces noise.

Courtesy of US Transportation Research Board

Great Britain

Busways are becoming increasingly common in such English cities as Leeds, London, Reading, and Ispwich.

Australian and New Zealand programs

Several cities in Australia and New Zealand have launched Bus Rapid Transit programs. Operating systems are in place in Adelaide and Brisbane (see margin note on the Brisbane Busway). Systems are also being planned in Perth, Sydney, and Auckland.

The Brisbane Busway

Impressive initial results

Brisbane's Southeast Busway, which opened in April 2001, led in the first 6 months of operation to an increase in ridership of 12% along the same routes, compared to the previous year.

The Busway rapidly gained further popularity. After a year of operation, the service was recording 27,000 extra passengers per week, with patronage on core bus services up by 45%. A study in 2002 showed that property values along the Busway had risen substantially, though property values have also risen elsewhere in the city over the same period.

A long term solution for a rapidly growing metropolitan region

The Southeast Busway, to be followed by the Inner Northern Busway (due for completion in late 2003), is aiming to fulfill the long-term mobility needs of the city. It is seen as a long-term solution for the rapidly growing metropolitan area, rather than a transitional measure toward a rail-based system.

As in Bogotá, implementation of the BRT system is done in stages, with e.g., major extensions such as the Inner Northern Busway, and regular ongoing improvements at particular stations, interchange facilities, etc. For more information please see http://www.transport.qld.gov.au/busways/.

Fig. 14 ◀ ▲

The Brisbane Busway features excellent station design, 50 new natural gas "green buses", good passenger support and information, and excellent modal integration and marketing.
It has extensive grade-separation, elevated and underground, in the city centre area.

Karl Fjellstrom, April 2001

3.2 Light Rail Transit

Light Rail Transit (LRT) systems are a relatively new and promising concept for application in certain urban locations, though more relevant to wealthy than to developing cities. Comparable to BRT systems in terms of capacity, LRT produces no local emissions.

As with BRT, LRT lines are usually segregated from other means of traffic by barriers or slightly elevated tracks, or by full grade separation.

Current applications

LRT ranges from the conventional on-street tramways of Eastern Europe and Egypt to the elevated and segregated systems of Singapore and Kuala Lumpur. With the exception of the extensive tram systems of Central Eastern Europe and the former Soviet Union, LRT systems exist or have been planned only in relatively wealthy developing cities such as Hong Kong, Shanghai, Tunis, and Kuala Lumpur, or for high income developments such as the Tren de la Costa of Buenos Aires.

Recent examples of LRT systems in developing cities include the elevated Putra and recently opened (July 2002) monorail systems in Kuala Lumpur and Shanghai's Pearl line.

LRT and Metro lines in Shanghai

The elevated (for 80% of its length) "Pearl" LRT line (see Figure 15) in Shanghai serves high density, high-rise apartments to the north of the city centre. A second line is being built to form a rough circle with the existing LRT line.

The system provides excellent examples of well-planned modal integration. The northern point of the Red Metro line connects with the long distance train station. Bicycle parking is provided near all MRT stations. The major Shanghai Stadium interchange is located next to a major bus terminal. Figure 16 (see also Figure 20) shows the positive influence the MRT can have on land use in the city, with a row of high density developments focusing on the Shanghai Stadium area; a major transit interchange.

On the downside, it is doubtful that the system can be expanded at a pace to match the rapidly expanding city. New developments in outer areas combined with a frenetic road-building program tend to promote car-dependency. Traffic conditions and speeds in the city centre are already poor for buses and will worsen.

Fig. 15

'Shanghai City Plan' shows the two Metro lines in Green and Red, and the LRT line in purple.

Shanghai Tourist Map, Tourism Administrative Commission, 2005

The decline of trams in developing cities

Trams, historically a feature of many developing cities, retain a role in some cities, such as Hong Kong, but are in decline. In Cairo the percentage of all motorised trips by tram has fallen from 15% in 1971 to 2% in 1998 (Metge, 2000). Historically many developing cities had tram systems along major corridors, but these were dismantled to make way for increasing private car traffic. Tram lines, now largely paved

Fig. 16

The MRT system in Shanghai has had a positive impact on land use, with densification occurring along Metro routes.

Karl Fjellstrom, Jan. 2002

Rail system descriptions and maps, world-wide

For a comprehensive and reasonably up-to-date listing of current rail systems and projects world-wide, including for example rail projects and expansion plans in Bangkok, Guangzhou, Shanghai, Taipei, Santiago, Sao Paulo, Manila, Kuala Lumpur, and Hong Kong (several different projects) see http://www.railway-technology.com/projects/index.html.

Maps of rail systems world-wide are available at http://www.reed.edu/~reyn/transport.html.

Fig. 17

Cairo's dwindling, neglected tram system, though averaging only around 11 km/h speeds, offers a pleasant community atmosphere and a fare from the upmarket Heliopolis to downtown Cairo of less than US$0.07.

Karl Fjellstrom, March 2002

Fig. 18

City-centre tram LRT lines in Sapporo, Japan (top) and Frankfurt, Germany (right). In both cities the trams act as feeders to extensive Metro systems.

Karl Fjellstrom, 2002

over, are still visible in streets in many developing cities in Asia and Latin America. Cairo (Figure 17) is one of the few developing cities with a functioning tram system, though this has gradually dwindled to one line.

Renewed interest in wealthier cities

In many richer cities the trends of tram decline are reversed (see Figure 18). A European best practices report notes that the decline in tram use in Munich, for example, has been reversed and patronage has increased in the last 10 years through a program of tram priority at intersections and integration with other rail services (Atkins, 2001). Many other European cities have introduced and expanded tramways, both in the inner city (e.g., Amsterdam, Vienna, Frankfurt) and serving outlying commercial and leisure facilities (e.g., Oberhausen, Germany).

In North America, many cities have successfully combined public transport projects with a policy of revival of their city centre. Well-designed and planned LRT systems are attractive to passengers, even in car-dominated, low density North American cities. In the last 20 years, 14 cities in the US and Canada have introduced LRT systems.

Building 'transit malls' with LRT access, trees and pedestrian zones can encourage private investment in city centre office blocks, shops, and apartments.

3.3 Metros

Metros in developing cities carried about 11 billion journeys in 2000, more than twice the ridership of commuter rail and more than four times the ridership of LRT systems.

Both Metro and commuter rail systems require exclusive right-of-way (ROW) and safety measures due to relatively high speeds. To provide exclusive ROW many heavy rail systems are built underground or elevated, causing very high costs. Metro systems may cover their operational costs in urban areas with high population density, such as in Hong Kong or Sao Paulo, but normally they require subsidies. A successful Metro also requires integration with existing transport modes and policies, and planned densification around Metro stations.

Fig. 19

Mexico City has an extensive Metro system with 11 lines. Fares are low at a flat 2 peso, though the service is often overcrowded and run-down. An entrance is shown here, to the right of a bus lane.

Karl Fjellstrom, Feb. 2002

Fig. 20

Cairo's 63 km, two-line Metro carries 700 million passengers per year. Its stations, marked by a distinctive "M", have promoted development along its route (top) and also serve poor areas (above).

Karl Fjellstrom, Feb. 2002

Metro systems are being developed or expanded in several developing cities, such as Bangkok, Santiago de Chile, Kuala Lumpur, Sao Paulo, Buenos Aires, Mexico City (Figure 19), Cairo (Figure 20), Manila, Shanghai, and Hong Kong (see http://www.railway-technology.com/projects for a list).

Older, generally successful systems include Mexico City, Buenos Aires, and Sao Paulo, though in all cases the Metro ridership is far below the ridership of the bus system. In this module we describe the cases of Bangkok and Kuala Lumpur in more detail, as these cases illustrate the strengths and weaknesses of Metro applications in developing cities. While the Bangkok Skytrain system is described following, the Kuala Lumpur heavy rail and LRT systems are described in next section of the module, comparing costs of the various MRT options.

The Bangkok Skytrain (BTS)

Three separate mass transit schemes were initiated in Bangkok in the 1990s:

- The Bangkok Transit System (BTS or better known as the Skytrain), initiated by the Bangkok Metropolitan Administration;
- The failed Hopewell elevated rail project, initiated by the then Ministry of Transport and Communications;
- The Blue Line, initiated by the Mass Rapid Transit Authority (a 20 km underground rail line still in planning stage, connecting to the suburban and BTS systems).

