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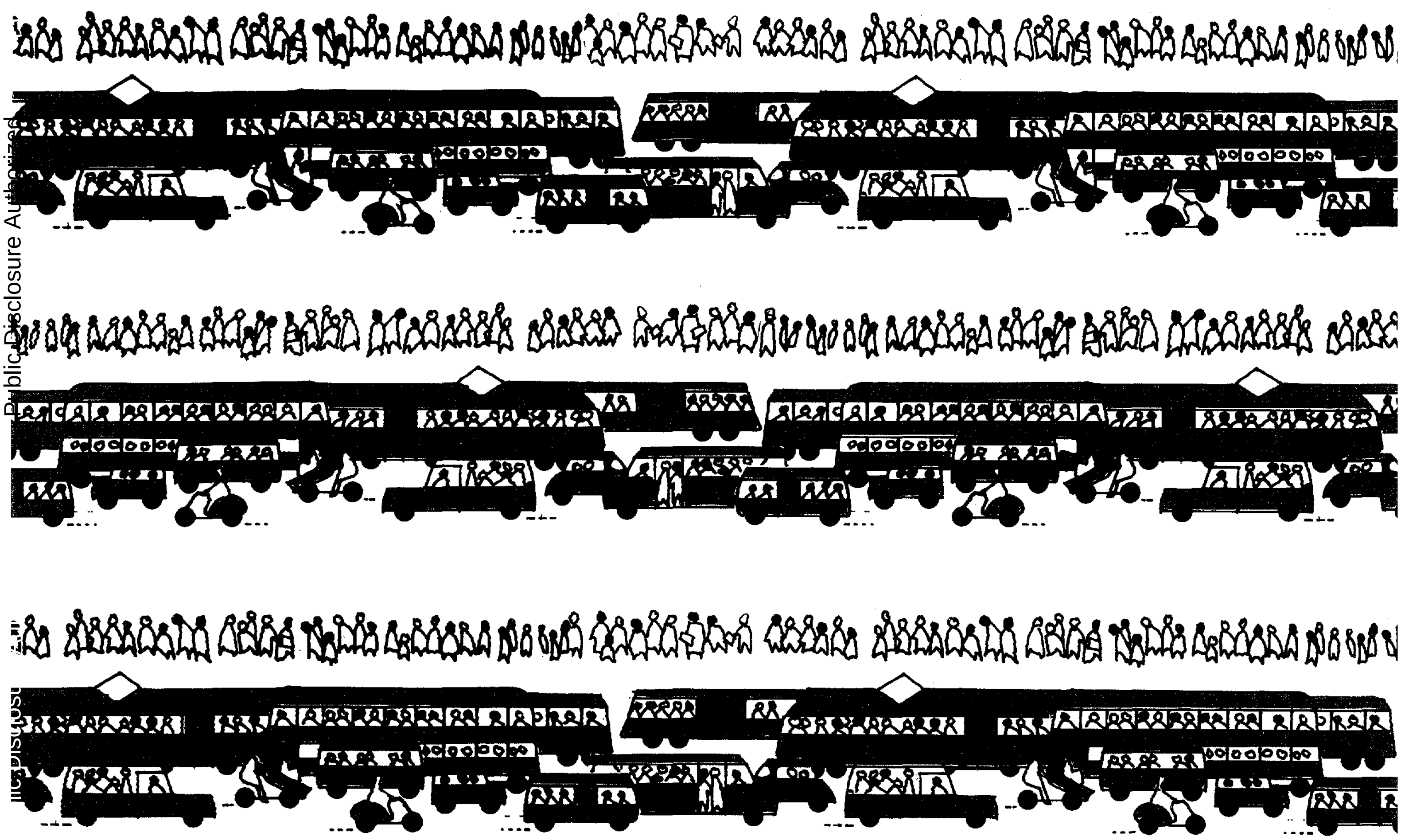
Urban Transit Systems

Guidelines for Examining Options

Alan Armstrong-Wright



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Urban Transit Systems

Guidelines for Examining Options

URBAN TRANSPORT SERIES

This series is produced by the Water Supply and Urban Development Department to provide guidance on a number of technical issues in the urban transport field. The series supports the sector policy paper Urban Transport published by the World Bank, and is designed to assist city and central government officials, as well as World Bank staff and consultants, concerned with urban transport in developing countries.

The series will comprise a number of papers:

Institutional Building for Traffic Management (published as World Bank Technical Paper Number 8)

Urban Transit Systems: Guidelines for the Examination of Options

Bus Companies: Performance Evaluation and Improvement (under preparation)

Bus Services: Criteria for Profitability (under preparation)

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A complementary paper Toward Better Urban Transport Planning in Developing Countries has been published in the World Bank Staff Working Paper Series (Number 600).

It is expected that further guidelines will be added to the Urban Transport Series to cover other urban transport issues when the need arises.

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Urban Transit Systems

Guidelines for Examining Options

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ABSTRACT

This paper compares the characteristics and costs of the main types of urban transit systems, including buses, trains, light rail, rapid rail and suburban rail systems.

As well as covering the examination of existing transport systems, the paper suggests a simple and quick screening process to avoid costly detailed examination of inappropriate solutions and to focus attention on systems most likely to meet the particular needs of a city.

The paper asserts the need for careful consideration of all the implications of new transit systems before firm commitments are made to any systems in particular. It provides a series of checks to ensure that important questions, such as feasibility to meet changing demands, problems of revenue leakage, undue sophistication of systems, financing and cost recovery, and environmental impact, are not overlooked.

Annexes to the paper contain details of city transport characteristics, bus services and rail services, together with brief case studies of transit systems in both developing and developed countries.

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FOREWORD

Most cities in developing countries are expanding rapidly and, having only strictly limited resources, often suffer serious deficiencies in urban services. Public transport, in particular, in many places is far from adequate and is unable to cope with the very heavy and increasing demands placed upon it. As a result services are severely overcrowded, and passengers have to endure excessive journey times and long periods of waiting.

Inadequate public transport usually affects a high proportion of the public, and city authorities are under considerable pressure to make urgent and substantial improvements. Since it may be costly and time-consuming to correct faulty decisions, it is very important for city authorities to consider most carefully the various options they have to improve matters before becoming committed to any particular solution.

These guidelines do not pretend to provide the final answer to transit deficiencies, but are designed to enable city and central government officials who may not be transport specialists to gain a better understanding of the options available for improvement and to appreciate the comparative characteristics and full costs of the main types of transit.

By suggesting a simple, quick and inexpensive screening process, the guidelines should make it easier to focus on solutions most likely to meet the particular needs of a city and to avoid costly detailed examination of inappropriate transit systems.

The process should lead to the identification of a number of options that may be worthy of detailed feasibility study. It also provides a series of checks to ensure that important questions, applying particularly to high capacity transit systems, are not overlooked.

In view of the range of urban problems facing developing countries, Urban Transit Systems: Guidelines for the Examination of Options is but one of the Urban Transport series being prepared by this department to provide guidance on a number of technical issues in the urban transport sector.

Anthony A. Churchill
Director
Water Supply and Urban
Development Department

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Finally, the author wishes to express his thanks to his colleagues in the Urban Transport Group of the World Bank for their support and advice on the preparation of these guidelines.

Chapter 1

INTRODUCTION

The purpose of these guidelines is to help city authorities in making crucial investment decisions when faced with transit system deficiencies. The guidelines recognize that the need for assistance arises in quite different circumstances. For example, city authorities may:

- wish to commission feasibility studies of prospective transit systems but want to avoid detailed and costly examination of inappropriate systems;

- need to consider the results and recommendations of feasibility studies to determine whether or not important implications have been properly taken into account;

- be faced with conflicting advice and wish to weigh the advantages and disadvantages of alternative systems;

- need independent data to confirm or support their decision.

These guidelines are not intended to replace detailed feasibility studies carried out by professional staff or consultants. Instead, they are designed as an aid to decision makers who may not necessarily be transport experts. In Chapters 2 through 5 the guidelines discuss the basic characteristics of a range of transit systems, including the capacity, costs, advantages, and disadvantages of each one. The main types of transit systems discussed in these guidelines are:

- Bus transit systems, including motor buses and trolley buses normally operating on public streets, in either mixed traffic, bus only lanes or exclusive busways.

- Light rail transit, ranging from trams operating in mixed traffic along public streets to semi-metro rail systems on exclusive tracks. Passengers usually board from the road surface or from low platforms and vehicles operate in single units or in short trains at slow to moderate speeds.

- Rapid rail transit (often called metros, subways or "the underground") invariably operates on completely exclusive rights-of-way at high speeds and high capacity. Passengers board from high level platforms to facilitate rapid loading. Vehicles operate in trains composed of four to ten passenger cars.

- Surburban rail transit (sometimes termed commuter rail systems) operate on tracks shared with inter-city passenger trains and freight trains. Rolling stock may be similar to heavy inter-city trains or metro trains.

A method of assessing the existing situation and opportunities for improvement is suggested in Chapter 6, while Chapter 7 presents a procedure for eliminating inappropriate options.

To assist in the screening process and to provide a better understanding of the different types of transit, comparative data on transit systems and methods for giving approximate demand and costs, together with brief case studies, have been assembled in the Annexes. Also included in the Annexes are draft terms of reference designed to provide guidance for a Transit Options Screening Study and to provide the basis for obtaining external technical assistance, should that be required.

Capital and operating costs are based on 1985 prices, unless specifically indicated otherwise.

Chapter 2

BUS TRANSIT

CHARACTERISTICS OF BUSES AND TROLLEYBUSES

Bus transit systems comprising motorbuses or trolleybuses carry fare-paying passengers and normally operate on public streets. Routes, frequencies, fares, and stopping places are generally prescribed and are subject to various levels of government regulation. Fares may be uniform flat rates or rates based on zones or distance, and are usually collected on board the vehicles by conductors or drivers. Transit buses may carry from 12 to 240 passengers; some operate only with all passengers seated, but mostly there is a mixture of standing and sitting passengers.

Various types of bus operations are possible, including local services with frequent stops, express services with limited stops, peak period services, shuttle services, and feeder services.

The standard of service is usually perceived in terms of reliability, frequency, journey time, and quality of ride, which may vary from air-conditioned comfort to extreme crush loading conditions.

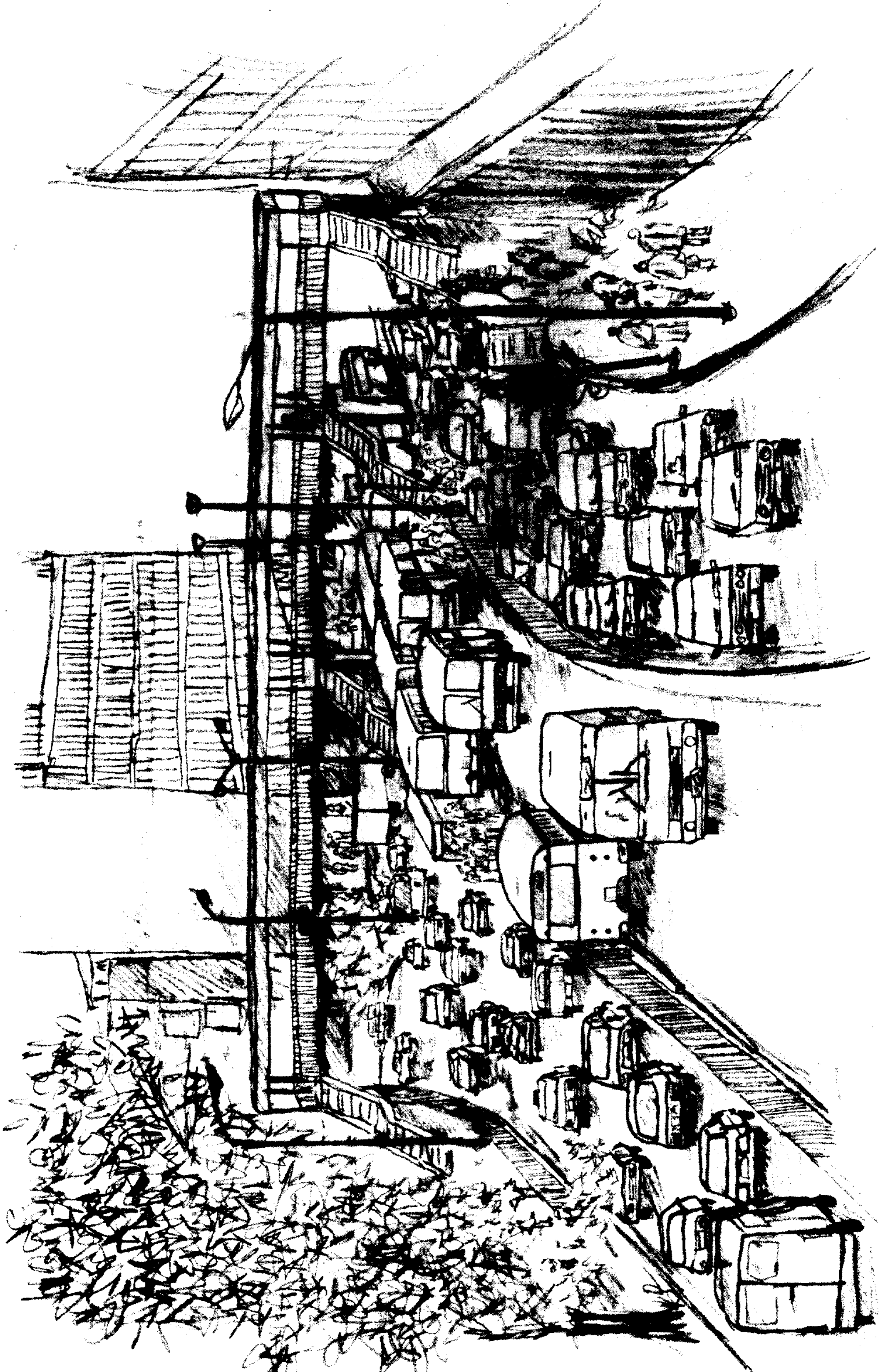
Proper maintenance is vitally important, since buses often travel 60,000 to 70,000 km per year. Buses that are not properly maintained will suffer from substantially reduced output and operational life. In addition, poor maintenance causes air pollution and excessive noise, and leads to frequent breakdowns and traffic holdups. Most of the maintenance needed by minibuses and small buses requires only basic skills and is often undertaken by the owner. The maintenance of larger buses, which involves work on more sophisticated and non-standard equipment (e.g., retarders, articulation systems, remote-controlled doors, etc.), may require specifically trained staff and special facilities.