Fig. 21

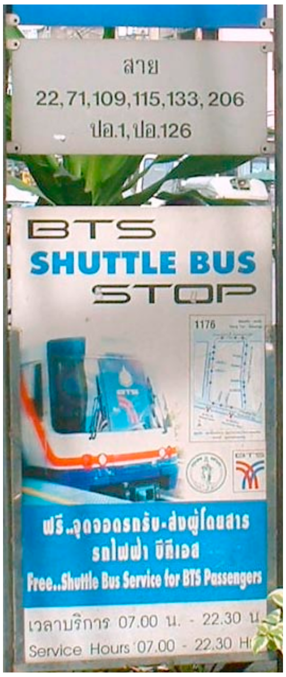
Victory Monument, Bangkok. BTS trains run on dual tracks, carried on a 9 metre wide viaduct, supported on single box viaduct girders, each 12 metres above the road level.

Karl Fjellstrom, Jan. 2002

Bangkok Skytrain service innovations

Recent Skytrain innovations include regular promotional events. All are advertised, both in the mass media and at the BTS stations.

In October 2001 a free shuttle bus service for pass-holding Skytrain passengers was implemented on 5 different routes. BTS cannot charge for these services. If they could, and BTS was able to determine routing, this would put pressure on the BMTA to change. Hence, a multi-modal concession for the BTS extensions (under construction) may be a good idea. Singapore's northeast corridor is an example of a multi-modal concession, with SBS—a bus operator—now also running trains.



The Skytrain, which opened in late 1999, is an elevated heavy rail system running above some of Bangkok's busiest commercial areas. It has a peak capacity of around 45,000 passengers per hour per direction. Trains run on 5 to 7 minute headways from 6 am to midnight, though as demand increases and for special occasions such as New Year's Eve, headways can be shortened to 2 minutes (Sayeg, 2001) and running time extended. The BTS has two lines, with a total length of 23.1 km and 23 stations. The lines intersect at the city centre station.

Tender documents for a turnkey BTS system were issued in March 1993 to five consortia. The agreement was later amended to cover not just the construction, but maintenance and operation of the completed network. (For further discussion of private sector participation in the BTS see Module 1c: *Private Sector Participation in urban Transport Infrastructure Provision*.)

Fares, ridership and operating costs

Fares range from 15–40 Baht, or around US$0.37 to $1.00. This is relatively expensive, even compared to air-conditioned bus fares for long trips, which are less than $0.50, or around $0.11 for shorter trips. Economy bus fares are much cheaper, from around $0.05 for short trips up to $0.20 for long trips.

First year ridership was only one-quarter of forecast ridership. Though it is improving, increasing from around 160,000 to 200,000 trips per day in its first two years of operation (average 280,000 weekday passengers in Oct. 2002), this is still only one-third of the forecast. Similar disappointing ridership has been recorded for recent urban rail systems in Kuala Lumpur (discussed later in this module) and in Manila (Metrostar). Diversion from car drivers to the BTS system appears to be relatively high, however, with around 10% of passengers being former car drivers. Interestingly, one-third of BTS trips are new trips.

Fig. 22

Each car is air-conditioned, and the BTS offers a comfortable and fast ride through the central city area.

Karl Fjellstrom, Dec. 2001

Ridership should, however, continue to increase, especially as densification around stations takes place (encouraged by rising land values near stations), road traffic to the central area becomes even more difficult, integration with other modes is improved, and complementary mass transit systems are completed.

Despite the initially disappointing ridership, an International Finance Corporation (one of the system's investors) funded study indicates that: *At present, BTS is covering operating and maintenance costs through the fare box. …As the marginal cost of carrying passengers on the BTS is well below the average cost, its cost recovery will increase markedly as patronage grows (IFC, 2001). BTS has also developed commercial spots in the stations and gets a considerable amount of revenue from this activity.*

Modal integration

Integration of BTS with other modes of transport is poor; a contributing factor to the disappointing ridership. The Bangkok Mass Transit Authority, Bangkok's monopoly bus services provider, has been slow to act. The BTS meanwhile has taken steps to provide its own feeder services (see margin note), but they are severely constrained. Some clear opportunities for modal integration were missed, with the northern line terminating only around 2 km from the newly constructed northern bus terminal, and no feeder service or pedestrian walkway connecting the two.

Facilities for bicycles are either not provided, or are located in an unsupportive environment for cyclists, and are therefore unused (such as at Ekkamai station). Eight stations are directly connected to adjacent shopping complexes.

Rolling stock

Thirty-five three-car, 1,100 passenger capacity trains, 65.1 metres long, are currently operated. The quality, cleanliness and reliability of the system are all outstanding. The three-car trains can in future be doubled in length at peak times.

Future arrangements

From the start of commercial operations, all operating revenue for the following 30 years was to be handed to BTSC. However, the current situation is that the BTS has been transferred back to the BMA, although BTSC still carries out the system maintenance.

The (inevitable) need for expansion

Almost all developing cities which are considering MRT applications or extentions are expanding at a rapid rate. It is therefore inevitable that Metro systems, which are very expensive and therefore often limited to one or two short lines, soon come under pressure for expansion to serve new areas of the city. This has also happened in Bangkok. BTS system expansion was approved in 1999, and construction has commenced but is proceeding slowly due to problems of cost and complexity. The four approved extensions add up to an extra 33.4 km (see further http://www.bts.co.th/en/btstrain_04.asp).

3.4 Commuter rail

Current applications

Commuter or suburban rail services are mostly provided by general railroad companies and they share track with freight and long-distance transport. While in theory the capacity would be limited to the number of available seats, in practice these services are often run at crush passenger loads in developing cities (Figure 23).

Suburban railways in developing cities are usually radially oriented into the city centre. Although even in relatively well-served cities like Bombay, Rio de Janeiro, Moscow, Buenos Aires, and Johannesburg, they carry less then 10% of trips, they can be important in supporting a transit-friendly city form and maintaining a strong city centre (Figure 24).

Fig. 23

An overloaded commuter train in Jakarta, Indonesia. Commuter/suburban rail services are in decline in many developing cities.

Kompas, 17–Jun–01

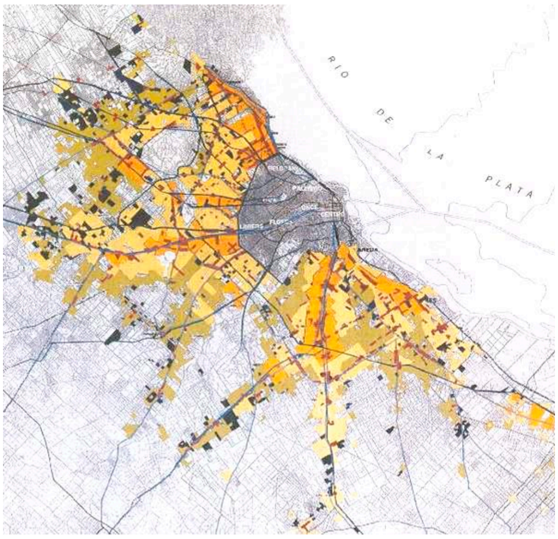


Fig. 24

Radial commuter rail lines have influenced the urban form in Buenos Aires.

Nora Turco, 2001

As shown in Bombay, where each day 6 million passengers are carried by suburban railways, this mode may even serve as a backbone MRT for a developing city. Like Metros, suburban railways need an independent institutional body which allocates funds and distributes

Commuter rail in Bombay

Fig. 25

Six million passengers per day are carried by suburban rail in Bombay, India.

Manfred Breithaupt, Feb. 2002, Churchgate Station, Bombay

Fig. 26

Market differentiation in Bombay extends to women-only carriages, similar to Cairo’s Metro.

Manfred Breithaupt, Feb. 2002

earnings, as well as fare and timetable intregration with other transport services.

Measures which can increase capacity and safety include the elimination of at-grade road crossings (or introduction of safety equipment), the purchase of double-deck-trains and improvement of boarding/alighting facilities, though in all cases the cost implications may be too large for many developing cities. As with all other MRT systems, high ridership on commuter lines requires feeder services (e.g., by bus) and good interchange facilities.

The rehabilitation and improvement of suburban railways show good cost-benefit-ratios and can contribute to poverty alleviation, as poorer people generally live further from the city centre.

The most serious obstacles to rail developments are frequently institutional. When operated by national rail organisations, suburban railways tend to be given low priority—in particular in comparison to the road lobby—and are poorly coordinated with other urban public transport services. In many cases the weakness of publicly owned national rail undertakings leaves their capacity severely underdeveloped (as in Manila, Jakarta, and Surabaya).

Positive experience with concessioning of commuter rail services

In Module 1c: *Private Sector Participation in Urban Transport Infrastructure Provision*, it was seen that positive experience is possible where these weaknesses are addressed. A program of concessioning to the private sector in Buenos Aires revitalised the system, doubling patronage over a five year period while at the same time reducing the budget burden of the system by nearly US$1 billion per year; although the system still requires an ongoing operational subsidy and operating conditions have considerably worsened in 2002.

In Brazil the transfer of responsibility for suburban railways from the highly centralised CBTU (Companhia Brasileira de Trens Urbanos) to local (state) control, together with a government funded rehabilitation program, has improved service in most of the major cities. Assisted by a program of concessioning, it is greatly reducing the fiscal burden.

4. Comparison on key parameters

Though ideally cities developing a MRT system will draw from different combinations of road and rail-based MRT, experience shows that most developing cities will probably focus on one choice for a MRT system. Once one form of MRT is implemented, it is likely that other MRT options will be neglected. It is therefore important that this choice is well informed.

4.1 Cost

For any municipality, the infrastructure cost of a transit system is a pre-eminent decision-making factor. Bus Rapid Transit is relatively economical to develop. Without costs of excavation and expensive rail cars, Bus Rapid Transit can be over 100 times less expensive than a Metro system.

> *"New subway systems in the US show that costs have been well above, and ridership well below, forecasts made when the projects were approved. This has also been the experience of many rail transit systems in developing countries."*
>
> Gregory Ingram, World Bank, *Patterns of Metropolitan Development: What Have We Learned?, Urban Studies*, Vol. 35, No. 7, 1998

The cost difference extends to other infrastructure items, such as stations. A busway station in Quito, Ecuador costs only about US$35,000 while a rail station in Porto Alegre that serves a similar number of persons costs US$150 M.

Fig. 27
BRT station in Quito, Ecuador: US$35,000

Fig. 28
Rail station in Porto Alegre: US$150 M

Thus, for the same amount of investment, a Bus Rapid Transit system can serve as much as 100 times the area of a rail-based system. A city with enough funding for one kilometre of Metro might be able to construct 100 km of BRT.

Capital costs for rail-based MRT

Capital costs usually cover planning and construction costs as well as technical equipment and rolling stock. The capital costs of US LRT systems are on average US$21.6 million per kilometre.

The capital costs depend on the extent of grade separation and right-of-way, as well as on specific geological conditions and the prices of building materials and labour, but also extend to planning procedures and institutions. Allport (2000) shows also that the effectiveness of planning procedures contributes to a large extent to capital costs. The study found that similar Metro systems in developing countries were much more expensive, for example, than a system implemented in Madrid (see Table 3). Table 4 provides a rough assessment of factors influencing rail-based MRT capital costs. Similar factors and influences can be assumed to apply to BRT systems.

Table 4 shows, perhaps counter-intuitively, that it is not the construction phase (with labour and equipment costs) or details in system features, but rather strategic decisions on management and organisation that have the greatest influence on MRT capital costs. Additionally the integration in the urban fabric and the fundamental decision of vertical alignment will have a major bearing on capital costs.

Table 3: Capital costs of various rail systems.

UTSR 2001; Allport 2000; GTZ 2001

Railway	Type	Cost/km (US$ M)	Notes
West Rail Hong Kong	Heavy Metro	220	38% tunnel
Kuala Lumpur – Putra	LRT	50	Elevated, driverless
Kuala Lumpur – Star	Heavy Metro	50	Largely elevated
Manila–Line 3 extension	Light Metro	50	Elevated
Bangkok Skytrain	Metro	74	Elevated
Caracas – Venezuela	Metro	90	
Mexico City	Metro	41	
Madrid	Metro	23	
Tunis	LRT	13	
Recife–Brazil	Comm Rail	12	

Table 4: Factors influencing Metro capital costs.

Adapted from Allport 2000

Influence	Factor
Dominant	- Management/organisation quality - New system, or progressive expansion of existing system
Large	- Ground conditions (underground construction, and foundations for elevated viaducts) - Urban constraints and topography (utilities diversions, proximity to buildings, ability to divert traffic, environmental constraints, earthquake protection) - Design and safety requirements - Financing costs - Depth of water table (can make cost prohibitive for underground)
Moderate	- Land costs - Competition in the equipment supply and construction market
Small	- Labour costs - Taxes and duties - System features (long trains, AC, special access, etc.)

Fig. 29
BRT: US$1–10 million per kilometre

Fig. 30
Metros: US$55–207 million per kilometre

Table 5 underlines the impacts of alignment decisions on capital costs for rail MRT systems.

Table 5: Impacts of alignment on cost: rail-based MRT.

Allport 2000

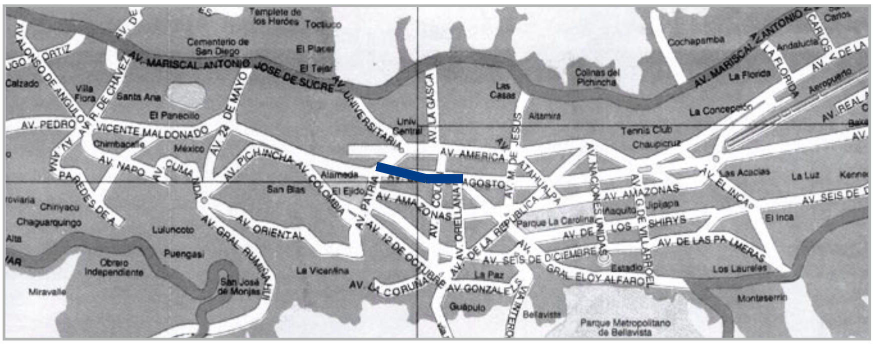
Vertical alignment	All-in cost (US$ M) per route km	Ratio
At-grade	15–30	1
Elevated	30–75	2–2.5
Underground	60–180	4–6

Further information on comparisons, and transit levels of service

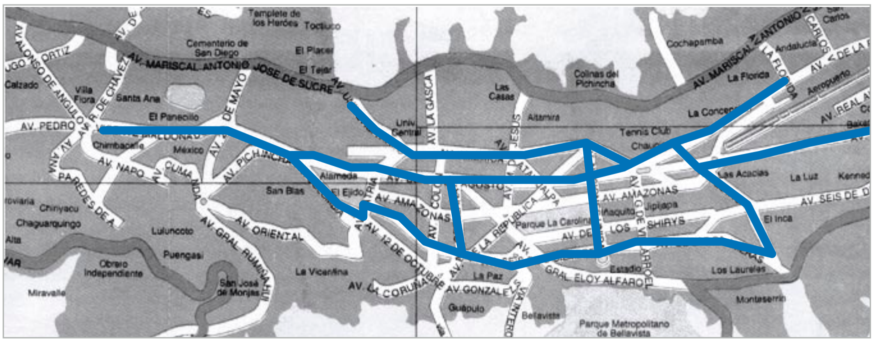
More information on transit level of service, relevant to comparisons between modes—although from a North American rather than developing country perspective—can be obtained from the *Transit Capacity and Quality of Service Manual* (http://kittelson.transit.com), prepared for the Transit Cooperative Research Program (TCRP), 1999.

Fig. 31

Two systems at the same cost: (1) Rail



(2) Bus Rapid Transit



Capital costs for Bus Rapid Transit

Whereas rail-based MRTs may cost from US$20–180 million per kilometre, Bus Rapid Transit systems are an order of magnitude cheaper: US$1–10 million per kilometre.

We can view these cost differences graphically, in terms of the length of MRT system achievable for roughly the same cost.

Table 6 summarises costs of Bogotá's TransMilenio BRT system, discussed in more detail in Module 3c: *Bus Rapid Transit.*

Table 6: Infrastructure cost components of Bogotá's TransMilenio BRT system.

Lloyd Wright, 2002

Component	Total cost (US$ million)	Cost per km (US$ million)
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**

Operating costs

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.

Rail systems do have an apparent operational cost advantage from the standpoint of labour costs, specifically with regard to the cost of a driver. Bus coaches each require a driver while several rail coaches connected together only requires a single driver. However, in developing nations, the lower wage differentials mean that this advantage is largely overwhelmed by the other components. Porto Alegre, Brazil offers a unique opportunity to compare urban rail and BRT operating costs on an even basis. The city has both types of systems operating in similar circumstances. The Trensurb rail system requires a 69% operating subsidy for each passenger trip (Thomson, 2001). 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.