A major advantage of bus transit is its flexibility in meeting changes in the shape of city development and in changes in demand in terms of both quantity and quality. If necessary, existing bus routes can be modified almost overnight at virtually no cost. Expanded or new services can be introduced quickly and at relatively low initial cost. Since bus transit is often provided by the private sector, the burden on city budgets is small.

Trolleybus systems, however, lack the flexibility of conventional bus transit because they are constrained by their overhead power transmission system, and involve considerably higher capital costs.

CAPACITY AND SPEED

Transit systems using standard-size buses, each with a capacity of about 80 passengers, are able to carry up to 10,000 passengers per hour per lane in <u>mixed traffic</u>. Systems using larger buses with a capacity of 120 or



more, operating in the same conditions, can carry up to 15,000 passengers per hour. Journey speed (including stops) in mixed traffic is likely to be in the region of 12 km/hr.

Where buses can use several lanes in the same street, much greater passenger volume can be accommodated. Under these circumstances the limiting factors are likely to be the amount of stopping space for boarding and alighting, and terminal facilities. Although journey speeds are low, particularly in congested areas, volumes of between 25,000 and 30,000 bus passengers per hour in one direction occur on main roads in a number of cities throughout the world. In Bogota, Colombia, for example, a mixture of more than 800 small and standard buses per hour, travelling in one direction and utilizing three lanes in mixed traffic, are regularly recorded. It has been estimated that these buses carry a total of approximately 32,000 passengers per hour. Although bus speeds within the heart of the central business district (CBD) of Bogota are low at 7 km/hr, bus journey speeds for the urban area as a whole are in the region of 25 to 30 km/hr.

The journey speed and output of buses can be greatly enhanced by bus priority measures, in particular reserved bus lanes. (These can also be used by emergency vehicles.) Reserved lanes permit bus journey speeds to be increased, often to more than 18 km/hr. Furthermore, passenger volumes of about 15,000 passengers per hour per lane for standard buses and 20,000 passengers per hour per lane for larger buses can be expected. During an average peak hour in Bangkok, approximately 18,000 passengers per hour using a mixture of 250 standard buses and 150 minibuses have been recorded in a single bus lane; journey speeds were about 20 km/hr, and sometimes higher. As well as reducing journey times for passengers, the increased speed allowed by reserved lanes permits quicker turnaround of buses, substantially improves bus utilization, and reduces operating costs. Once again, much higher volumes are achieved when additional lanes are available for buses in the same street.

Maximum bus transit performance is provided by exclusive busways in which buses are physically separated from other traffic by medians and barriers, with grade separation or priority at intersections. With off-line stations and terminals providing multiple boarding platforms, volumes in excess of 30,000 passengers per hour per lane, and journey speeds between 15-30 km, may be reached.

Busways with the potential for achieving these levels of performance exist in several cities (e.g., Curitiba, New York City). Yet, even without completely exclusive conditions, the Sao Paulo busways regularly carry more than 27,000 passengers per hour in a single lane at journey speeds of 19 km/hr. Buses operate in convoys and stop opposite a series of designated bus stops in a predetermined sequence so that passengers can embark or disembark from several buses simultaneously. Comparatively low-cost modifications to the system could greatly boost capacity.

Clearly, where reserved bus lanes and exclusive busways are established in several streets in the same corridor, the capacity of the system to move passengers along that corridor can be substantially increased.

Between the two extremes of mixed traffic and exclusive busways are many variations. Although not described here, most are equally successful in moving large numbers of bus passengers, with capacities roughly corresponding to degree of reservation.

Since buses using busways or bus lanes can disperse to several terminals in downtown areas, very high concentrations of passengers in buses can be avoided. Similarly, outbound buses are able to fan out into suburban areas after leaving busways or bus lines. In other words, passengers can be taken close to their destinations at both ends of these high-capacity facilities.

COST

Capital Costs

By far the biggest element of capital cost is for vehicles. But vehicle costs vary considerably, depending upon model, size, and place of manufacture. Generally, mass-produced vehicles cost much less than custom-built vehicles. The effective life of buses depends on the conditions under which they are operated and maintained and the extent to which rebuilding is practical. A broad indication of the costs and life of various types of buses is given in the Table 2.1.

TABLE 2.1. Characteristics of Buses

Type of Bus	Capacity Seated	Capacity Total	Purchase Price excluding tax (US$)	Life (years)
Minibus	12	20	25,000	8
Small bus	20	30	40,000	10
Standard bus	40	80	50,000	12
Large single-deck bus	50	100	80,000	*15
Large double-deck bus	80	120	100,000	*15
Super-large double-deck bus	80	170	120,000	*15
Articulated bus	55	120	130,000	*15
Super-articulated bus	55	190	150,000	*15

*These figures assume that rebuilding is possible.

The costs of the infrastructure necessary to operate buses in mixed traffic comprise part of the costs of road construction and maintenance. These costs are usually recovered through taxes on vehicles and licenses and are sufficiently small to be disregarded here. Similarly, the cost of exclusive bus lanes, which are often used by other traffic during non-peak periods, is comparatively small and can be disregarded. On the other hand, the construction of exclusive busways in combination with graded intersections may cost from US$2 million to US$7 million per km.

The costs of depot facilities and overnight garaging vary considerably from place to place. (For example, in some places owners/drivers are able to park and service their vehicles on their own property; in others planning regulations require special facilities to be provided.) Some indication of the likely costs can be determined from the cost of similar facilities in the same area.

Operating Costs

Operating costs, measured in terms of cost per passenger-km, comprise mainly operators' wages, fuel, tires, repairs and maintenance, cleaning, garaging, and general administration. The costs of owner/operator bus systems may be as low as US¢2 per passenger-km. For public corporations with lower productivity and higher overhead, operating costs may exceed US¢8 per passenger-km.

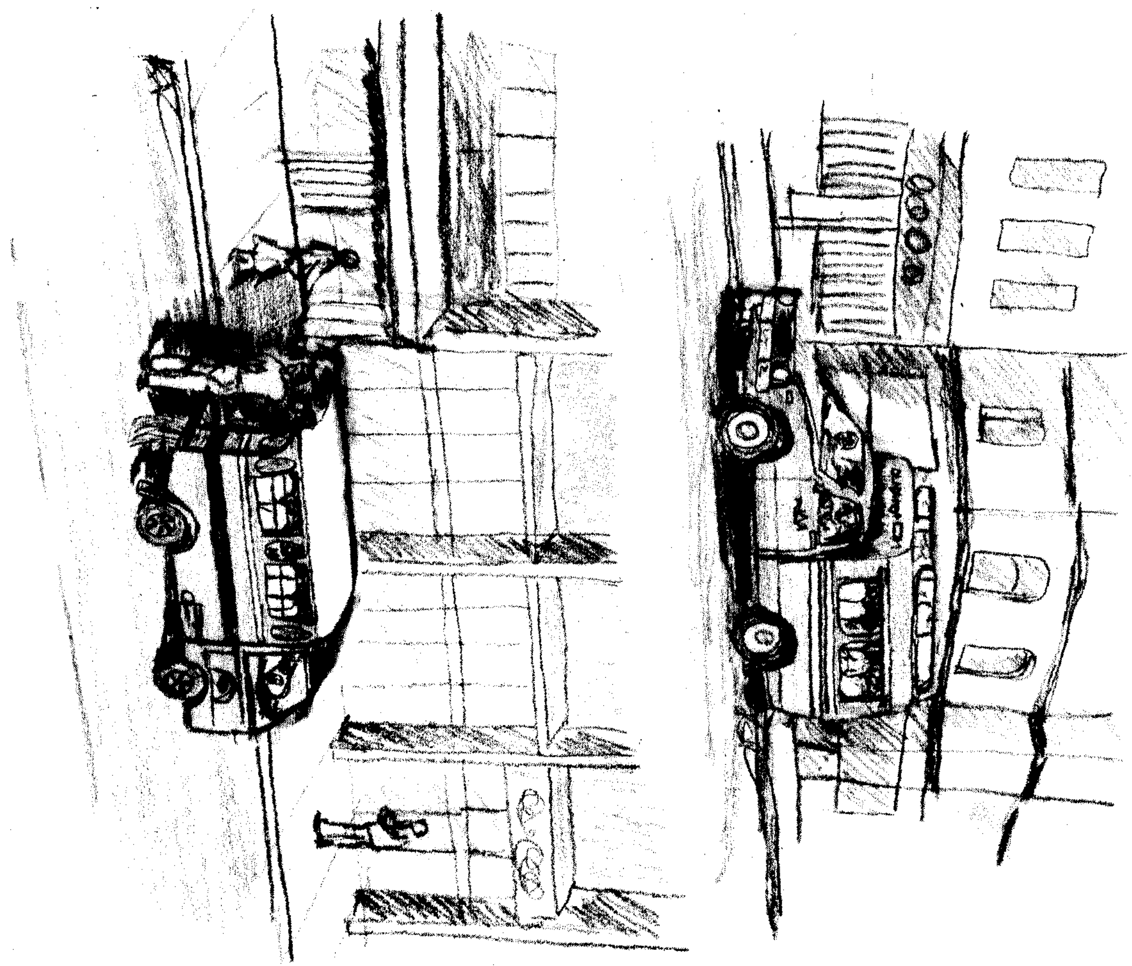
Total Costs

Taking into account both operating costs and financial charges (following the method described in Annex IV.), Table 2.2 gives total costs of bus transit systems of the following order of magnitude:

TABLE 2.2. Bus Transit Total Costs

Right-of-Way	Cost per Passenger-km (US$)
Mixed traffic	0.02 - 0.05
Reserved lanes	0.02 - 0.05
Segregated busways	0.05 - 0.08

(For trolleybus systems approximately 20% should be added to the above costs.)



Examples of the total costs of specific systems are provided in Annex II.

ROLE OF PARATRANSIT

Paratransit, the term applied to small passenger transport vehicles operating informally on a fare-paying basis, often is a valuable supplement — and in some places an alternative — to regular bus transit services.

Paratransit systems are characterized by the variety of services they offer. These may include:

(a) personalized door-to-door service;

(b) shared service with routes determined by individual passengers;

(c) regular service along fairly well-defined routes (similar to bus transit).

In developing countries, paratransit vehicles may be pedal or motor rickshaws (e.g., Delhi), converted vans and pickups (e.g., matatus in Nairobi), converted jeeps (e.g., jeepneys in Manila), shared taxis (e.g., dolmus in Istanbul) or minibuses (e.g., publicos in Puerto Rico). They carry from 4 to 20 passengers in crush conditions, with journey speeds of motorized vehicles ranging from 12 to 20 km/hr. The costs of higher capacity paratransit run about 10¢ to 20¢ per passenger-km, about the same as small transit buses; the costs of smaller paratransit vehicles may run as high as 50¢ per passenger-km. (In places where extreme over loading occurs, e.g., the matatus of Nairobi, costs may be as low as US¢3-5 per passenger-km.)

Generally, operators are free to choose vehicles, routes, frequency, and hours of operation. But fares may be regulated, and in some cities congested routes are barred to paratransit.

Paratransit operators are responsive to the needs of the public and adapt quickly to changing patterns of demand. Because of their small size, paratransit vehicles are able to provide frequent and viable service at low levels of demand. Often, small paratransit vehicles are the only form of transport able to penetrate the labyrinth of narrow streets sometimes found in the old parts of cities and in squatter areas.

Almost without exception, paratransit is operated by individual private owners or small enterprises, is highly competitive, and is run at a profit. As a result, paratransit places very little burden on city finances.

Although the safety standards of paratransit vehicles are often low, and large numbers of paratransit vehicles can cause serious congestion, these disadvantages can usually be overcome with a minimum of intervention.

It is sometimes argued that paratransit operations provide unfair competition to other forms of public transport. This is rarely, if ever, true. In fact, paratransit services often improve the viability of large-scale bus services by supplementing capacity during peak periods. Because of this, the size of a fleet of conventional buses, and its under-utilization during off-peak periods, is reduced. Paratransit is particularly advantageous in areas where demand is insufficient to support the use of large buses at desirable frequencies. But even the largest types of paratransit vehicles, each with a capacity of about 20 passengers, are only able to carry 4000 passengers per hour per traffic lane. Paratransit is therefore unlikely to provide a complete alternative to bus transit along corridors where demand is heavy.

Chapter 3

LIGHT RAIL SYSTEMS

TYPES OF LIGHT RAIL SYSTEMS

The term "light rail" refers to a wide range of electrically powered rail systems. At one extreme are trams or streetcars which operate on tracks and share the roadway with other users. At the other extreme are "pre-metro" systems operated on exclusive rights-of-way and often designed for conversion to rapid rail when conversion is warranted by demand. The distinguishing features of light rail systems are (a) that passengers usually board from the road surface or from low platforms; (b) that the vehicles operate in single units or in short trains at slow to moderate speeds; (c) that trackways may be shared with other traffic and may have sections of exclusive rights-of-way.

For ease of comparison, these guidelines consider three main categories of light rail systems. They are:

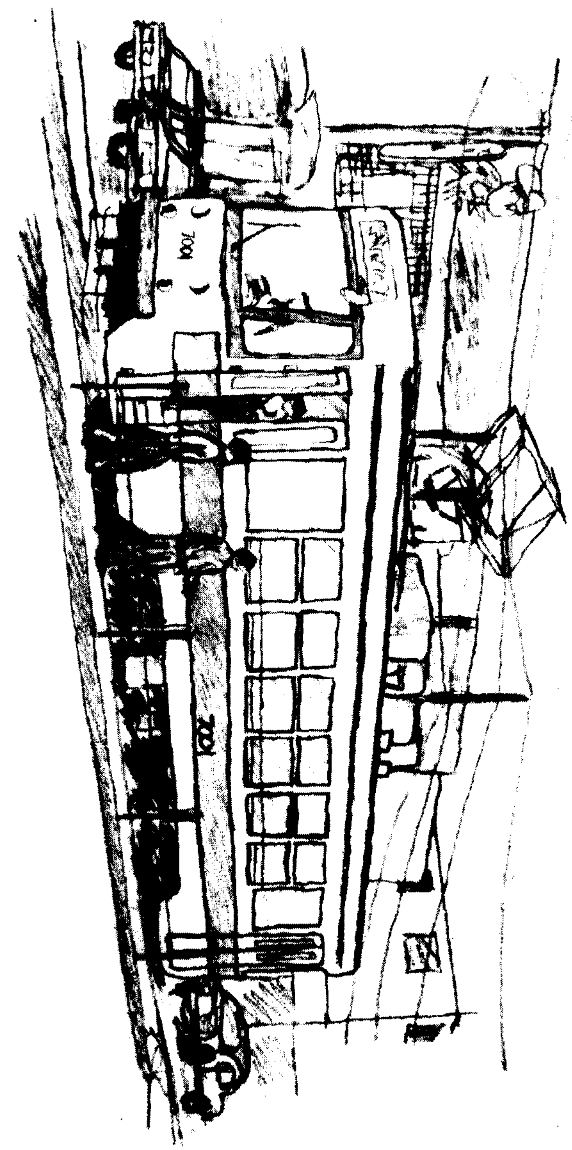
Tramways:	simple trams or streetcars on fixed rails, usually operating as single units, in mixed traffic and mostly on city streets.
Light Rail Transit (LRT):	light rail vehicles, sometimes articulated, usually operating in trains of one or more units, either on-street or in segregated rights-of-way, or a mixture of both.
LRT Metro:	light rail vehicles operating in trains, along completely segregated tracks, either on the surface, on viaducts, or in underground tunnels.