Profitability of bus systems in developing cities

Public transport by bus in developing countries is already characterised by a high level of cost recovery, and usually such services operate at a profit. The fact that such services can be profitable under inferior and deteriorating operating conditions (chiefly congestion), and a poor and unsupportive regulatory and planning framework, indicates that where a range of operational and regulatory improvements encouraging competition and service innovation are implemented along with physical measures such as bus priority, there is little doubt that BRT in developing cities will be profitable.

In addition, the form of many developing cities is still suited to transit, as development is often still channelled along major arterials rather than dispersed to all areas of the city. Even car-saturated cities such as Bangkok can be more accurately considered “car-saturated transit cities” rather than “car-dependent cities”. These circumstances (unlike in car-dependent cities where activities are highly dispersed) tend to favour a high ridership.

Rail system operating costs

Operating costs include salaries, fuel and maintenance of both vehicles and infrastructure. The operational costs depend partly on the amount of cars required to provide a service. The higher operating speeds the lower the circulation time and in consequence the number of cars needed for a single line.

> ***“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.”***
>
> Gregory Ingram (*op cit*)

A recent US survey (GAO, 2001) confirms that operational costs of LRT systems are much higher than for BRT. The report compares six US cities having both LRT and BRT systems. It refers to three categories of operating costs:

- Costs per vehicle hour;
- Costs per vehicle revenue km;
- Costs per passenger trip.

Operating costs per vehicle hour of 5 LRT systems are between 1.6 to 7.8 times higher than those of BRT systems. LRT operating costs per vehicle hour ranged from $89 to $434. Similar findings were made for operating costs per vehicle revenue kilometre.

The World Bank (2001) provides some figures for developing countries (see also Table 1). Operating costs per passenger range from US$0.61 in Hong Kong to $0.19 in Santiago, while revenues per passenger range from $0.11 in Calcutta to $0.96 in Hong Kong.

Fare Box Ratio

The Fare Box Ratio gives an indication of economic viability of a MRT system. It describes the ratio between fares collected and operational costs. Table 7 indicates that five railway operations are able to cover operational costs and to use the surplus for depreciation of infrastructure. These are exceptional: Most railway operations are subsidised by an agency or surpluses in other branches of the city budget.

Table 7: Fare Box Ratios, selected rail MRTs.
TCRP 1999, Allport 2000, GTZ (edited)

Railway	Fare Box Ratio
Regional Metro Porto Alegre	0.25
Kuala Lumpur Putra LRT	0.50
Buenos Aires Metro	0.77
Kuala Lumpur Star Metro	0.90
Sao Paulo Metro	1.06
Singapore Metro	1.50
Santiago Metro	1.60
Manila Light Metro	1.80
Hong Kong Metro	2.20

Fare Box Ratios of BRT systems

The Fare Box Ratio of BRT systems in Porto Alegre, Curitiba, Bogotá, and Quito exceeds one, as do most bus systems throughout the developing world.

Furthermore, as shown in Module 3c: *Bus Rapid Transit* (see Figure 6) revenues from the TransMilenio BRT in Bogotá do not only cover operating costs for the trunk line operators, but also cover a range of other costs, including the costs of the feeder services, the system planning and regulatory body (3% of fare revenues), the fare collection company, the funds administrator, and a contingency fund.

Rolling stock

Table 8 provides an approximation of the cost difference between buses with different

Table 8: Costs of various bus technologies, compared to a standard rail car.
International Energy Agency, 2002.

Propulsion technology	Cost per vehicle (US$)
New diesel, constructed in developing country	30,000–75,000
New diesel (Euro II)	100,000–300,000
CNG, LPG bus	150,000–350,000
Hybrid electric bus	200,000–400,000
Fuel cell bus	1.0–1.5 million
Metro rail car	1.7–2.4 million

Extra costs of new technologies

Providing refueling infrastructure can also be a consideration. According to the International Energy Agency, refueling instrastructure and other support system costs for fuel cell buses cost approximately US$5 million.

A major additional cost for new technologies such as fuel cells, which is not included in Table 8, is the cost of research and development for the transit agency concerned.

propulsion systems, compared to a standard rail car. The purchase cost does not include substantial and ongoing additional costs such as specialised maintenance, and research and development needs that accompany the most advanced technologies.

Public finances

In terms of public sector affordability, BRT is the most favourable form of MRT system. BRT systems require a relatively small initial outlay. Bogotá, for example, was able to build the system's first phase of around 40 km without taking out loans.

Savings, meanwhile, can be used in other areas, such as health and education, public space facilities, and conditions for pedestrians and cyclists.

Rail systems—both LRT and Metros—require much greater initial outlays and ongoing subsidies. Though the advent of private sector concessionaires was expected by many to change this situation, the evidence is that the various new Build-Operate-Transfer projects are all in financial trouble and are nowhere achieving profitability (see further Module 1c). Alone among rail MRT systems, the Hong Kong Metro funds all its costs (capital, asset replacement, and operating) from its mainly farebox revenues, and can be considered profitable. All other rail MRT systems require support from the public sector; often very substantial (Allport, 2000).

The problems encountered by new rail MRT systems in developing cities are in many ways illustrated by the experience of the Star and Putra rail MRT systems in Kuala Lumpur, Malaysia (see text box on the next page).

Construction time advantages of bus rapid transit

Bangkok's Skytrain system took four-and-a-half years to establish, from the time of signing the construction contract to first operation.

Bogotá's TransMilenio BRT system—with 56 stations compared to the Skytrain's 25 stations and with a large range of associated improvements such as pedestrian and cyclist facilities, public parks and so on—took less than 3 years from concept to full implementation. The actual physical construction of the entire system, including the associated public space improvements, took only around 8 months.

Construction time

Fig. 32

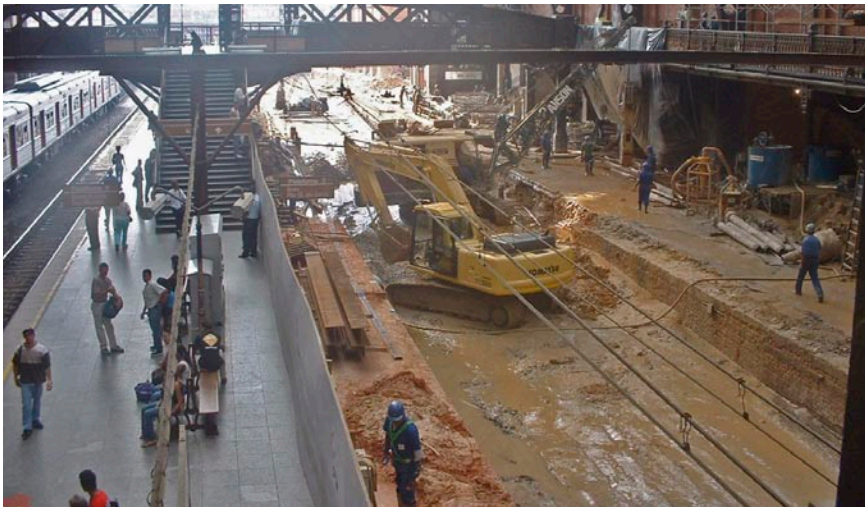
BRT: < 18 months ▸

Lloyd Wright, 2001 (Bogotá)

Fig. 33

Metros: > 3 years ▾

K. Fjellstrom, Feb. 2002 (Sao Paulo)



4.2 Planning & construction time

Project development and planning

The project development and planning process is generally quicker for BRT than for rail-based MRT systems. The BRT planning process for a 'world class' BRT system, described in Module 3c: *Bus Rapid Transit*, takes about one year and costs around US$400,000–US$2 million.

Due to the relatively low costs, financing is also generally easier and quicker for BRT than for rail-based systems. Jakarta, Indonesia, for example, decided in late 2001 to implement a BRT system, and the government was able to quickly allocate funds from the routine city development budget.

> *"Mayors who are elected for only three or four years can oversee a BRT project from start to finish."*

Construction

The simpler physical infrastructure of Bus Rapid Transit means that such systems can also be built in relatively short periods of time, often in less than 18 months. Underground and elevated rail systems can take considerably longer, often well over three years.

This time difference has a political dimension. Mayors who are elected for only three or four years can oversee a BRT project from start to finish. Successfully implemented BRT systems have positively influenced the re-election and political careers of mayors in cities such as Curitiba and Bogotá.

Rail-based MRT in Kuala Lumpur

Malaysia has developed several new rail MRT systems, often portrayed as paragons of technological progress and sophistication. But are they sustainable? The systems include STAR Light Metro (operating from Dec. 1996) Putra LRT (from Dec. 1998), the KLIA Airport Express (from Apr. 2002), and the Monorail LRT (from July 2002). The various rail systems all intersect at the city centre, though there is no fare integration between them.