LRT metros have many of the characteristics, including infrastructure costs, of rapid rail systems, and are generally covered by the discussion on "Rapid Rail Transit" in Chapter 4.

TRAMWAYS

Operating along streets in mixed traffic, tramways provide a slow and low-capacity, but cheap, form of transit. The vehicles run on rails flush with the roadway and consist of trams (or streetcars) that can carry about 100 to 200 sitting and standing passengers. Fares are usually collected on the vehicle by a conductor or by the driver. Both the vehicles and the infrastructure are comparatively simple to operate and maintain.

Clearly, the flexibility of tramways is constrained by the alignment of tracks and their connections to power transmission systems. As a result, either temporary or permanent re-routing involves a considerable amount of civil and electrical construction work. In addition, power failures may affect several trams at once and thus paralyze a large part of the system.



Capacity and Speed

Trams operating in single units in mixed traffic, with headways of one minute, are able to carry 6,000 passengers per hour per track. Journey speeds are about 12 km/hr. This capacity can be boosted to 12,000 by providing larger trams, and can be further increased to 15,000 if the vehicles operate on exclusive rights-of-way.

Cost

Capital Costs. The capital costs of tramways are moderate, particularly in the case of tramways operating in mixed traffic, since the cost of the roadway is minimal. The main costs are for tracks and power transmission systems and run about US$4 million per km. Modern tramcars with a total crush capacity of 100 passengers cost approximately US$300,000 each.

Operating Costs. Operating costs, including depreciation, are likely to be in the range US¢2 to 8 per passenger-km for a well-patronized and efficiently run system.

Total Costs. Since tramways have comparatively low capital costs and little indebtedness, total costs (i.e., operating costs, including depreciation, together with financial charges) are likely to be of the order of US¢3 to 10 per passenger-km.

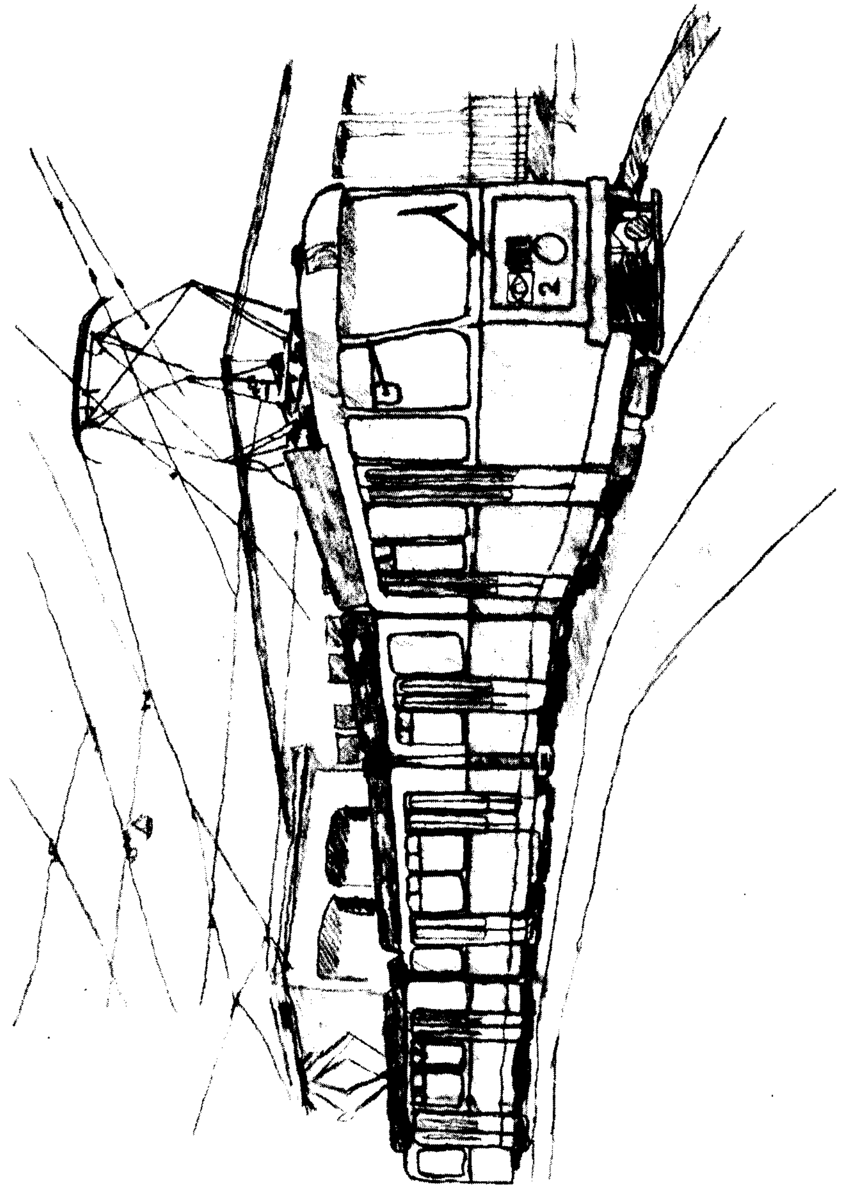
Revenue. It should be possible to recover costs, at least at the lower end of the scale, through fare boxes. As with publicly owned bus services, however, higher costs may apply, and there may be some revenue leakage. Because of this, most tramway systems are subsidized.

Details on the revenues and costs of selected tramway systems are set out in Annex II.

CHARACTERISTICS OF LIGHT RAIL TRANSIT

LRT systems usually operate on tracks along streets and may be provided with segregated rights-of-way over all or part of their routes. They may be grade-separated or given priority signalling at intersections. Passengers board at stops or stations, either from the road surface or from low-level platforms. Fares may be flat rates or based on zones or distance, with a variety of fare collection methods. Tickets may be purchased on or off the vehicle, and the ticketing system may consist of automatic dispensing and cancelling equipment. LRT systems operate trains comprising two, three, or four rail cars. A typical LRT train consisting of three double-articulated units has a crush capacity of up to 800-900 passengers.

As with other rail systems LRT lacks flexibility in dealing with the need, either temporarily or permanently, to realign routes to cope with changing traffic and development patterns.



LRT passengers travelling to areas where demand has been insufficient to justify extension of the rail system must change modes to reach their destination. This is a distinct disadvantage of LRT systems.

Because LRT is intended to provide high capacity service, LRT vehicles must be both fast and frequent. Trackworks, signalling, and control, as well as the vehicles themselves, must therefore be more technologically sophisticated than conventional tramways, and high speeds may dictate extensive segregation of the tracks. On track areas open to other road vehicles, or in areas where pedestrians or animals can gain access to the tracks, LRT operating speeds must be substantially reduced. If the tracks are not grade-separated at junctions, the LRT system will be slowed by other traffic and lose capacity. On the other hand, giving priority to a high-freqency LRT system may disrupt crossing traffic. (It was because of this that the authorities in Tunis suspended work on that part of a new LRT system passing through the city center. Studies showed that maintaining the necessary LRT frequency would make it very difficult for other traffic to travel from one side of the city to the other.)

Because of the problem of disruption of other traffic at junctions, consideration may be given to building an LRT system with either an elevated or underground right-of-way. Under such circumstances, most of the discussion on RRT in Chapter 4 will also apply to LRTs of this type.

CAPACITY AND SPEED

Where LRT systems operate on a reserved street track and intersections are located at grade, capacity is in the region of 20,000 passengers per hour per track at journey speeds of 15 km/hr where 5 or 6-car trains run on segregated tracks with grade-separated intersections, peak capacity may be as high as 36,000 passengers per hour per track. Journey speeds of 25 km/hr may be achieved.

COST

Capital Costs

When provided at ground level, a light rail infrastructure composed of trackway, signals, and power systems will cost between US$6 million and US$10 million per km. The cost of light rail cars is approximately US$800,000 each (i.e., $4.0 million per train set of 5 cars).

Thus, if a light rail system can be established on an existing and exclusive right-of-way, its cost and capacity may make it an attractive proposition. A different picture emerges, however, if the system must be elevated or placed underground. Under these circumstances the capital costs are more in line with those of an underground rapid rail system.

Operating Costs

Operating costs, including depreciation, for surface systems are in the region of US¢8-10 per passenger-km.

Total Cost

For LRT on a surface right of way, total costs (i.e., operating costs, depreciation, and financial charges) are likely to be US¢10-15 per passenger-km.

Chapter 4

RAPID RAIL TRANSIT (METROS)

CHARACTERISTICS OF RAPID RAIL TRANSIT

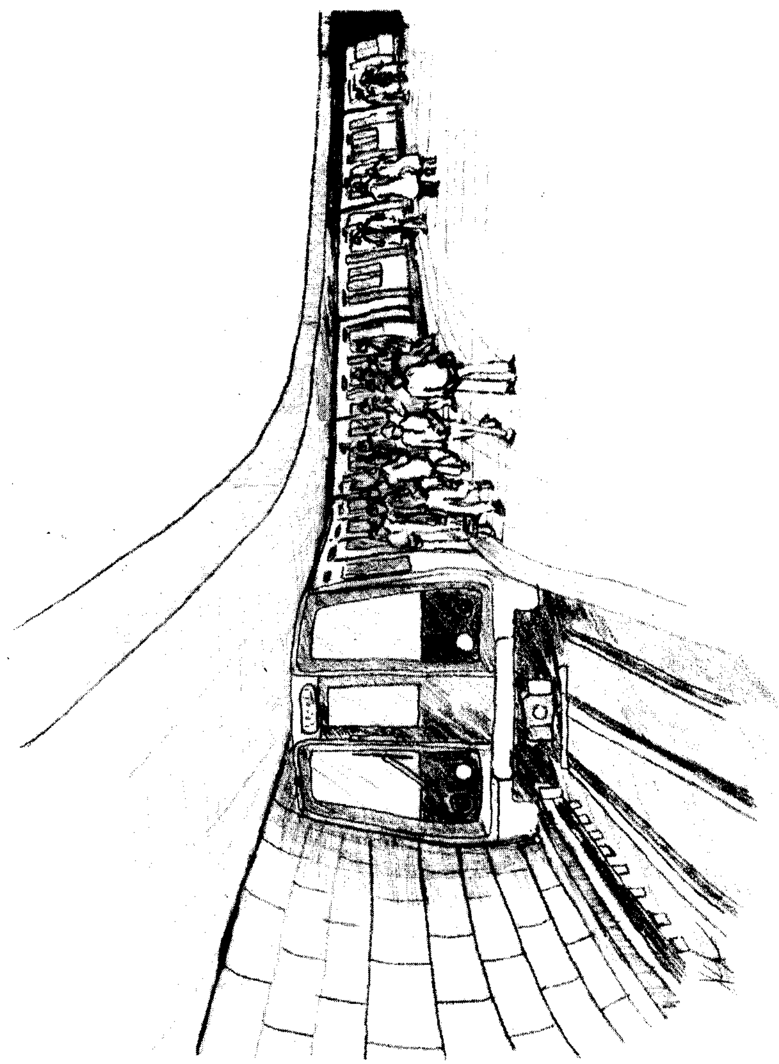
Rapid rail transit systems (often called metros, subways, or "the underground") invariably operate on completely exclusive rights-of-way and at high speeds; they provide the highest transit capacity currently available. The exclusive right-of-way is usually provided in underground tunnels, but may be elevated or in cuttings. These systems are generally owned by city authorities or public corporations. Because of the very high capital investment required, rapid rail systems are rarely owned or operated by the private sector. The exceptions are mainly a number of surface suburban systems constructed in Japan at the turn of the century. Fares may be flat rates, zone rates, or distance-based rates, and are usually collected through automatic or manned ticketing systems within stations. Rapid rail systems operate trains composed of four to ten passenger cars. With six cars, trains may have a crush capacity of 1,500 to 2,250 passengers, most of them standing. (With extreme crush loading, six car trains of the Osaka metro regularly carry 2,750 passengers; eight-car trains on the Hong Kong metro carry 3,000 passengers each.)

To cope with high passenger volumes, rapid rail systems usually require sophisticated signaling and control devices that allow the operators to maintain high speeds and frequencies. The stations of rapid rail systems usually have wide, high-level platforms that facilitate rapid loading and unloading, and are usually equipped with escalators. Underground systems need comprehensive ventilation, particularly in countries with high temperatures and humidity. In vehicles stopped in tunnels without ventilation, temperatures can rise to fatal levels within a short period. Hence, contingency arrangements must be established to evacuate passengers from trains in tunnels in the event of breakdowns.

Rapid rail systems involve a high level of sophistication and technology that is often quite new to cities in developing countries. Since the technical experience for proper operation and maintenance is unlikely to be readily available, comprehensive training programs will be necessary. The establishment of such programs may take several years. It may also be necessary to rely heavily on overseas technical assistance during the training period and initial years of operation.

Once the right-of-way for a rapid rail system has been constructed, the costs of modifying routes are likely to be enormous. While there may be some scope for making changes to planned extensions, changes to existing routes will not be practical. This inflexibility of rapid rail systems is a distinct disadvantage in developing countries, where there is often a high degree of uncertainty about the future development and shape of cities.

Because rail systems are limited to a number of fixed routes (complete city coverage being impractical and prohibitively costly), they have



to be supplemented by more flexible systems, in particular buses. Also, in order to recoup the extremely high costs of rail systems, there is considerable pressure to maximize patronage and revenue by developing an "integrated" public transit system. This usually involves reshaping the bus network to provide feeder services to rail stations and curtailing competing bus routes. This inevitably erodes the viability of bus services and may necessitate large subsidies for both the bus and rail systems. Furthermore, through-ticketing to improve the attractiveness of integrated systems may prove difficult if it involves revenue-sharing between public and private transit operators.

The construction of a rapid rail system is likely to take five years at the very least, and may take much longer. Much of the construction will take place on or under city roads and will involve substantial excavation and construction-related traffic. If serious and costly disruptions are to be avoided, very careful consideration needs to be given to traffic arrangements, and to diverting and protecting utility services.

Rapid rail transit, particularly when underground, provides a very high level of reliability and safety in all weather conditions and is immune to the problems of traffic congestion.

CAPACITY AND SPEED

Rapid rail systems provide the highest capacity and the fastest speeds of all urban transit modes. Operating at headways of 2 minutes, and with top speeds of as much as 100 km/hr, rapid rail systems are able to carry up to 70,000 passengers per hour per line in each direction. Journey speeds are in the region of 30-35 km/hr.

COST

Capital Costs

Table 4.1 gives an indication of the range of costs for elevated and underground (cut and cover construction) double-track rapid rail systems:

TABLE 4.1. Rapid Rail Capital Costs
(millions of US$)

Item		Elevated	In Tunnel
Structure/tunnel(km)		20 - 40	60 - 90
Track	(km)	1.0 - 1.5	1.0 - 1.5
Signals	(km)	1.0 - 5.0	1.2 - 5.0
Power	(km)	1.0 - 3.0	1.0 - 1.5
Stations	(each)	2 - 5	5 - 20
Depots	(each)	10 - 40	
Workshops	(each)	15 - 50	

Note: Rapid rail cars cost about US$1.0 million each (i.e., US$ 6.0 million per train set of six cars).

These broad indicators mean that the total capital cost of a 25-kilometer underground rapid rail system with 25 stations, 400 cars, and two depots and workshops would be about US$3,000 million, or US$120 million/km.

Operating Costs

The operating cost of rapid rail systems, including depreciation but excluding financial charges, is in the region of US¢10-15 per passenger-km.

Total Costs

(Calculated in accordance with the procedure set out in Annex IV.) Because of considerable capital expenditures and inevitable indebtedness, financial charges will be a major element of the total cost of rapid rail systems. Total costs -- that is, operating costs, depreciation, and finance charges -- can be expected to be about US¢15-25 per passenger-km. That is US¢75-125 for an average 5-km trip.

REVENUE

The farebox revenues of rapid rail systems are rarely able to cover total costs. Some systems may recover operating costs, including depreciation, but most require substantial capital and operating subsidies.

The Osaka surface rapid railway, for example, shows a profit, while the Sao Paulo underground metro requires operating subsidies of US¢7 for every passenger trip, together with substantial capital subsidies. Details of the revenues and costs of selected rail systems are set out in Annex II.

Chapter 5

SUBURBAN RAIL

CHARACTERISTICS OF SUBURBAN RAIL

Suburban rail systems (sometimes termed commuter rail systems) operate on tracks shared with intercity passenger trains and freight trains. They either use heavy rolling stock similar to that used on intercity systems, or metro-type vehicles. When provided with exclusive use of tracks and platforms, suburban rail systems using metro vehicles take on most of the characteristics of the surface rapid rail system described in Chapter 4.

Considerable benefits are obtained when the suburban sections of intercity rail systems are used to provide fast, high capacity, reliable and convenient commuter service. Upgrading of the rail system is usually required, and this upgrading usually involves electrification, improved platforms, new track and control systems, and new rolling stock. Because much of the right-of-way is likely to exist already, upgrading will not involve the construction of tunnels or elevated structures. As a result, the total cost of upgrading is likely to be only a fraction of the cost of building a new metro system. In Hong Kong, complete modernization and rebuilding of the suburban rail system, including electrification, double-tracking, and new rolling stock, cost only US$13.2 million per kilometer, compared to US$112 million per kilometer for the Hong Kong underground Island Line.

Although suburban railways do not have the cost disadvantages of rapid rail systems, they do suffer from a number of the other disadvantages of fixed rail systems described in Chapter 4. Nevertheless, upgrading of an existing rail system is likely to be an attractive and viable solution along suburban corridors of high demand because of the low cost of upgrading.

CAPACITY AND SPEED

When a suburban railway is part of a multipurpose rail system, its performance depends on the amount and type of track sharing. A typical system that shares its track with intercity passenger and freight traffic will have a capacity of 10,000 to 20,000 passengers per hour in one direction.

Where track priority is given to the suburban system, or where it has exclusive use of tracks, capacity and regularity may be comparable to those of a rapid rail system. For example, the upgraded Porto Alegre suburban railway, with stations every 2 km and exclusive use of its tracks, has a capacity of 48,000 passengers per hour in one direction. The design provides for capacity to be boosted to 72,000 passengers per hour in one direction by comparatively simple extension of platforms and the introduction of longer trains.

Journey speeds are greatly influenced by the type of vehicle and the spacing of stations. These vary considerably on suburban lines. Using modern metro-type vehicles and with stations every 2 to 3 km, journey speeds are in the region of 45 to 55 kph.

COST

Capital Costs

For a new surface suburban rail system provided with an exclusive right-of-way, fully grade-separated, the cost of trackway, signals, and power system is likely to be about US$6-10 million per km. The cost of cars is approximately US$1.0 million each (i.e., US$6.0 million for a typical 6 car train).

For the upgrading of an existing system, capital costs can be as low as US$2 to $5 million per km, excluding the cost of new cars. Thus, the cost of upgrading a 25-km suburban line, including 35 new train sets, would be about US$250 to 350 million.

Operating Costs

The operating costs of a suburban railway, including depreciation but excluding interest and financial charges, are in the region of US¢5-10 per passenger-km.

Total Cost

Depending on the level of sophistication and the amount of track sharing involved, total costs are likely to be in the region of US¢8 to 15 per passenger-km, assuming high utilization and patronage levels.

REVENUE

Some suburban railways are able to recover operating costs, including depreciation, from farebox revenues. Very few are able to recover total costs, including interest and financial charges. These few include several highly efficient surface systems (mainly in Japan) introduced at an early stage of city development, when right-of-way could be obtained with comparative ease and at low cost. These systems operate at very high levels of patronage, charge competitive fares, and are able to show a profit. A number of similar systems rely heavily on profits from the development of property that they own.

Chapter 6

EXAMINATION OF THE EXISTING SYSTEM

A prerequisite to considering transit options is a review of the existing system to determine both its deficiencies and opportunities that can be developed for improvement. Substantial investment in new systems should only be considered after these potential opportunities have been explored and found to be insufficient.

PERFORMANCE OF THE EXISTING SYSTEM

A broad indication of the extent to which transit services are deficient can be obtained by measuring degrees of overcrowding, travel times, and fares against several rules of thumb.

Overcrowding

In any transit system, short periods of overcrowding must be expected. Heavy peak demand during the evacuation of a sports stadium or a traffic tie-up can often be discounted. But if overcrowding and excessive travel delays occur on a regular basis, then a serious condition exists.

Overcrowding can be determined by counting the number of loaded buses that pass a bus stop without allowing people to board. If more than two or three buses, or 15 minutes, pass before boarding is possible, this can be considered as overcrowding at that location at that time. If such overcrowding extends over many kilometers of route and lasts more than an hour, a serious overcrowding condition exists. The number of hours and the extent of overcrowding will indicate the severity of the condition.

Excessive Travel Time

A condition of excessive travel time can be considered to exist when many journeys comprising transit use and a reasonable amount of walking (say 2 km) and waiting consistently exceed 40 minutes for a door-to-door trip of 6 km, 60 minutes for a 10-km trip, and 90 minutes for a 16-km trip. This may arise when transit journey speeds, including stops, are less than 12 km per hour.

Discriminatory Fares or Service

There are great variations in fare structure between cities and between modes. A fare structure discriminates against low-income people when cost makes it impractical for them to use the transit system. One reasonable criterion is the cost of a week's transit fares for trips to work in comparison with the total weekly income of the household. If the cost exceeds 10% of income for more than 15% of the population, the fare structure can be considered to be discriminatory. An examination of fares in eight cities in developing countries determined that, for seven of them, on at least one transit mode (the regular bus), even the low-income sector of the population could travel unlimited distances for less than 10% of income. In the other city the fare structure was such that the poorest 20% of the population would need more than 10% of household income for one worker to travel only 5 km to work.

Transit systems may also provide discriminatory services. For example, the rail transit system and the bus routes may be laid out primarily to provide service to more affluent regions.

ROOT CAUSES OF DEFICIENCIES AND OPPORTUNITIES FOR IMPROVEMENT

The main causes of transit service deficiencies are inadequate transit equipment, poor transit operations, and street congestion.

Inadequate Transit Equipment

In some cases the root problem is simply that there is not enough transit equipment or that the equipment is in poor condition. There simply may not be enough transit vehicles in running condition to provide the needed public transport. Annex II., Table II.1. shows the number of buses per thousand people in a number of cities. The cities in developing countries with inadequate transit equipment tend to be those with less than one bus per 2,000 people.

The availability of transit vehicles has been improved in a number of ways. These include:

- liberalizing the regulations for entry into the transit market in order to stimulate investment by the private sector;

- avoiding undue taxation or financial restraints on investment and operation of transit vehicles; and

- encouraging public corporations to improve their cost effectiveness in order to support investment in additional transit vehicles.

Poor Transit Operations

Even when transit equipment is adequate, operations may be so poorly organized and executed that the service is inadequate. This will usually be seen when the average kilometers travelled by each bus in service are seriously below what would be expected. The average revenue-service distance for each transit vehicle should be at least 150 km per day. A lesser number is evidence of either poor transit operations or congested street conditions. The goal should be 230 to 260 km per bus per day.

A further indication of performance is the percentage of the vehicle fleet available for service. Anything less than 70% during peak periods is an unsatisfactory situation. Many well-run bus operations are able to out-shed between 80% and 90% of their fleets. These and other indicators of bus service performance are described in Annex V.

Poor transit operations may result from inadequate organization and management, due to either personnel weaknesses or institutional constraints. The results are inefficiency and low productivity.

Experience indicates that the adequacy and viability of transit services can be improved by:

- providing incentives for higher productivity in all aspects of transit services, including operations, fare collection, maintenance, administration, etc.;

- ensuring that owners and managements have flexibility in dealing with staff recruitment, dismissals, and redundancy;

- giving operators freedom to choose routes, size of vehicles, and frequency of service;

- permitting competition between transit operators and between modes of transit, and providing greater freedom to set fares; and

- using competitive bidding to ensure the operation of unprofitable but socially desirable services, with any necessary subsidies directed towards selected users rather than operators.

Street Congestion

Traffic congestion is a frequent cause of deficient transit service. Congestion has been greatly reduced in many busy cities at comparatively low cost by a number of traffic management measures, including:

- restrictions on on-street parking and stopping during peak periods on busy streets;

- controls on street trading;

- reducing conflicting traffic movement by traffic control at intersections, re-routing traffic flows, one-way streets, and banning certain turning movements;

- providing priority for transit (discussed more fully in Chapter 2);

- applying restraints on the use of uneconomic road vehicles, in particular private cars; and

- providing facilities, such as flyovers and foot bridges, to separate heavy vehicle and pedestrian movements.

Substantial improvements have been achieved in a number of cities throughout the world through vigorous use of such measures. Examples include Abidjan, Bombay, Porto Alegra, Bangkok, Tunis, and Manila. Through the introduction of low-cost improvements and innovations the capacities of existing systems have been increased enough to meet demands with reasonable standards of service. These cities have thus avoided or have delayed for several years the need for expensive new systems and infrastructure.

Chapter 7

THE SCREENING OF OPTIONS

The purpose of this section is twofold:

(a) to screen the several options that are available -- including improving an existing system -- in order to determine which of the options may be worthy of a detailed feasibility study; and

(b) to determine the appropriateness of systems that already have been proposed or recommended.

The objective is to avoid expensive examination or design of a system that may not be appropriate.

FORECAST OF DEMAND

As a first step, it is necessary to gain some indication of the level of demand that can be expected in the future. Initially, it should be sufficient to identify the main traffic corridors and to estimate the likely range of future demand along those corridors. If a transport study has already been undertaken, as is the case in most cities, it should be possible to revise the traffic predictions and the likely share of the transit system on the basis of up-to-date population growth forecasts, income trends, and anticipated car ownership trends.

If transit patronage forecasts are already available, care should be taken to ensure that these have not been overestimated. Competition from existing modes, higher fares, the low value that commuters sometimes place on time, and requirements that passengers interchange between modes often have a much greater dampening effect on demand than expected. It is important to be sure that these factors have been adequately taken into account.

In the event that data from previous transport studies are not available, it may be necessary to commission a prelimary transport study to establish the likely range of demand along the main corridors. A shortcut method of assessing the approximate magnitude of demand is described in Annex III.

If high demands are forecast, it is important to consider potential ways of reducing these before deciding to create an expensive new system. It is possible that excessive demand may have arisen because of direct or hidden subsidies -- for example, low bus fares or low fuel prices. In these circumstances, a rational pricing policy will reduce demand. Heavy demand, particularly along radial corridors, can be reduced by modifying the road network, by pursuing city development plans that influence the pattern of demand, and by constructing bypasses and road links to disperse demand into other roads or corridors.

MATCHING SUPPLY TO DEMAND

Once the likely range of demand along main corridors has been determined, it is possible to consider the systems that are likely to be able to cope with this demand. In this regard it must be borne in mind that much lower levels of demand are likely to occur in other corridors and areas of the city. Hence, a combination of compatible systems may prove to be the best solution (e.g., buses operating on reserved lanes or busways along the main corridors, buses in mixed traffic on secondary routes, minibuses to serve commuters in low-density areas).

In matching supply to demand, the first step should be a review of the existing system to determine the extent to which it can be improved to cope with future demand, a step discussed in Chapter 6.

If opportunities to improve the existing system have been explored and found to be insufficient, it will then be necessary to consider systems that provide higher capacity. Capacities in terms of peak hour volumes and journey speeds for the main categories of transit systems are set out in Annex II., Table II.5.