Fig. 34

Putra's grand Dang Wangi station is often deserted. Pedestrian access is difficult, with no crossing provided in front of the station.

In its first three years of operation Putra's ridership increased 10-fold, from 15,000 to 150,000 passengers per day. This increase in ridership, however, was only achieved after substantial fare reductions which probably had a negative overall effect on revenue (Sayeg, 2001). Despite this ridership gain, however, Putra has been a financial failure and along with STAR the venture was nationalised in late 2001. After only 3 years of operation, Putra had accummulated debts of more than US$1.4 billion (see margin note).*

The Monorail and KLIA airport services

KL's monorail, linking the LRT lines, was due to open in mid 2002. However, a mishap during a trial run in July (a wheel fell off, striking a journalist) has led to the opening being delayed until early 2003. Major commercial areas and trip attractors—many currently under construction—line its route.

Two rail connections to the city's International Airport, 70 km from the city centre, are also being built. One of these, the US$260 million, 57 km KLIA Airport Express line, opened in April 2002 but at only 3,000 passengers per day (and a hefty fare of US$10), ridership has been well below forecasts.

Fig. 35

Kuala Lumpur's city centre monorail has experienced many delays in construction since 1997. Though it serves thriving commercial areas and interlink with the other rail systems, after the experience with STAR and Putra, the government must be questioning the financial viability of its rail-oriented MRT strategy.

Fig. 36

This makeshift tent (above) serves as the major bus stop at Kuala Lumpur's largest shopping mall (top left). Buses are infrequent and overloaded, and passengers are forced to scramble past taxis (above). The megamall is actually only around 1.5 km from an LRT station, though no feeder bus service to the mall is provided, and nobody walks from the LRT station to the megamall, as the walkway is pot-holed, very narrow, and unprotected from the sun and rain (top right).

Photos Karl Fjellstrom, Dec. 2001

Gov't completes takeover of two LRT operators

Kuala Lumpur 1:51pm, Fri: (AFP)—
The government today completed the takeover of two debt-ridden light railway companies in its largest ever restructuring exercise, dealers said.

The government issued four tranches of bonds totalling RM5.467 billion with maturities of five, seven, 10 and 15 years in a debt conversion scheme to settle the two companies' debts, bond dealers said.

The serial bonds will be issued to creditors of Projek Usahasama Transit Ringan Automatik (Putra) and Sistem Transit Aliran Ringan (Star) in the debt replacement, they added.

The deal, made through a special purpose vehicle Syarikat Prasana Negara, would see the government acquiring 80% of the assets of both operators, the *New Straits Times* said.

The railway networks are to be leased back to the private firms to operate.

Putra, which is owned by debt-ridden conglomerate Renong, is the biggest debtor among the two, with total debts amounting to RM4.27 billion, the newspaper said.

* **Note:** On 1 Sept. 2002 Syarikat Prasarana Negara Berhad (SPNB), a wholly-owned subsidiary of the Minister of Finance, completed the sale and purchase of the assets and business operations of Sistem Transit Aliran Ringan Sdn Bhd (STAR) and Projek Usahasama Transit Automatik Sdn Bhd (PUTRA) from the Renong Group. SPNB said it will continue operating STAR and Putra.

Under-achieving new urban rail systems in the Asia-Pacific region

Star, Putra, and KLIA Airport Express MRTs in Kuala Lumpur, Metrostar in Manila (17 km, Dec. 1999), the Sydney Airport rail link (10 km, June 2000 and now in receivership), the Hong Kong Airport Express Rail (34 km, mid 1997), the Bangkok Sky Train, and the Brisbane Airtrain airport link: all of these new MRT rail systems have shown disappointing ridership, generally about one-quarter the projected levels. From these systems the longest in operation, Star, has stabilised at around 20–25% of projected ridership. Brisbane's Airtrain opened in May 2001 and operates without government subsidy. However the Airtrain has an uncertain future, with ridership of just 6,000 per week compared to a projected 52,000 per week.

An important factor here is the fare: the Singapore and Hong Kong successful MRT systems have fares comparable to air-conditioned bus services, and, relative to income, are about one-quarter as expensive as fares in Bangkok, Manila, and Kuala Lumpur (Sayeg, 2001).

Fig 37

People walking or taking a bus to the megamall (see Figure 36) must cross a busy road with no help from signals or road markings. Not surprisingly, almost everyone gets to and from the mega-mall by car or taxi. Long queues form all day for taxis.

Photo Karl Fjellstrom

Rail at the expense of bus services?

Though Kuala Lumpur has made much recent progress, including many initiatives to improve conditions for pedestrians in the city centre, and major new rail facilities, bus services remain unreliable, unintegrated, unprofitable, and neglected (*The Star*, 21 Dec. 2001).

The lack of attention to buses is reflected in the poor conditions at Kuala Lumpur's main bus station. The bus station is a stark contrast to the shiny new expressways and rail lines of modern KL. Litter is scattered around and water forms standing pools. The litter and water, combined with the confined exhaust smoke (there are no exhaust fans and little circulation), foul odour, slippery stairs, and poor lighting, contributes to a wholly unpleasant experience for passengers. (This situation should be rectified by a major new bus terminal under construction in the city centre, which integrates directly with the Star MRT line. Further improvements were achieved with the opening in 2002 of KL Sentral Stesen, the new central rail station, which links the Metro and LRT systems with the commuter rail lines.)

It is not just Kuala Lumpur which is preoccupied with large-scale projects to the detriment of bus systems and non-motorised transport. In developing cities ranging from Jakarta to Buenos Aires, Bangkok to Guangzhou, Ho Chi Minh City to Surabaya, policy-makers have consistently given more attention to large-scale, expensive projects such as expressways, ring roads, LRT, and Metros, rather than to lower cost approaches.

4.3 Passenger capacity

Misconceptions abound about the potential of BRT, especially in dense developing cities. A common misconception is that "Any city seriously wishing to move toward sustainability by changing the private car/public transport equilibrium…must move in the direction of electric-rail-based transit systems" (Newman & Kenworthy 1999, p. 90). Table 9 draws from Newman & Kenworthy's book to present—and then counter—several typical "myths" of BRT.

Another misperception is that Bus Rapid Transit cannot serve high passenger numbers. The results in Colombia and Brazil show that Bus Rapid Transit can handle passenger flows in the range of 20,000 to 35,000 passengers per hour per direction. Table 10 shows passenger numbers actually recorded for different systems in selected cities. Some of the biggest factors determining capacity is not the mode of transport but rather the techniques used for boarding and alighting.

Table 9: Some 'myths' of Bus Rapid Transit.

'Myth'	In fact…
Only rail systems are fast enough to compete with the private car (p. 90)	May be true in some cases, though a recent study (GAO, 2001) shows that in 5 of 6 US cities with both BRT and LRT, BRT was faster
Buses are effective in transit cost recovery only where there are large numbers of captive users, as in newly developing Asian cities (p. 117)	Success to date with BRT has come from cities other than developing Asian cities, including Latin America and Canada. Curitiba has the largest car-ownership in Brazil, after Brasilia
Rail systems offer a "more fundamental way to recover transit costs" (p. 117) and are "c…heap in comparison to…any highway option" (p. 155)	Many developing cities have tragically wasted scarce development funds on expensive infrastructure megaprojects. BRT is a cheaper option
Buses cannot cope with a high passenger demand (p. 196)	Passenger flows in many BRT systems regularly reach more than 25,000 pax/hr/dir
LRT is a natural progression 'up' after BRT (p. 200)	BRT is implemented as a long term strategy in many cities

Table 10: Actual and theoretical maximum ridership, selected MRT systems.

Line	Type	Ridership (pass/hr/dir)
Hong Kong	Metro	81,000
Sao Paulo East Line	Metro	60,000
Santiago La Moneda	Metro	36,000
London Victoria Line	Metro	25,000
Buenos Aires Line D	Metro	20,000
Buenos Aires Line E	Metro	5,000
Mexico Line B	Metro	39,300
Bangkok BTS	Metro	50,000*
Kuala Lumpur Putra	LRT	30,000*
Bogotá TransMilenio	BRT	33,000
Recife Caxanga, Brazil	BRT	29,800
Belo Horizonte, Brazil	BRT	21,100
Goiania, Brazil	BRT	11,500
Sao Paulo 9 de Julho	BRT	34,911
Porto Alegre Farrapos	BRT	25,600
Porto Alegre Assis	BRT	28,000
Quito Trolleybus	BRT	15,000
Curitiba Eixo Sul	BRT	15,100
Ottawa Transitway	BRT	10,000

* Theoretical max., not actual ridership. Putra ridership is approx. 150,000 per day; BTS less than 300,000 passengers per day.