It is important to understand that these capacities are based on a single track or lane. For example, the design capacity of a single lane of segregated busway may be as much as 30,000 passengers per hour in one direction; if two parallel busway routes in separate streets can be established, 60,000 passengers per hour can be moved down the same corridor. Even in mixed traffic, volumes as high as 35,000 bus passengers per hour in one direction have been observed in a single street if several bus lanes are available. It is likely that several different systems will offer sufficient maximum capacity to meet demand. A major factor in choosing from among these systems will be the total costs of each.

COSTING OF SYSTEMS

The cost characteristics of transit systems vary considerably. Operating costs predominate in bus systems in mixed traffic -- for example, the ratio of operating costs to capital costs usually exceeds 5:1 (84% operating costs, 16% depreciation and interest costs). But in the case of underground metros capital costs predominate (25% operating costs, 75% depreciation and interest costs). Operating costs, in turn, are greatly influenced by the costs of labor, energy, and materials, which vary considerably from country to country. Capital costs are closely related to the useful lives of vehicles and infrastructure. Useful life may vary from 8-15 years for buses to 30 years for rail cars and 100 years for tunnels.

These variations and differences must be taken into account in calculating comparative costs. This is achieved by examining the operating cost elements of each system and by expressing capital costs in terms of annual depreciation and interest charges. The cost effectiveness of the various systems can then be compared by expressing total costs (operating costs, depreciation, and interest) in terms of passenger-kilometers.

Annex IV. offers a simplified method of determining total costs for screening purposes. Although the examples chosen to illustrate this costing method represent the main types of systems available, the method can be appplied to variations and combinations of these systems.

Although the costs of transit systems vary considerably from country to country, an examination of some 40 bus services and 30 rail services around the world has made it possible to determine the range of costs likely to arise in developing countries. These have been discussed in chapters 2, 3, 4 and 5; for ease of reference they are consolidated here.

Infrastructure and Equipment Costs

Broad indicators of the main infrastructure and fixed equipment costs of transit systems are provided in Table 7.1.

TABLE 7.1. Infrastructure and Equipment (for two lanes or two tracks)
(US$ millions)

		Busway	Tramway	LRT	Rapid Rail	Life
Elevated structure	(km)	-	-	20 - 40	20 - 40	40 - 60
Tunnel	(km)	-	-	60 - 90	60 - 90	100
Segregated roadway(1)	(km)	2.0 - 7.0	-	1.5 - 5.5	5 - 10	40 - 60
Track	(km)	-	1.0 - 2.0	1.0 - 2.0	1.0 - 1.5	20 - 35
Signals	(km)	-	-	0.5 - 1.0	1.0 - 5.0	20 - 30
Power	(km)	-	2.5 - 3.0	2.5 - 3.0	1.0 - 3.0	30 - 35
Stations:						
Surface	(ea)	<0.05	<0.05	0.1 - 0.15	0.2 - 0.5	40 - 60
Elevated	(ea)	-	-	1.0 - 3.0	2.0 - 5.0	40 - 60
Underground	(ea)	-	-	4.0 - 10.0	8.0 - 20	100
Yards	(ea)	5 - 20	5 - 20	10 - 40	10 - 40	40 - 60
Workshops	(ea)	10 - 30	10 - 30	15 - 50	15 - 50	40 - 60

(1) Segregated roadway costs assume ground level construction with grade separation at intersections.

Vehicle Costs

The costs of vehicles vary considerably, depending on level of comfort, domestic or overseas manufacture, production-line or custom-built models. Table 7.2 provides only a general indication of comparative costs.

TABLE 7.2. Vehicle Costs

Vehicle	Capacity Seated	Capacity Total	Purchase Price, excluding tax (US$)	Life (in years)
Minibus	12	18	25,000	8
Small bus	20	30	40,000	10
Standard bus	40	80	50,000	12
Large single-deck bus	50	100	80,000	15
Large double-deck bus	80	120	100,000	15
Super-large double-deck bus	80	170	120,000	15
Articulated bus	55	120	130,000	15
Super-articulated bus	55	190	150,000	15
Trams	60	100	300,000	20
Light Rail Vehicles	50	300	800,000	25
Rapid Rail Vehicles	50	350	1,000,000	30

Operating Costs, Depreciation, and Interest Charges

Generally reliable details on operating costs are readily available, and in these guidelines it has been possible to make use of data provided by surveys. However, because of the wide variety of methods adopted by operators, the uniform method described in Annex IV. is used to calculate annual capital costs. In this way, total costs in terms of passenger-kilometers are approximated in Table 7.3.

TABLE 7.3. Total System Cost

(Operating cost, depreciation, interest charges)

System	Cost per Passenger-km (in US$)
Bus in mixed traffic	0.02 - 0.05
Bus in reserved lane	0.02 - 0.05
Bus in expressway	0.05 - 0.08
Tramway	0.03 - 0.10
LRT (surface)	0.10 - 0.15
Rapid rail (surface)	0.10 - 0.15
Rapid rail (elevated)	0.12 - 0.20
Rapid rail (underground)	0.15 - 0.25

By using the method described in Annex IV., the results above can be refined for specific cities and specific systems. Care should be taken to adjust for the levels of patronage forecast.

It is important to remember that the results given in Annex IV. assume that the systems will be efficient, well-managed, and heavily patronized. In fact, rarely are all of these favorable circumstances found in transit systems, either in developed or developing countries. It is therefore advisable to test these results to determine what would happen if the desired standards were not achieved. For example, a 30% shortfall in patronage and a 30% capital cost over-run would cause the cost per passenger-km of the systems examined in Annex IV. to rise as shown in Table 7.4.

TABLE 7.4. Sensitivity of Costs

	Cost per Passenger-km (US$)	
	Original Estimate	Adjusted for 30% cost over-run & patronage shortfall
Busway	0.06	0.09
LRT	0.08	0.13
RRT	0.12	0.21

As would be expected, the capital-intensive LRT and RRT systems are particularly sensitive to cost over-runs.

After all the options (including improvement of the existing system) have been costed, the financial implications and the benefits can be compared.

FINANCIAL IMPLICATIONS

Since the commissioning of a new transit system is likely to be the largest single investment undertaken by most city authorities, it is vital that very careful consideration be given to the full financial implications of each option. Of primary importance is the impact of each investment option on the city's budget (or, as the case may be, on the national budget) and on user affordability.

In assessing the impact on city finances (or national finances), the relationship between the investment for a new transport system and the city's investment program as a whole should be examined. For this purpose, an investment program outline should be prepared covering at least the period of implemention of a new transport system as well as all other major investments under consideration. The ability of the city to undertake the proposed level of investment needs to be closely examined, and the source of funding needs to be clearly identified. One means of gauging the likely impact of new transport investments is to compare the city's total investment program with levels of investment in urban transport in previous years.

Another indication of the appropriateness of each option can be obtained by relating its total capital cost to the total number of people to be served. In Manila, for example, the capital cost of the new LRT is US$200 million. Approximately 500,000 people (8% of the population) are expected to use the system regularly, so the capital cost will be equivalent to US$400 for each user. Meanwhile, the city will spend an insignificant amount on public transport for the remaining millions of commuters, who mainly travel in privately owned buses and minibuses. An extreme example is provided by Caracas, where only 5% of the population regularly uses the underground metro, which was built at a cost in excess of US$1,440 million. That is equivalent to US$10,000 for each user. City expenditures on public transport for the remaining 95% of the population, including large numbers of urban poor, are negligible. In comparing options, therefore, the equity of wide variations in levels of expenditure needs to be considered.

In considering user affordability, it is necessary to calculate the fare levels that would be required to achieve full cost recovery. An indication of these is given in Table 5 of Annex II. The likely household expenditure on transport at these fare levels as a proportion of household income needs to be assessed, and compared with current household expenditure on transport. Due consideration must be given to the likely reaction of the public to any fare increases that may be required for each of the systems being screened.

It is not uncommon to find that 5%-10% of urban household income in developing countries is spent on transport. In some cities it is 15% or more. Table 7.5 indicates the affordability of various systems.

TABLE 7.5. Income Required for Cost Recovery

	Bus	LRT	RRT
Cost of 10 km[(1)] round trip (US$)	0.20 - 0.50	1.00 - 1.50	1.50 - 2.50
% of income spent on transport	Annual per capita income required to afford cost recovery fares[(2)]		
5	1,200 - 3,000	6,000 - 9,000	9,000 - 15,000
10	600 - 1,500	3,000 - 4,500	4,500 - 7,500
15	400 - 1,000	2,000 - 3,000	3,000 - 5,000
20	300 - 750	1,500 - 2,250	2,250 - 3,750

(1) Higher daily expenditure on transport will result where it is necessary to interchange between modes.

(2) Assuming 300 working days per year.

If full cost recovery is not contemplated, the implications of subsidies and their source will need to be carefully examined. (The implications of subsidies for urban transport systems are fully discussed in the World Bank Urban Transport Policy Paper.)

ECONOMIC APPRAISAL

While there are clear advantages to undertaking a full economic appraisal of each of the options, it is sufficient for screening purposes to establish the approximate costs and to broadly quantify the main user benefits. For transit in developing countries the primary user benefits are savings in journey times. Other benefits, such as convenience, comfort, safety, and reduced environmental impact need to be considered, but detailed appraisal can be deferred until a feasibility study of the options that survive the screening process is carried out.

The savings in journey times should be assessed by comparing the forecast journey times (including waiting and interchange times) of each option with the journey times of the existing system. The magnitude of the benefits will depend on the number of passengers and the value placed on the time saved by each passenger. Most passengers on transit are commuters making non-business trips. Some authorities consider that no value should be placed on the time saved in taking non-business trips, while others suggest that it is equivalent to 25%-30% of the income earning rate. (Business trips are usually assessed at the full earning rate.)

For screening purposes, and to recognize other user benefits, the value of time saved on non-business trips can be increased to 50% of passengers' earning rates. This will avoid eliminating systems with appreciable but unmeasured user benefits. A simple way to make a rough calculation of the significance of time savings benefits is to determine the level of income at which the value of time saved equates to the extra cost of switching to a new system.

Table 7.6 shows the level of earnings necessary for the value of time savings to equate to a range of extra costs:

TABLE 7.6. Level of Income for Benefits to Equate to Extra Costs[1]

Extra Cost Per Day (US$)	Annual Per Capita Income[2] US$
0.10	400
0.20	800
0.30	1,200
0.40	1,600
0.50	2,000
1.00	4,000
1.50	6,000
2.00	8,000

(1) Assumptions: time savings equal one hour per passenger on a 10-km round trip per day
: time savings are valued at 50% of the rate of earnings
: "extra costs" are derived from Annex II., Table II.5., and are for a 10-km round trip

(2) Sensitivity: If time savings are doubled to two hours (which is not very likely) the above income levels will be halved. But if time savings are only 30 minutes per day (which is more than likely) then the above income levels would need to be doubled.

In effect, the above table indicates that, on the basis of time savings, the increased cost ($1.00) of switching from bus service to a metro would be justified only if the average annual income of commuters exceeded $4,000.

ENVIRONMENTAL ASPECTS

Because of very considerable differences in the value placed on the environment in different countries, and the complexity of the subject, no attempt is made in these guidelines to quantify the environmental impact of transit systems. Nevertheless, environmental impact on the community, including disruption of city life, is an important consideration in the selection of transit modes.

For the purpose of this screening process, a system should not be ruled out on environmental grounds unless the system is also low or a borderline case among the options selected for detailed feasibility study. Nevertheless, the value of each option in reducing environmental impacts should be considered.

The following Table 7.7 provides a broad qualitative indication of the environmental impact of various systems:

TABLE 7.7. Environmental Impact of Transit Systems

Mode	Air Pollution	Noise	Visual Intrusion	Safety
Buses in mixed traffic	Poor	Average	Good	Average
Buses in reserved lanes	Average	Average	Good	Average
Buses in busways	Good	Good	Good	Good
Tramways	Very good	Average	Average	Average
LRT surface	Very good	Average	Average	Good
RRT surface	Very good	Poor	Poor	Good
RRT elevated	Very good	Poor	Poor	Very good
RRT underground	Very good	Very good	Very good	Very good

OTHER CHARACTERISTICS

The other characteristics of transit systems that need to be taken into account are:

- flexibility in coping with changing demands — that is, temporary or permanent re-routing;

- the amount of interchanging that may be necessary;

- problems of fare collection, fare evasion, and revenue leakage;

- degree of sophistication of operation and maintenance;

- comfort and reliability;

- construction and implementation difficulties.

These are outlined in chapters 2, 3, 4, and 5 for each type of transit system. The particular problems that need to be addressed in an examination of high-capacity systems are listed in Annex VI.

COMPARISON OF RESULTS

When all the steps in the screening process have been completed, the findings concerning each of the systems need to be summarized and consolidated for ease of comparison. This can be done by setting out the details of each system along the lines of the data sheets used for the examples illustrated in Annex IV. In addition, the summary should cover the financial impact of each system, together with a brief note on its economic and environmental aspects. The checklist in Annex VI. should be used to ensure that important questions have not been overlooked. The answers, if significant, should be added to the summary.

There are likely to be some options that are clearly inappropriate and that should be rejected, while others may clearly deserve more detailed examination. Before any borderline cases are rejected, the possibility of modifying them to make them more acceptable should be carefully considered. Systems that offer insufficient capacity to meet demand but which otherwise are attractive should be examined to see if they can be duplicated in other streets to meet demand along the same corridor. Or it may be possible to combine attractive systems to provide the best arrangement.

These guidelines have been designed to provide a rapid method of examining an array of transit options, and they are not intended as a substitute for a detailed feasibility study. Such a study will be necessary before the most appropriate solution can be selected and before detailed designs can be undertaken. Nevertheless, the guidelines should provide decision makers with a useful tool in assessing the validity of suggestions and recommendations for new transit systems and avoiding the costly examination and implementation of inappropriate options.

Annex I.

Transit Options Study:

Draft Terms of Reference

Background

[Here insert a brief description of the city, providing details of its population, area, and basic transport data. Outline problems in the current transport situation which are causing the most concern. List any earlier transit investigation and transport studies that may be relevant or of assistance to this study. Also, describe current Government policies regarding urban transport and development, and possible policy changes that may be under consideration.]