Source: Lloyd Wright; GTZ; from various sources, 2001

Capacity and patronage are cardinal points when it comes to assessing the financial viability of a MRT. Capacities up to 30,000 passengers per hour per direction (pphpd) are currently handled by bus while capacities exceeding 35,000 pphpd can only be handled by Metros.

The maximum recorded ridership of most LRT systems are limited to approximately 12,000 pphpd, although the Alexandria-Rami (Egypt) line serves 18,000 pphpd.

The necessity for very high capacity flows in part depends upon the structuring of a system. Cities such as London and New York are fairly dense and enjoy high usage of their Metro systems. However, peak capacities are only in the area of 20,000–30,000 pphpd. This occurs, because these systems feature multiple lines distributing passenger flows about the city. In cities such as Hong Kong and Sao Paulo, the higher capacities are achieved by offering a limited number of lines and then feeding large passenger numbers into a single corridor. Sometimes this situation occurs due to geographical constraints (Hong Kong), but it is often due to a lack of funding for a city-wide Metro system. Thus, in a sense, the high capacity figures become inevitable. However, such situations can be avoided by offering more distributed systems.

Whether a city is utilising bus or rail transit systems, system designers may wish to keep capacity figures within manageable bounds. If a system is operating at over 50,000 pphd and a technical or operational problem occurs, the entire system can become overwhelmed with passenger backlogs very quickly. Further, very high capacity lines can be uncomfortable and unsafe for passengers if tight passenger "packing" becomes necessary.

4.4 Flexibility

Unlike rail-based options which are by nature more fixed, BRT allows a great deal of flexibility for future growth. Making new routings and other system changes to match demographic changes or new planning decisions is fairly easily accomplished. Bogotá's plans for a phased BRT expansion (see Figure 38) provides a good example of matching technology to the dynamics of urban centres.

Fig. 38: Growing and changing with the city

TransMilenio 2001 *TransMilenio 2015*

TransMilenio, SA, Bogotá, Colombia

BRT systems provide greater flexibility than LRT in implementation and operation. Improvements such as signal prioritisation and interchanges, which improve capacity and bus speed, can be added incrementally.

Since buses approach and leave busways at intermediate points, many different routes can serve a passenger catchment area, with fewer passenger transfers than would be required in a fixed

Flexibility in operation

Bus-based systems' ability to operate both on and off a busway or bus lane provides Bus Rapid Transit the flexibility to respond to operating problems. For example, buses can pass disabled vehicles, while Light Railtrains can be delayed behind a stalled train or other vehicle on the tracks. Thus, the impact of a breakdown of a Bus Rapid Transit vehicle is limited, while a disabled Light Rail train may disrupt portions of the system (GAO, 2001).

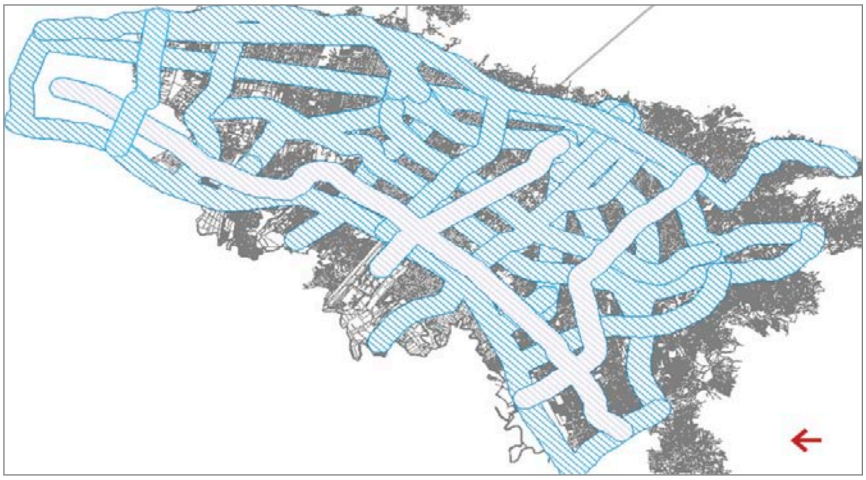


Fig. 30

A medium term goal in Bogotá is to expand the TransMilenio BRT system so that 85% of the city's 7 million inhabitants live within 500 meters of a TransMilenio line. Such an expansion program would be unrealistic for a rail-based MRT system.

Enrique Penalosa, 2001

guided system. This is an important feature of Curitiba's successful system, where express buses combine some feeder features at the extremity of the route, thereby minimising transfer needs of passengers. Bus Rapid Transit can also more closely match capacity and service quality to changing passenger demands and special events, and buses are more able to segregate the market, providing a range of services (air-conditioned, express, etc.).

> *"Expanding and adjusting a rail system is much more costly and complex."*

In terms of flexibility to expand and adapt to a changing city, Bus Rapid Transit offers clear advantages over a rail-based system (Figure 30). Expanding and adjusting a rail system is much more costly and complex. Developing cities following rail-based MRT approaches have quickly encountered a need to expand their initial limited systems. Bangkok is a typical example; similar situations apply in Cairo, Shanghai, Buenos Aires, and virtually all developing cities which have developed rail-based MRT systems.

4.5 Speed

Grade separated Metros, LRTs and BRTs can operate at high speeds. Street-running LRT systems like Alexandria-Madina (Egypt) perform less well due to interferences from street traffic and maintenance problems.

A recent comparative study between BRT and LRT systems in the same city found that bus systems on segregated bus lanes can easily match urban rail transit in terms of velocity (Figure 31). Thus, low-cost bus systems can match the travel times of expensive rail systems.

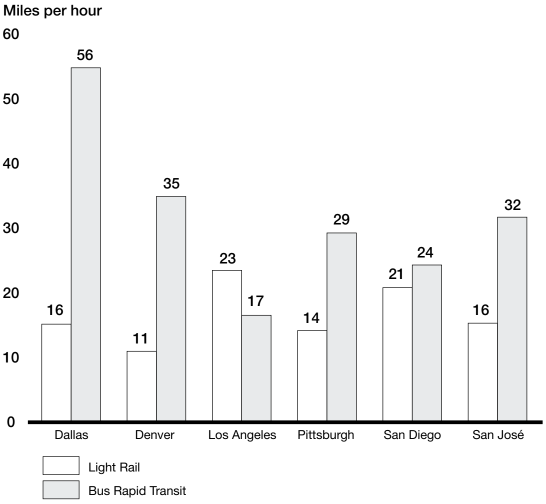


Fig. 31

In five of six cities with both BRT and LRT systems, BRT speeds were higher. The one exception was Los Angeles, where the BRT system does not provide dedicated bus lanes.

GAO,2001 (from National Transit Database and six transit agencies)

4.6 Institutional capacity for successful implementation

Institutionally, rail-based systems are demanding: *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. Accordingly it is usually necessary to set up a new institution with new people and fresh ideas (Allport, 2000).*

A BRT system also poses major institutional challenges. The need for a 'new institution' cited above probably also applies to BRT in developing cities, as the experience of Bogotá suggests. Bogota created a new institution to plan and regulate TransMilenio.

The scope of the challenge

Various basic prerequisites of successful rail-based MRT projects include (Allport, 2000):

- Corridors with outstanding trip volume (more than 700,000 trips per day);
- More than 5 million inhabitants or linear spatial development;
- At least US$1,800 *per capita* annual income at the city level;

- A city management with positive experience with traffic regulation;
- Integration of other modes/fares;
- Competitive fares;
- A strong institutional framework;
- Steady population growth combined with economic prosperity;
- City center growth.

Even where such circumstances exist, institutional capacity may be insufficient for Metro implementation in developing cities. Even where corridor size, city income, growth prospects, city centre growth, low cost alignment, fares policy, city management, and Metro management needs are met, Allport (2000) compared the options and concluded that:

Metros are a different order of challenge, cost and risk…most likely to be applicable to serve the largest corridors of the biggest and more affluent developing cities.

Institutional challenges—and associated risks and costs—are much higher for rail-based MRT compared to BRT.

Role of the private sector

Private sector involvement in MRT construction and operation can be highly beneficial to all parties, provided the government is able to establish an appropriate regulatory setting. The case of Bogotá provides an excellent illustration of how to successfully draw upon the private sector to build and operate a BRT system (see text box). Buenos Aires is often cited as a success story of concessioning of suburban rail services to the private sector, although in the case of rail-based systems the situation is more complicated in that the government will almost always be required to provide an ongoing subsidy.