Study Objectives

The main objectives of this study are to:

- identify the transit systems (which might include the existing transit systems) that are likely to be viable and to meet future demands, and thus worthy of detailed feasiblity study;

- avoid expenditure of funds and other resources on detailed study of inappropriate systems;

Specifically, the objectives of the study are to:

- outline deficiencies in existing transit systems;

- estimate the approximate current and future demand for transit services;

- establish the most effective way of improving existing transit systems and determine the extent to which these are likely to be able to cope with future demand;

- establish the general scope and character of new transit systems which are more likely to be viable and able to meet anticipated future demand;

- assess the operational and economic feasibility and overall practicability of each transit option;

- after eliminating those options that do not merit further considerations, compare the remaining alternatives with an improved existing system. The analysis should be made in sufficient depth to determine whether it justifies the cost of a subsequent feasibility study;

- present the findings in a form that assists the authorities in reaching a decision about a possible feasibility study. This may include the identification of candidate transit systems to be evaluated in greater detail and the Terms of Reference for a subsequent feasibility study.

Scope

Geographic. The study should examine the main commuter corridors [here identify two or three corridors with the heaviest demand and causing the most concern] and should cover the areas which significantly contribute to demand along these corridors.

Technological. All transit technologies which have a chance of proving viable are to be considered. [Insert here any specific technologies that should be excluded because they recently have been considered in depth and are known to be inappropriate.]

Particular attention is to be given to any system previously proposed [insert a description of any specific proposals which are required to be evaluated].

The study should consider the different forms of right-of-way that can be provided and which have a chance of proving viable. These may include shared, semi-exclusive, or completely exclusive rights-of-way over all or part of the network or route. Similarly, wholly or partly grade-separated crossings and systems should be considered.

Institutional Options. The study should consider the institutional options that may be available and appropriate to ensure the viability of the improved or proposed new transit systems. In particular, the study should consider the opportunities for participation by the private sector.

Problems to be Addressed

The present transit system is suffering from [insert details of overcrowding, excessive travel time, etc. Identify the causes if these are known, such as inadequate transit equipment, poor transit operations, street congestion, or some other, and give details of any reports that diagnose the problems]. The final report must demonstrate how the systems proposed for further study will effectively address these problems in a cost-effective fashion.

Available Data Sources

Wherever possible, the analysis should be based on available statistics and past surveys of travel characteristics, and other relevant planning data. The gathering of new field data, if required at all, is to be kept to a minimum. Some limited investigation, however, may be necessary to obtain up-to-date and reliable cost details.

Study Approach

Since only a broad indication of the suitability of various options is required, the study should rely on readily available data, experience, and simplified comparative analysis. It should avoid the need for comprehensive travel studies and detailed analysis of options.

To reduce the amount of study time and effort involved, the study should concentrate on two or three of the main transit corridors. [If there are several major transit corridors, the most heavily utilized corridor and another which is most representative of the remainder should be selected for study.] The balance of the transit network need not be examined in detail, but compatibility with options for the main corridors should be checked.

Study Methodology

Base Year. A base year which represents the first full year of operation of the selected option should be chosen for analysis. [Initially it should be assumed that the base year will occur five years after completion of the feasibility study. Subsequently, the base year may have to be adjusted, depending on the anticipated implementation period of the options listed for further study.]

Study Period. Assessments and forecasts should be made for the base year, for one year in the medium term [5 years after the base year], and for one year in the long term [15 years after the base year] [insert actual years].

Assessment of Demand. Estimate the base-year, medium-term, and long-term travel demands and modal splits for each of the corridors to be studied. Detailed travel surveys should not be undertaken. Instead, future demand in each of the study years should be estimated by projecting current passenger flows using simple growth factors based on forecast urban population growth and, if available, details of past trends in transport demand. Allowance should be made for unsatisfied demand and for demand likely to be generated by new development in areas close to the corridors being studied. If projections available from previous studies are to be used, the validity of the data should be checked.

The study should examine opportunities to restrain the use of private cars (e.g., road pricing, user taxes), and to reduce demand where it is expected to be particularly heavy (e.g., by dispersing routes, road network modifications, etc.). The impact of these measures on the selection of options should be indicated in the study.

Generating Options. A wide range of transit options, including improvements to the existing system, should be generated and defined in sufficient detail to permit initial screening. These options should include a variety of:

- technical options;
- right-of-way options;
- network configuration options; and
- institutional options.

Screening of Options. Using experience and simplified comparative analysis, the many options generated should be screened to eliminate clearly inappropriate systems and to reduce the number to a manageable size. Approximately five options, including the neutral case, should be listed for further examination.

Costs. For each transit system on the short list, estimate capital costs and operating costs for each of the three study years (the base year, medium-term year, and long-term year) [insert dates]. The estimates should assume that sufficient infrastructure, rolling stock, and operating resources will be provided when necessary to keep pace with the travel demand forecast for each of the study years.

Economic Evaluation. A simplified method of cost-benefit analysis should be employed to judge each of the transit options on the short list, including the neutral case. The analysis should be for each of the three study years: the base year, the medium-term year, and the long-term year [insert dates].

Financial Evaluation. A financial evaluation should be made of each transit option on the short list, with particular regard to the funding of both capital and operating costs, and opportunities for full cost recovery.

Sensitivity Test. The sensitivity of both the economic and financial evaluation results to key parameters, such as interest rates, fare levels, energy costs, and patronage levels should be tested for each system on the short list.

Implementation, Integration, and Operational Aspects. For each option on the short list the study should consider in general terms:

- the effect on traffic, services, and the environment during and after implementation;

- the ease or difficulty of integrating any new system into the existing system, particularly the problems of any proposed rescheduling or curtailing of other services that may be involved;

- the impact of highly concentrated demand on other city services and facilities;

- operational feasibility, and the capability of meeting changing patterns and levels of demand;

- ability to provide adequate services in areas of low and high density;

- the level of sophistication and technology of any new systems, and the availability of people with the necessary skills for operation and maintenance.

Schedule and Reporting

An interim report in .... copies will be submitted within .... weeks of instructions to proceed with the project. The interim report will outline the assessment of the problem, the proposed neutral case, and the wide range of options, with a description of the screening process and the shorter list of alternative transit systems proposed for more detailed investigation. It will also describe the estimation of unit costs, both for the fixed infrastructure and for operations.

The draft final report will be submitted in .... copies within .... weeks of instructions to proceed with the project. The draft final report will present both the findings of the investigation and the data upon which the findings are based. The report will also contain proposed Terms of Reference for a subsequent feasibility study, provided such a study has been judged to be worthwhile. The final report in .... copies will be submitted within .... weeks of receiving the client's comments on the draft final report.

Staffing

It is envisaged that this study will require about .... man-months of professional work. It will be the consultants' responsibility to mobilize a team which can do justice to the requirements of the study. Expertise should be provided on the following subjects:

- civil engineering, with particular experience in costing,
- economics,
- bus operations and management,
- transport planning,
- traffic engineering.

Government Responsibilities

The Government undertakes to give the consultants access to all available data that are relevant to this study. This will include the following data sources:

- [here insert a description of the data sources, including reports, statistical series, etc.]

The Government will also provide office space, secretarial and drafting help, transportation, and office equipment necessary to conduct the study quickly and efficiently. Moreover, it will assign ....to the study full-time to provide liaison between the consultants and various Government Departments.

Other Sections [Include here standard clauses on:

- Method of payment

- Reference to a standard form of agreement
- Exclusion of agents of manufacturers of transit equipment from the project
- Procedures for immigration, work permits, housing, importation of equipment, etc.
- Procedure for settlement of disputes.]

TABLE II.1. Urban Transport Data: Selected Cities

CITY	POPULATION 1980 (1,000)	RATE OF POPULATION GROWTH 1970-80 %per annum	METRO AREA 1980 km2	GNP PER CAPITA* WDR 1980 US $	TOTAL NO. OF CARS 1980 (1,000)	CARS PER 1,000 POP. 1980	RATE OF GROWTH OF CARS 1970-80 %pa	TOTAL NO. OF BUSES 1980	BUSES PER 1,000 POP. 1980	NO. OF COMMER. VEHICLES 1980	MARKET PRICE OF ECONOMY CAR 1983 US $	PRICE OF REGULAR GAS/LITRE 1983 US $	BUS FARE FOR 5 km TRIP 1983 US $	MODAL SPLIT OF MOTORIZED TRIPS: AUTO	TAXI	BUS	PARA-TRANSIT	RAIL/ SUBWAY	OTHER
ABIDJAN	1,715	11.0	261	1,150	85	50	10	2,410	1.41	-	6,560	0.80	0.26	33	12	50	-	-	5
ACCRA	1,447	6.7	1,390	420	27	19	-	709	0.49	7,411	6,000	0.45	0.18	-	-	-	-	-	-
AMMAN	1,125	4.1	36	1,420	81	72	-	433	0.38	32,000	10,850	0.54	0.48	44	11	19	26	0	0
ANKARA	1,900	4.4	237	1,470	65	34	14.2	781	0.41	-	7,097	0.50	0.14	23	10	53	9	2	2
BANGKOK	5,154	9.1	1,569	670	367	71	7.9	6,300	1.22	34,155	10,870	0.48	0.09	25	10	55	10	-	-
BOGOTA	4,254	7.1	-	1,180	180	42	7.8	9,081	2.13	-	6,075	0.23	-	14	1	80	0	0	5
BOMBAY	8,500	3.7	438	240	180	21	6.1	3,066	0.36	38,447	7,327	0.61	0.05	8	10	34	13	34	-
BUENOS AIRES	10,100	1.7	210	2,390	537	53	10	12,089	1.20	97,245	4,500	0.40	0.11	-	-	45	27	-	28
CAIRO	7,464	3.1	233	580	239	32	17	8,177	1.10	42,000	10,002	0.20	0.07	15	15	70	-	-	-
CALCUTTA	9,500	3.0	1,414	240	95	10	5.6	3,160	0.33	28,500	7,922	0.69	0.04	-	2	67	14	10	4
HARARE	670	5.2	-	630	107	160	3	504	0.75	5,300	-	-	0.15	-	-	-	-	-	-
HONG KONG	5,067	2.5	1,060	4,240	200	39	7.4	9,278	1.83	58,801	5,833	0.56	0.13	8	13	60	-	19	-
JAKARTA	6,700	4.0	650	430	222	33	9.8	4,798	0.72	77,781	18,697	0.34	0.16	27	-	51	-	1	21
KARACHI	5,200	5.2	1,346	300	184	35	8.4	12,064	2.32	17,628	10,741	0.46	0.04	3	7	52	18	6	13
KUALA LUMPUR	977	3.5	244	1,620	37	38	-	1,148	1.18	7,923	8,616	0.49	0.15	37	-	33	17	0	13
LAGOS	1,321	3.1	665	1,010	62	47	-	-	-	58,857	-	-	0.45	-	-	-	-	-	-
LIMA	4,415	4.2	-	930	333	75	7.2	8,853	2.01	1,060	8,000	0.30	-	-	-	45	27	-	28
MANILA	5,925	5.1	636	690	266	45	8.0	31,403	5.30	100,725	9,187	0.49	0.07	16	2	16	59	-	8
MEDELLIN	2,078	3.2	1,152	1,180	91	44	-	4,800	2.31	10,800	6,975	0.23	0.07	6	4	85	5	0	-
MEXICO CITY	15,056	5.0	1,479	2,090	1,577	105	-	18,500	1.23	155,500	7,000	0.26	0.09	19	-	51	13	15	2
NAIROBI	1,275	8.8	690	420	60	47	-	1,100	0.86	-	-	-	0.15	45	-	31	15	0	9
RIO DE JANEIRO	9,200	2.4	6,464	2,050	957	104	12.1	11,000	1.20	95,945	4,506	0.77	0.21	24	2	62	2	11	-
SAN JOSE, CR	637	3.5	180	1,730	-	-	-	500	0.78	-	-	-	0.07	21	2	75	0	0	2
SAO PAULO	12,800	4.5	1,493	2,050	1,935	151	7.8	16,400	1.28	240,000	5,469	0.65	0.26	32	3	54	-	10	1
SEOUL	8,366	5.0	627	1,520	127	15	11.7	13,000	1.55	63,222	5,574	0.85	0.16	9	15	68	0	7	0
SINGAPORE	2,413	1.5	618	4,430	164	68	6.8	6,512	2.70	78,038	16,563	0.70	0.24	47	-	-	-	-	53
TUNIS	1,230	6.4	115	1,310	38	31	-	642	0.52	-	8,106	0.47	0.27	24	4	61	-	10	-
LONDON	6,851	-0.9	1,579	7,920	1,932	282	2.6	11,479	1.68	78,723	8,354	0.70	0.61	61	1	23	0	12	2
NEW YORK	7,086	-1.0	759	11,360	1,545	218	-	10,481	1.48	90,692	9,000	0.33	0.75	12	2	14	0	72	0
PARIS	8,800	0.6	454	11,730	3,240	368	12.3	7,100	0.81	255,000	4,592	0.54	0.30	56	-	8	0	21	15
STOCKHOLM	1,528	3	6,489	13,520	391	256	3	1,850	1.21	34,036	8,569	0.53	-	48	-	53	-	-	-
STUTTGART	581	-0.8	207	13,590	199	343	2.5	332	0.57	-	7,833	0.55	0.82	44	6	33	6	-	11
TOKYO	8,352	-5.6	592	9,890	2,219	266	2.5	6,393	0.77	130,427	3,516	0.59	0.59	32	-	6	0	61	0
WELLINGTON	135	-0.7	266	7,090	61	452	-	256	1.90	24,432	9,279	0.59	0.67	56	-	26	-	5	10

* National Data

\+ Some cities have very substantial proportions of walk trips not reflected in motorized modal split.

\- Data not available.

SOURCES: World Bank surveys, studies and appraisals.

TABLE II.2. Bus Services: City Comparisons, 1983 Data

(Covering principal corporation or group of private operators in each city does not include paratransit.)

CITY	OWNER-SHIP	NUMBER OF BUSES (1)	AVAIL-ABILITY (%)	km PER OPERATING BUS PER DAY	STAFF PER OPERATING BUS	PASSENGERS PER OPERATING BUS PER DAY	ANNUAL OPERATING COST (US $ mill) (2)	TOTAL COST PER PASSENGER KILOMETER (3)	ANNUAL OPERATING REVENUE (US $ mill) (4)	FARE (typical, 5 km) (US $)	RATIO: OPERATING REVENUE /TOTAL COSTS (3)
1 ABIDJAN	MIXED	1,044	85	183	7.1	829	91.29	0.07	69.40	0.26	0.67
2 ACCRA	PUBLIC	44	24	292	28.1	2,092	1.03	0.03	0.63	0.13	0.51
3 ACCRA	PRIVATE	665	73	223	5.5	676	10.43	0.04	17.72	0.18	1.37
4 ADDIS ABABA	PUBLIC	164	58	205	13.1	2,467	7.96	0.02	6.59	0.07	0.67
5 ANKARA	PUBLIC	899	67	210	5.8	1,273	25.62	0.01	15.31	0.14	0.48
6 BOMBAY	PUBLIC	2,325	92	216	14.0	2,093	81.95	0.01	72.97	0.05	0.77
7 CAIRO	PUBLIC	2,454	69	246	14.6	2,417	60.41	0.01	36.19	0.07	0.50
8 CALCUTTA	PUBLIC	981	64	133	18.0	1,641	23.05	0.01	13.09	0.04	0.45
9 DAKAR	MIXED	439	70	287	9.6	1,193	22.97	0.04	20.41	0.26	0.76
10 GUATEMALA CITY	PRIVATE	1,600	95	304	-	1,037	29.00	0.02	54.60	0.10	1.55
11 HONG KONG	PRIVATE	2,392	85	243	4.7	1,610	117.96	0.03	136.10	0.13	1.00
12 KARACHI	PUBLIC	646	65	267	9.9	1,135	11.73	0.01	6.73	0.04	0.43
13 KUALA LUMPUR	PRIVATE	358	80	250	4.3	753	12.03	0.02	12.38	0.17	1.00
14 MOMBASA	MIXED	89	90	315	7.5	1,640	3.93	0.03	4.48	0.11	0.96
15 NAIROBI	MIXED	295	84	330	9.7	1,762	16.31	0.03	17.98	0.15	1.08
16 PORTO ALEGRE	PRIVATE	1,492	95	218	4.3	669	46.68	0.05	65.35	0.23	1.17
17 SAN JOSE	MIXED	621	80	128	-	2,013	19.39	0.02	24.24	0.07	1.04
18 SAO PAULO	PUBLIC	2,631	83	284	7.4	795	159.51	0.03	75.64	0.26	0.41
19 SAO PAULO	PRIVATE	6,590	83	280	5.1	765	-	-	-	0.26	1.00(5)
20 SEOUL	PRIVATE	8,310	95	340	3.9	1,326	398.18	0.03	443.43	0.16	1.04
21 SINGAPORE	PRIVATE	2,859	91	269	3.9	374	110.23	0.10	147.75	0.24	1.32
22 ATHENS	PUBLIC	1,768	87	245	6.6	910	100.36	0.05	37.39	0.23	0.34
23 BERLIN	PUBLIC	1,505	85	199	5.8	992	234.99	0.16	130.08	0.78	0.51
24 CHICAGO	PUBLIC	2,275	93	125	3.1	750	339.28	0.08	194.54	0.90	0.52
25 LONDON	PUBLIC	4,901	88	202	6.8	842	605.90	0.17	319.21	0.61	0.48
26 PARIS	PUBLIC	4,005	87	142	4.5	419	512.00	0.25	191.45	0.30	0.37
27 SENDAI	PUBLIC	777	92	128	2.5	495	57.76	0.11	59.44	0.58	0.96

(1) Number of buses belonging to the principal corporation or group of private operators covered by the survey. The total number of buses operated in the city as a whole is given in Annex I.
(2) Operating costs excluding depreciation and interest charges.
(3) Total costs including operating costs, depreciation and interest charges. For comparative purposes a uniform method to determine depreciation and interest charges has been used to obtain total costs. Passenger kilometers are imputed using an average trip length of five kilometers.
(4) Operating revenue including fare box and advertising revenue but excluding subsidies.
(5) Cost and revenue data for Sao Paulo private operators are not available; however private operators receive no subsidy from the government and are known to at least break even.

SOURCES: World Bank survey of operators, studies and appraisals.

TABLE II.3. Rail Services: City Comparisons, 1983 Data

CITY	TYPE OF SYSTEM	LENGTH OF LINE (km)	PERCENT BELOW GROUND	TOTAL NUMBER OF STATIONS	CAPACITY PER TRAIN: SEATED	CAPACITY PER TRAIN: SEATED PLUS STANDING	CAPACITY PER TRAIN: CRUSH (1)	NO. OF TRAINS OPERATED	TOTAL ANNUAL PASSENGERS (mill)	MAX. PASSENGER FLOW ONE DIR. ON BUSIEST LINE PEAK HOUR	ANNUAL OPERATING COSTS (US $ 1983) (mill) (2)	TOTAL ANNUAL COSTS (incl. cap. costs) (US $ 1983) (mill) (3)	ANNUAL OPERATING REVENUES (US $ 1983) (mill) (4)	FARE (5 km) (US $)	RATIO: OPERATING REVENUE/ TOTAL COSTS (INC. ANN. CAP. COSTS) (3)	TOTAL COSTS PER PASS-ENGER-km (US $ 1983) (3) (5)
1 CARACAS	METRO	12.3	90	14	408	1,265	1,668	14	80.6	28,700	33.34	120.28	42.16	0.47	0.35	0.332
2 SANTIAGO	METRO	25.6	81	35	193	844	1,000	49	109.0	14,295	15.32	76.89	20.31	0.18	0.26	0.136
3 SAO PAULO	METRO	25	70	26	198	666	-	52	347.0	58,000	67.15	210.54	40.68	0.07	0.19	0.081
4 TUNIS	SUBURBAN RAIL	26	0	20	500	1,300	-	9	24.0	8,000	7.55	11.41	4.05	0.20	0.36	0.044
5 ADELAIDE	SUBURBAN RAIL	152.1	0	93	556	665	840	76	12.9	3,600	31.70	51.88	4.29	0.54	0.08	0.538
6 BALTIMORE	METRO	12.8	56	9	456	540	996	12	7.8	-	99.20	147.33	48.10	0.75	0.33	2.518
7 BERLIN	METRO	100.8	100	114	228	1,182	1,182	172	346.2	40,000	126.44	498.15	104.05	0.78	0.21	0.228
8 CALGARY	LIGHT RAIL	12.5	10	8	128	324	440	20	11.9	4,650	5.44	15.43	-	0.81	-	0.146
9 CHICAGO	METRO	395.8	9	143	200	1,340	-	300	149.7	12,395	101.50	388.79	61.30	0.90	0.16	0.221
10 HONG KONG	METRO	26.1	77	25	288	2,250	2,250	92	412.0	60,000	60.96	152.06	132.27	0.06	0.87	0.049
11 LONDON	METRO	388	42	247	290	750	814	449	563.0	23,000	440.08	1,094.58	440.99	0.51	0.40	0.259
12 MONTREAL	METRO	50.3	100	57	360	1,440	1,440	84	199.9	20,000	92.53	180.38	31.68	0.69	0.18	0.141
13 NAGOYA	SUBURBAN RAIL	544.5	0	369	184	520	920	210	379.8	37,000	189.34	224.78	261.43	-	1.16	0.032
14 NAGOYA CITY	METRO	57.5	96	59	211	603	1,508	93	330.0	43,697	127.09	326.43	158.73	0.72	0.49	0.432
15 NEW YORK	METRO	370	60	465	600	1,760	2,200	564	952.6	68,000	1,100.00	4,750.99	955.34	0.90	0.20	0.480
16 OSAKA	METRO	90.9	88	74	370	1,100	2,750	115	856.6	62,696	414.37	780.32	416.49	0.72	0.53	0.182
17 SAN DIEGO	LIGHT RAIL	25.6	0	18	128	376	800	24	4.7	1,267	5.30	14.86	4.34	0.50	0.29	0.524
18 SAN FRANCISCO	METRO	113.6	28	34	540	810	1,080	43	55.5	15,086	128.20	401.66	69.80	0.60	0.17	0.341

(1) Crush capacity represents the maximum passengers that can be safely carried in very crowded conditions but without causing serious discomfort.
(2) Operating costs excluding depreciation and interest charges.
(3) Total costs including operating costs, depreciation, and interest charges. For comparative purposes a uniform method to determine depreciation and interest charges has been used to obtain total costs.
(4) Operating revenue including fare box and advertising revenue but excluding subsidies.
(5) Passenger kilometers where not specified in the survey response are imputed using an average trip length of 7.5 kilometers.
SOURCES: World Bank survey of all operators, supplemented by World Bank analyses and studies.

TABLE II.4. Rail Services: Capital Cost of Typical Rail Systems

(A) Existing Systems: Recently Constructed Sections

	CITY	TYPE OF RAIL AND RIGHT OF WAY	SECTION	LENGTH (km) TOTAL	LENGTH (km) UNDER GROUND	STATIONS TOTAL	STATIONS UNDER GROUND	TOTAL CAPITAL COSTS (1983 US $ mill) TOTAL	TOTAL CAPITAL COSTS (1983 US $ mill) PER km
Light Rail									
	SAN DIEGO	Surface Trolley	Total	25.6	0	18	0	127	5.0
	HANOVER	Surface LRT	Total	69.0	12.0	110	14	750	10.9
	MANILA	Elevated LRT	Total	15.0	0	18	0	200	13.3
	CALGARY	Elevated LRT	Main Line + Ext.	22.3	1.5	24	1	348	15.6
	ROTTERDAM	LRT/Metro	N-S Ext.	4.3	0	3	0	86	20.1
	UNIS	Surface LRT	Line 1	8.1	0.2	11	1	233	28.6
	HANOVER	Tunnel LRT	Section of B	2.8	2.8			108	38.5
Suburban Rail									
	NAGOYA	Surface	Various Lines	414.0	1.7	291		13,668	33.0
Metro									
	SANTIAGO	Underground	Total - 2 lines	25.6	20.8	35	28	1,015	39.7
	BALTIMORE	Surface/Underground	NW Line + Ext.	18.1	6.7	12	6	996	55.0
	BERLIN	Underground	Extension (tunnel)	4.6	4.6	5	5	275	59.7
	OSAKA	Underground	Extension	14.1	13.8	13	12	898	63.7
	HONG KONG	Underground/Elevated	Mainland	26.1	20	26	18	1,519	58.2
	SAO PAULO	Underground	Total - 2 lines	24.3	17	26	16	2,338	96.2
	NAGOYA	Underground	Line 3	16.3	16.3	17	17	1,808	110.9
	HONG KONG	Underground/Elevated	Island Line	12.5	10.5	12	9	1,400	112.0
	NAGOYA	Underground	Line 6	14.9	14.9	17	17	1,685	113.1
	CARACAS	Underground	Line 1 Phase 1	12.3	11.0	14	12	1,440	117.1

(B) PLANNED SYSTEMS

	CITY	TYPE OF RAIL AND RIGHT OF WAY	SECTION	LENGTH (km) TOTAL	LENGTH (km) UNDER GROUND	ESTIMATED CAPITAL COST TOTAL	ESTIMATED CAPITAL COST PER km
Light Rail							
	SAN JOSE, CA USA	LRT		32.0	0	316	9.9
	TORONTO	LRT		7.1	0	109	15.3
Metro							
	MEDELLIN	Surface/Elevated	Two Lines	22.5	0	500	22.2
	BANGKOK	Elevated		30.0	0	730	24.3
	LAGOS	Elevated		25.7	0	950	33.9
	CALCUTTA	Underground		16.4	15.0	1,100	67.1
	SINGAPORE	Underground/Surface	Sec. 1	17.1	14.6	1,200	70.2
	BAGHDAD	Underground	Sec. 1	5.5	5.5	450	81.8
	CARACAS	Underground	Total by 1989	40.0	30.9	3,600	90.0

SOURCES: World Bank survey of operators, studies and appraisals.

TABLE II.5. Transit System Characteristics(1)

System Characteristics	Private Cars	Para-transit	Buses (and trolley buses)(2): mixed traffic	Buses (and trolley buses)(2): bus only lanes	Buses (and trolley buses)(2): segregated busways	Trams: mixed traffic	LRT: surface exclusive	Rapid Rail: surface	Rapid Rail: elevated	Rapid Rail: under-ground
Vehicle capacity	4 to 5 (1 to 2) (occupancy)	4 to 20	80 to 120	80 to 120	120	100 to 200	car 200 to 300	300 to 375	300 to 375	300 to 375
Vehicles per train	-	-	-	-	-	1 to 2	3 to 6	4 to 10	4 to 10	4 to 10
Lane/track capacity: passenger/hr(3)	500 to 800	1,000 to 4,000	10,000 to 15,000	15,000 to 20,000	30,000	6,000 to 12,000	20,000 to 36,000	50,000	70,000	70,000
Journey speed with stops km/hr(4)	15 to 25	12 to 20	10 to 12	15 to 18	15 to 30	10 to 12	15 to 25	30 to 35	30 to 35	30 to 35
Capital costs US$ vehicles (each)	5,000 to 10,000	2,500 to 25,000	50,000 to 100,000	50,000 to 100,000	50,000 to 130,000	300,000 to 600,000	800,000	1,000,000	1,000,000	1,000,000
Complete system (less vehicles) costs US$ M/km	-	-	-	-	2 to 7	3 to 5	6 to 10	20 to 25	45 to 55	85 to 105
Total cost US$ passenger km (incl. interest)	0.12 to 0.24	0.02 to 0.10	0.02 to 0.05	0.02 to 0.05	0.05 to 0.08	0.03 to 0.10	0.10 to 0.15	0.10 to 0.15	0.12 to 0.20	0.15 to 0.25
Cost recovery fare: typical 5 km trip US$	0.60 to 1.20	0.10 to 0.50	0.10 to 0.25	0.10 to 0.25	0.25 to 0.40	0.15 to 0.50	0.50 to 0.75	0.50 to 0.75	0.60 to 1.00	0.75 to 1.25

(1) Costs and performance figures assume high utilization and patronage levels, and efficient operation.
(2) For trolley buses add approximately 20% to the bus costs.
(3) Lane/track capacity: the maximum number of passengers that can be carried on a single lane or track past a point during one hour.
(4) Journey speed: the average overall, speed taking into account loading and unloading time at stops and stations (journey speeds in mixed traffic may be substantially less in congested conditions).

Source: World Bank studies

Annex III.

The Approximation of Transit Demand

These notes describe a quick method of assessing, very approximately, the magnitude of demand for transit services along a specific corridor.

Existing Demand

To estimate existing demand, passenger counts should be carried out at a number of locations in the corridor during peak periods (say, two hours in the morning and in the late afternoon). The count should include, if possible, all public transport modes — that is, public buses, works buses, lorries carrying passengers, minibuses, paratransit vehicles, taxis, etc.