In the case of Kuala Lumpur, this ongoing subsidy resulted finally in the nationalisation of the rail MRT systems in 2001.

Reasons for the failure of the private sector involvement included:

- Overestimation of demand;
- Weak sectoral policies (no private car restraint; poor integration with buses; no integrated land use and transport policies; and a new tollway along a similar alignment);
- Inadequate institutional arrangements, with both fragmentation at the level of implementation and excessive centralisation at the level of policy-making contributing to a lack of transparency and a poor policy framework for making MRT investments.

TransMilenio & the private sector

TransMilenio S.A., a publicly owned company that provides PLANNING, MANAGEMENT, and CONTROL.

Infrastructure is developed and paid for by the local government:

- Trunk lines
- Stations
- Maintenance facilities
- Complementary infrastructure.

Fare collection is managed by the private sector:

- Smart cards
- Financial management and disbursements.

Bus operations are provided by 7 concessioned private sector bus companies (plus an additional 7 companies providing feeder services):

- System operation
- Bus procurement
- Employee management
- Maintenance.

Bus-based systems throughout the developing world, on the contrary, are often operated without subsidy by the private sector, even in a highly unconducive policy setting and poor and deteriorating operating conditions. Where private sector involvement is well-regulated, a quality MRT service can be provided at a relatively low fare, providing profit to the private sector operators and operating without subsidy.

Supportive policy setting

Successful MRT projects require additional measures in urban transport policy. Ideally infrastructural and institutional improvement will complement one another. The high capital costs of rail based MRT—and also but to a lesser extent BRT—will not be justified if shortcomings in urban and transport planning offset

Long term benefits of mass rapid transit

Perhaps the major long-term benefit of a mass rapid transit system, rail or bus-based, is the effect it has in concentrating a city's development along transit-accessible lines and nodes, and resisting urban sprawl.

Strong public transit systems and transit-oriented development are an essential ingredient in any strategy to reduce the level of "auto-dependency" of a city.

Cairo's MRT reduces pressures for urban sprawl

This is evident for example in Cairo, Egypt, where an impressive 60 km heavy rail metro network along major corridors now carries 20% of all motorised passenger trips in Greater Cairo. Without the metro network, north-south corridors and the city centre would have been overwhelmed by congestion, and development would have been forced into peripheral areas much earlier.

Metge, 2000

the benefits and harm operating conditions. Supportive policy settings include transport demand management, suitable land use planning, economic instruments, modal integration with non-motorised transport, public awareness and support, viable financing, and so on (see Module 3c: *Bus Rapid Transit*). This integrated and comprehensive approach to transport planning is evident in the successful MRT cases such as Bogotá, Curitiba, Singapore and Hong Kong.

Experience from several developing cities shows that this supportive policy setting for MRT will be easier to achieve where one institutional body provides MRT planning and regulation.

4.7 Long term influence on city development

MRT and city form

Importantly for land use patterns and transit-friendly development, nearly all MRT systems enable continuing city centre growth. A mass transit system is an indispensible aspect of a sustainable transport system for a large city, and in developing countries can play an important role in shaping future development of the city, leading to a transit-friendly city form.

It may, however, be unrealistic to expect major reductions in road congestion in developing cities. MRT infrastructure projects have only minor impacts on car ownership and use. Car ownership is generally more influenced by parking space supply and ownership costs rather than by MRT supply. This applies particularly in traffic-saturated developing cities like Bangkok. In Bangkok, 10% of all BTS passengers were previously car drivers, although there seems to be such a pent-up, suppressed demand that reductions in congestion are quickly absorbed by new trips.

Fig. 32

Curitiba's 5 BRT lines are lined with high density apartments, offices and commercial developments.

Karl Fjellstrom, Feb. 2001

The smart office buildings that line the corridors of Curitiba's bus system bear witness to the positive developmental impacts of Bus Rapid Transit (Figure 32). Businesses locate near bus lines and stations, because of the synergies with customer traffic. And likewise, the development helps provide a critical mass of customers to make the transit system economically viable.

MRT and development

Mass Rapid Transit stations help catalyse new economic and employment opportunities by acting as nodes of development.

This has been the experience in Bogotá, with rising land values in the vicinity of TransMilenio stations and strong demand from land-owners and businesses for the construction of stations in their local areas. Bogotá implemented an innovative value capture scheme in which the windfall benefits to landowners in the form of rising land values was partially diverted to help fund the construction of the stations.

Rail-based MRT systems can have similar effects, though in the case of bus and rail the government plays a crucial role in promoting development around stations and along routes.

However at the city-wide level the effects on city structure will be weaker than hoped for when unrestricted car use and weak building laws encourage urban sprawl and lower urban densities. Hong Kong's success, for example, results both from a well-designed and highly productive MRT-system and an enforced policy of high-density residential or commercial areas around the stations. In Paris the concept of five edge cities was fostered by the implementation of a heavy rail system (RER) linking these edge cities with the centre of Paris. In the city centre the RER is integrated with the underground network. However even in Paris, where the city centre is served by an excellent public transport system, car use has been increasing and densities falling, due to the lack of a policy of strong restriction of car use.

4.8 Poverty alleviation

In the World Bank *Urban Transport Strategy Review*, Allport (2000) points to a 'dilemma' in MRT policy for developing cities:

> *At the centre of MRT policy for developing cities is the apparent conflict between tackling poverty alleviation, for which affordable service is critical, and attracting car users, for whom service quality is critical.*

Experience with BRT, and with quality bus services in general, show this may be a false dilemma. Cases such as Curitiba, Bogotá, Sao Paulo, and Quito show that BRT systems in developing cities can provide an excellent service popular with high and low income users, and be profitable at a low fare. In comparison, rail systems provide a more limited geographical coverage—especially for poorer people relying on road-based transit (see Figure 33).

Mass Rapid Transit can play an important role in alleviating—or exacerbating—poverty. It is the poorest people who most depend upon public transit for access to jobs and services. In some cities the urban poor pay up to 30% of their income on transport. The poor also typically live in lower rent areas on the outskirts of the city (see Figure 34), and in some cases spend two to four hours commuting each day. Most importantly, public funds which are not poured into road-building and rail can be spent on improving health, education, public space, and quality of life of the urban poor.

Concentrating on the transport modes of poor people calls for the provision of affordable forms of public transport, although public transport should not be viewed as only for the poor, as wealthy European and Asian cities show.

Large cities in the developing world are centres of economic growth and magnets for poor people from the countryside, who often settle in the outskirts and along traffic arteries. They are heavily affected by noise and pollution.

Improved transit possibilities will provide faster access to work-places and enable more people to work. The MRTs in Cairo, Mexico, Bogotá and elsewhere are used extensively by poor riders who profit from quick access to the city centre and hence additional employment possibilities.

Fig. 33

A typical low income area of Cairo. Paratransit provides a feeder service to the Metro terminus.

Karl Fjellstrom, Mar. 2002

4.9 Environmental impact

Energy use by different transport modes, which is closely related to emissions, is presented in Table 11. Rail is the most environmentally friendly type of MRT in terms of energy use per person-kilometre, though only

MRTs: Poor service for the urban poor?

We should not assume low fares are the most important factor for low income users of public transport in developing cities. Surveys in the Indonesian cities of Denpasar and Surabaya, for example, have revealed that factors such as reliability, personal safety, frequency, speed, and comfort (especially not being cramped) are often rated as more important than low fares.

Secondly, it may be mistaken to assume that a high quality MRT system would necessarily be priced beyond the reach of poor users. High quality BRT systems in developing cities can operate at a low fare. One of the successes of Bogotá's BRT is seen in its socially integrating effect, with rich and poor rubbing shoulders in the bus. In many ways it is a social experiment, not just a MRT system.

Fig. 34

Miami, Buenos Aires, Paris… The rail-based MRT systems of Sao Paulo probably seem as inaccessible as the cities advertised on the billboards to the urban poor living on the outskirts of Sao Paulo. Bus Rapid Transit, with its potentially greater geographical reach, offers more hope to low income communities on the outskirts of all developing cities.

Karl Fjellstrom, Feb. 2002

Table 11: Energy use per passenger kilometre, various modes and operating conditions.

Armin Wagner, 2002, from various sources

System	Energy use per passenger-km [Watt-hours]
Bicycle (20 km/h)	22
Highly occupied Metro-systems (Tokyo, Hong Kong)	79
Buses (Khartoum, Sudan)	99
Buses (Occupancy 45%)	101
Paratransit (Mini-Bus, Khartoum)	184
Less occupied Metro systems such as Germany	184–447
Metro (occupancy 21%)	240
Paratransit (occupancy 67%/ Minibus/Aleppo (Syria))	317
Rail-based systems USA (22,5 passengers per unit/USA)	577
Buses (8,9 passengers/USA)	875

Table 12: Trends in public transport use in an international sample of cities, 1970 to the mid 1990s.

Barter 1999; GTZ SUTP

Percent of all motorised trips by public transport				
City	1970	1980	1990	’93–’96
Tokyo	65	51	48	?
Hong Kong				?
Seoul	81	74	63	?
Singapore	42	?	?	51
Manila	?	70	67	70
Bangkok	53	?	39	?
Kuala Lumpur	37	33	32	24
Jakarta	61	58	52	53
Surabaya	?	36	35	33

where occupancy is very high. Emissions vary greatly depending on the power source used to generate electric traction (for rail), and the bus and fuel technology in a BRT system. In addition, not all developing nation rail systems are electrified, and thus there are sometimes local emission impacts.

From an environmental perspective, however, the main point to note is that virtually all MRT systems offer environmental advantages to the extent that they replace trips by private motor vehicles. Perhaps most important in the long term, in terms of reducing emissions, is the impact of a MRT system on the modal split, or percentage of people travelling by public and private transport modes. In this regard experience shows that in developing cities it is the BRT systems such as Bogotá and Curitiba that have enabled public transit to maintain or even increase modal share compared to private transport. In other cities public transit has tended to decline, with corresponding negative environmental impacts not just in terms of local pollutant emissions, but also in terms of greenhouse gases, noise, and visual intrusion. Table 12 describes the progressive decline of public transport in a selection of cities. There are some exceptions in cities which have experienced increasing shares of passenger-kilometres by transit (e.g., Zürich, Vienna, Washington and New York: WBCSD, 2001) and increasing transit modal shares (e.g., Singapore), but in general the trend is for declining transit modal shares of around 1–2% per year in large cities.

In the longer term, then, the MRT systems which can be expected to have the best environmental impact are those which can halt or reverse the declining modal share of public transport. In the case of lower income developing cities such an impact on overall modal share in the city is probably possible only with bus-based MRT, rather than rail. Due to the larger cost, new rail systems can be developed in only very limited areas of a developing city, and do not have the capacity of BRT to reach and cover larger areas, or the flexibility to adapt to a changing and expanding city.

In terms of air quality the crucial factor in developing cities is not so much the emission performance of the different MRT modes, but rather their potential in getting people out of cars and off motorcycles, and into transit. To the extent that a BRT system can do this better than a rail system (with much more limited coverage), BRT has a greater positive environmental impact.

5. Conclusion

After comparing MRT options, in general we can conclude that there are few reasons for developing cities to favour rail-based systems where passenger capacities would be less than 25,000 passengers per hour per direction. Unless specific circumstances apply—such as when visual image of the system is quite important and a city is sufficiently wealthy to handle the higher capital and operational costs—this kind of rail-based transit for developing cities compares unfavourably with BRT systems on most terms, and especially for key parameters such as cost, flexibility, time frame, and institutional demands.

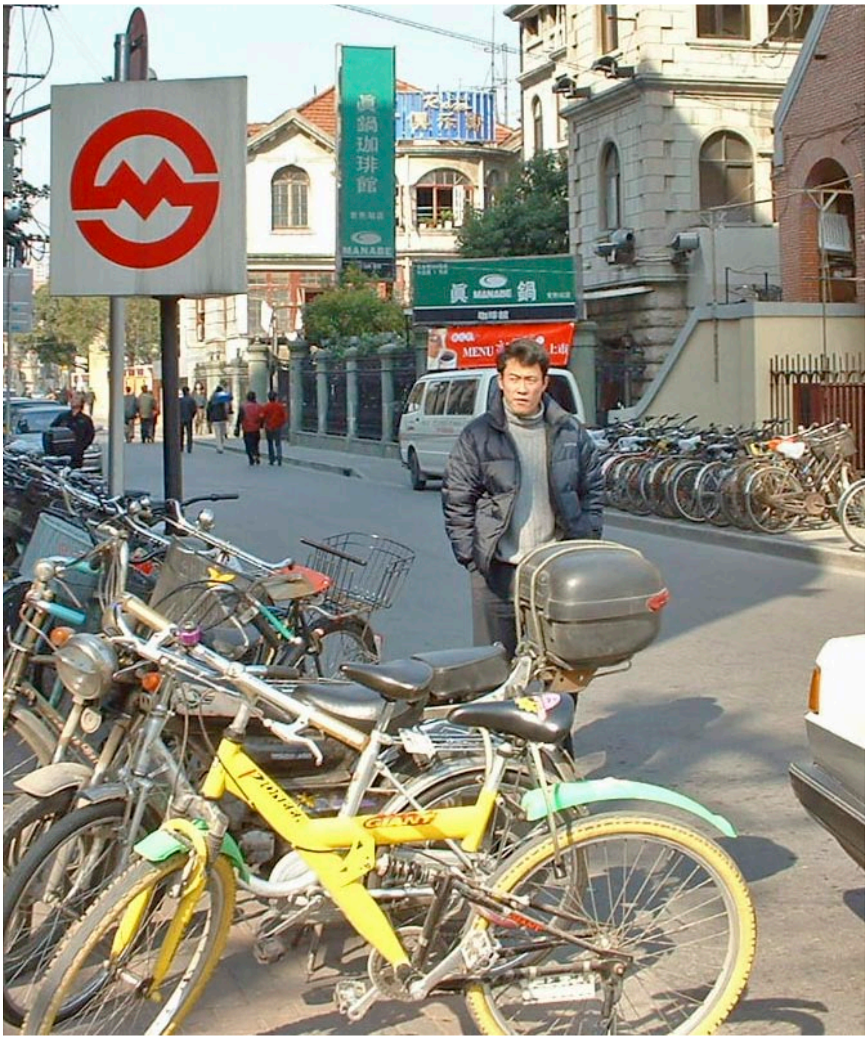
There is however no single "right" transit solution. The best system for a city will depend on local conditions and preferences and will involve a combination of technologies. Bus Rapid Transit may not be the solution in every situation. When passenger flows are extremely high and space for busways is limited, other options may be better, such as rail-based public transit; although we have seen that BRT can accommodate passenger volumes to match demand even in very large cities. In reality, it is not always just a choice between bus and rail, as cities like Sao Paulo, Brazil have shown that Metro and BRT systems can work together to form an integrated transport package.

It must however be recalled that city investments in Mass Rapid Transit systems come at a high opportunity cost. Funds used to build and subsidise the operation of a limited Metro could be used for schools, hospitals, and parks.

Bus Rapid Transit has shown that high quality public transit that meets the needs of the wider public is neither costly nor extremely difficult to achieve. Many organisations are ready to help municipalities in developing cities make efficient public transport a reality. With political leadership, everything is possible.

"Think rail, use bus."

Photo Karl Fjellstrom, 2002 (Curitiba, GTZ Transport Photo CD)



Karl Fjellstrom, Jan. 2002 (Shanghai's Hengshan Rd. Station)

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Urban Transport Strategy Review Reference on choice of MRT

The World Bank's *Urban Transport Strategy Review* includes a report which, like this module, offers advice on approaching Mass Rapid Transit options in developing cities. *Urban Mass Transit in Developing Countries* (Roger Allport, Halcrow Fox, with Traffic and Transport Consultants, 2000), includes an excellent discussion of the impacts, challenges and risks of rail-based projects, although in general it fails to draw out the experience of 'world best' Bus Rapid Transit applications such as Bogotá, since it was released only months after the TransMilenio system began operation. Major sections of the report include:

- MRT options
- MRT role
- Research results
- Scale of challenge
- Attitudes to MRT
- Forecasting MRT impacts
- Planning for tomorrow
- The private sector approach
- Affordability and the private sector
- Public transport integration
- Economic viability
- Poverty alleviation
- Land use and city structure
- The environment
- MRT planning
- Implementation and operations

This report can be obtained downloaded free of charge at the Urban Transport Strategy Review web site, http://wbln0018.worldbank.org/transport/utsr.nsf

Many more online resources on MRT topics can be obtained through the Univ. of Nottingham's *Sustainable Urban Travel: Comprehensive bibliography lists of relevant contacts, addresses, and worldwide Websites,* http://www.nottingham.ac.uk/sbe/planbiblios/bibs/sustrav/

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