All roads with significant public transport flows in the corridor should be included so that an overall picture of total demand can be built up.

These counts need only be approximate and can be performed by observers, estimating the number of passengers in a vehicle as a percentage of its capacity. Training may be necessary, with observers riding on the buses recording the capacity of different types and gaining experience in estimating percentages through roadside observation.

Bus company records may yield a significant amount of data on passenger volumes, route patterns, and frequency. Very often, local operators will intuitively know the pattern of demand and will have scheduled bus services accordingly. (However, formal sources of data, such as statutory returns, can be misleading. Records may indicate the scheduled frequency and pattern of services, but actual service may be very different. Similarly, operators are reluctant to record buses operating above their legal capacity, and actual ridership may be significantly higher. Hence, there is a need to carry out spot checks to determine the validity of operator records.)

Information on seasonal or monthly trends is likely to be available from local operators, and counts should be carried out when demand is highest (excluding holidays, etc.). There may be significant variations within individual months or weeks.

Future Demand

Generally, it can be assumed that demand for passenger transport services will grow at least at the same rate as urban population growth. Thus, approximate future demand can be assessed by using population growth factors. This estimate can be refined by taking into account any available details on past trends in transport demand and the effects of other trends (e.g., car ownership, household income). Special allowance should also be made for the demand likely to be generated by new development areas close to the corridor being studied.

The number of additional trips generated by new development will depend on the population of the new area and its proximity to the corridor and to main destination areas. Very roughly, the number of trips generated along the corridor by the new development area, in relation to proximity and population, is likely to be as follows:

distance between new development area center and the corridor, in km	2-3	5	10	15
peak hour trips generated by the new development area for every 10,000 population of the new area	up to 1,000	800	500	200

These totals should be added to the estimate of future demand for the area currently served by the corridor. The total should be expressed in terms of peak hour flow in peak direction so that this can be matched against the capacity of the systems under consideration. Opportunities to disperse heavy demand should not be overlooked (page 23).

Annex IV.

The Approximation of Transit Costs

The following procedure provides a rapid means of determining transit costs in just enough detail to permit a broad comparison of the options available. (In this procedure, operating costs exclude depreciation and interest unless specifically indicated.)

Chararacteristics of the Systems

The characteristics of each system being examined, including type of system, demand, capacity, and performance should be determined from appropriate chapters in these Guidelines. The details required, and a suggested format for presenting them, are set out in the worked examples at the end of this Annex.

Approximation of Operating Costs

Operating costs can be calculated by applying unit rates for:

(a) distance-related costs - for example, energy, maintenance and servicing of cars, etc. These costs are for the total of the distances travelled by the fleet of cars or buses in operation and are expressed in terms of car-kilometers.

(b) time-related costs - mainly operating staff wages, measured in terms of the total number of hours run by the fleet of cars or buses and expressed as car-hours.

Elements (a) and (b) are often termed "variable costs".

(c) route-related costs - for example, the maintenance of roadway, track, power lines, signals, and stations, expressed in terms of cost per kilometer of route per annum or per day.

(Depreciation and interest are dealt with under the section "Approximation of Capital Costs.")

The unit costs for these elements in developing counties can be expected to be within the ranges given in the following table.

TABLE IV. 1. Operating Unit Costs (1985 US$)

Cost	Bus	LRT	RRT
Distance costs per car-km	0.30 - 0.50	1.00 - 1.50	0.90 - 1.40
Time costs per car-hr	12.00 - 18.00	8.00 - 12.00	8.00 - 13.00
Route costs per km of route per day	2.00 - 20.00	150.00 - 250.00	600.00 - 900.00

It should be noted that:

- in the case of distance-related costs, the low end of the range would apply to countries with low energy costs, and vice versa;

- where labor rates are low and productivity is high, the low end of the time-related costs would apply. However, low labor rates are often associated with poor productivity (e.g., more than 15 staff per bus), in which case higher unit costs should apply;

- in the case of route costs for buses, the higher end of the range should be used for exclusive busways; the lower rates should be used for buses in mixed traffic.

Total operating costs are the sum of distance, time, and route costs.

Approximation of Capital Costs

For purposes of comparison, capital costs are annualized and represent depreciation and interest charges. The simplified method is based on the following:

- each category of capital cost is assumed to be financed by a loan for a term equal to the length of its useful life;

- an interest charge of 6 percent is applied to each year of the loan (6 percent is assumed to be the prevailing average real interest rate, i.e., interest rate adjusted for inflation);

- constant annual payments are made on the loan. It is assumed that equipment will be replaced at the end of its useful life and the replacements financed by a new loan;

- annual payments are calculated by annualizing the cost of each element of the system over its useful life, using conventional payment tables (Annex VIII.).

Unit capital costs of the various transit systems are given in Chapter 7.

Cost-Effectiveness

Once operating costs and annualized capital costs have been determined, the cost-effectiveness of various systems can be compared by expressing total costs (operating costs, depreciation, and interest) in terms of cost per passenger-km. Any results that fall well outside the ranges given in Table 5 of Annex II should be carefully reexamined.

The actual process of making these approximations is illustrated in the following worked examples based on hypothetical cases.

TABLE IV.2. Rapid Rail Transit (Example A)

1.	Type of system: Rapid rail transit, double track, underground.	
2.	Route length	25 km
3.	Spacing of stops/stations	1 km
4.	Operating hours/day	18
5.	Operating days/year	350
6.	Average trip	6 km
7.	Journey speed	30 kph
8.	Length of Peak Period	3 hrs

Demand

		Peak	Off-Peak
9.	Passengers, average working day	1,000,000	
10.	Average hourly boardings, both directions (peak 12% of daily)	120,000	43,000
11.	Heaviest flow in one direction (i.e., on busiest section)	54,000	27,000

Vehicle Requirements

		Peak	Off-Peak
12.	Hourly capacity assuming 90% loading	60,000	30,000
13.	Headway seconds	120	240
14.	Frequency: trains per hour	30	15
15.	Capacity per train	2000	2000
16.	Capacity per car	335	335
17.	Cars per train	6	6
18.	Cars per hour	180	90
19.	Round trip (50 km) time including stopover time of 15 mins	2 hours	2 hours
20.	Fleet size, assuming 90% availability	400 cars	
21.	Car-km day	95,000	
22.	Train operating hours per day	630	
23.	Car-hrs per day	3780	

Costs (US $ million)

24.	Total capital costs	US$3025 m	
25.	Annualized capital costs		190 m
26.	Annual operating costs (excluding depreciation and interest)		63.4m
27.	Annual total costs		US$253.4m
28.	Annual passenger-km		2100 million
29.	Cost per passenger-km		US$0.12

30. With capital cost overrun of 30% and patronage shortfall of 30%, cost/passenger-km = $0.21

TABLE IV.3. Calculation Sheet: RRT Example (A)

(These calculations are based on the RRT system of Annex IV.(A)).

Lines 1 to 6, 8, 9, 13: Based on typical characteristics of various existing systems

Line 7 Journey speed assumed to be 30 Kph

10 Daily boardings: system as a whole - passenger trips
Total = 1,000,000 (assumed)
(peak) 3 hrs x 120,000 = 360,000 (assumed)
(off peak) 15 hrs x 42,666 = 640,000 (balance)

11 Heaviest flow: assumption based on survey of typical systems; usually occurs over the busiest downtown section of the system.

12 $54{,}000 \times \frac{100}{90} = 60{,}000$

14 $\frac{60}{120} \times 60 = 30$; $\frac{60}{240} \times 60 = 15$

15 Hourly capacity (60,000) ÷ frequency (30) = train capacity (2,000)

16 Car capacity assumption based on surveys (rounded for convenience)

17 Cars per train (6) = train capacity (2000) ÷ car capacity (335)

18 Cars per hr (180) = number of trains per hr (30) x cars per train (6)

19 Round trip time = 50 km ÷ 30 Kmp = 1.67 hrs + 15 mins (.25) stop-over
= approx 2 hrs

20 Fleet size, based on vehicles required to meet heaviest flow (180 cars/hr) assumed to be sustained for at least as long as the round trip time (2.00 hrs), i.e., 180 x 2.00 = 360.

To provide for maintenance and repairs, assume availability of 90%, then fleet size required 400 cars.

21 Car-kilometers per day
(peak) 180 cars per hour for 3 hours = 540 x 50 km each = 27,000
(off peak) 90 cars per hour for 15 hours = 1,350 x 50 km each = 67,500
94,500

22 Train operating hours per day
(peak) 30 trains per hr for 3 hrs = 90 train trips/day
(off peak) 15 trains per hr for 15 hrs = 225 train trips/day
Total = 315
at 2.00 hrs per trip; 315 x 2.00 = 630 hrs

23 Car operating hours per day 630 x 6 = 3780

Line:24 Total capital costs (US$million)

Element	Unit Cost	Cost	Life	Annual Cost
Tunnel (25 km)	80 km	2,000	100	120.00
Track (25 km)	1.5/km	37.5	30	2.70
Signals (25km)	3.0/km	75	25	5.90
Power (25 km)	1.5/km	37.5	30	2.70
Station/stops (25)	15.0 ea	375	100	22.50
Yards (2)	25.0 ea	50	40	3.30
Workshops (1)	50 ea	50	40	3.30
Rolling stock (400)	1.0 ea	400	30	29.25
Total		US$3,025m		190

25 Annualized capital cost; 6% interest and loan repayment over lifetime of element. Last column line 24 above: US$190 m

26 Annual operating costs: (unit costs from Annex IV. Table 1 (US$))
Daily distance cost: car-km x 1.20 = 95,000 x 1.20 = 114,000
Daily time cost: car-hour x 12.50 = 3,780 x 12.50 = 47,250
Daily route cost: route km x 800 = 25 x 800 = 20,000
181,250 per day
x 350 = 63.4 million p.a.

27 Total annual cost 190 + 63.4 = 253.4 m

28 Annual passenger km 1,000,000 x 6 km x 350 days = 2,100 million

29 Cost per passenger-kilometer 253.4 m ÷ 2100 m = 0.12

30 $\frac{\text{Annual capital cost } 190 \times 1.3 = 247 \text{ plus operating cost } 63.4}{\text{Annual passenger-km } 2100 \times 0.7} = \frac{310.4}{1470} = 0.21$

TABLE IV.4. Light Rail Transit (Example B)

1. Type of system: Light rail transit, surface double track, 75% of route grade separated, 25% of route having priority at intersections.

2.	Route length	25 km
3.	Spacing of stops/stations	500 m
4.	Operating hours/day	18
5.	Operating days/year	350
6.	Average trip	6 km
7.	Journey speed	20 Kph
8.	Length of peak period	3 hrs

Demand

		Peak	Off Peak
9.	Passengers, average working day	500,000	
10.	Average hourly boardings, both directions (peak 12% of daily)	60,000	21,000
11.	Heaviest flow in one direction (i.e. on busiest section)	24,000	12,000

Vehicle Requirements

		Peak	Off Peak
12.	Hourly capacity assuming 90% loading	27,000	13,000
13.	Headway seconds	120	240
14.	Frequency: trains per hour	30	15
15.	Capacity per train	900	900
16.	Capacity per car	225	225
17.	Cars per train	4	4
18.	Cars per hour	120	60
19.	Round trip (50 km) time including stopover time of 15 mins	2hr45min	2hr45min
20.	Fleet size, assuming 90% availability	366 cars	
21.	Car-km per day	63,000	
22.	Train operating hours per day	866	
23.	Car-hrs per day	3,464	

Costs (US $ million)

24.	Total capital costs	US$637.3 m	
25.	Annualized capital costs		46.8 m
26.	Annual operating costs (excluding 63.4 depreciation and interest)		39.4m
27.	Annual total costs		US$ 86.2m
28.	Annual passenger-km		1050 million
29.	Cost per passenger-km		US$0.082

30. With capital cost overrun of 30% and patronage shortfall of 30%, cost passenger-km = $0.14

TABLE IV.5. Calculation Sheet: LRT Example (B)

(These calculations are based on the LRT system of Annex IV.(B).

Lines 1 to 6, 8, 9, 13: Based on typical characteristics of various existing systems

Line 7 Journey speeds from Annex II. Table 5 mid point

10 Daily boardings: system as a whole - passenger trips
Total 500,000 (assumed)
(peak) 3 hrs x 60,000 = 180,000 (assumed)
(off peak) 15 hrs x 21,333 = 320,000 (balance)

11 Heaviest flow: assumption based on survey of typical systems; usually occurs over the busiest downtown section of the system.

12 $24{,}000 \times \frac{100}{90} = 27{,}000$

14 $\frac{60}{120} \times 60 = 30$; $\frac{60}{240} \times 60 = 15$

15 Hourly capacity (27,000) ÷ frequency (30) = train capacity (900)

16 Car capacity assumption based on surveys (rounded for convenience)

17 Cars per train (4) = train capacity (900) ÷ car capacity (225)

18 Cars per hr (120) = number of trains per hr (30) x cars per train (4)

19 Round trip time = 50 km ÷ 20 Kmp = 2.5 hrs + 15 mins (.25) stop-over
= 2.75 hrs

20 Fleet size, based on vehicles required to meet heaviest flow (120 cars/hr) assumed to be sustained for at least as long as the round trip time (2.75 hrs), i.e., 120 x 2.75 = 330.

To provide for maintenance and repairs, assume availability of 90%, then fleet size required 366 cars.

21 Car-kilometers per day
(peak) 120 cars per hour for 3 hours = 360 x 50 km each = 18,000
(off peak) 60 cars per hour for 15 hours = 900 x 50 km each = 45,000
63,000

22 Train operating hours per day

(peak) 30 trains per hr for 3 hrs = 90 train trips/day
(off peak) 15 trains per hr for 15 hrs = 225 train trips/day
Total = 315
at 2.75 hrs per trip = 315 x 2.75 = 886 hrs

23 Car operating hours per day: 866 x 4 = 3464

24 Total capital costs (US$million)

Element	Unit Cost	Cost	Life	Annual Cost
Segregated right of way (25 km)	5.5km	137.5	40	9.14
Track (25 km)	2.0/km	50	30	3.63
Signals (25 km)	1.0/km	25	30	1.82
Power (25 km)	3.0/km	75	30	5.45
Station/stops (50)	0.15 ea	7.5	40	0.50
Yards (2)	12.5	25	40	1.66
Workshops (1)	25 ea	25	40	1.66
Rolling stock (366)	0.8 ea	292.8	25	22.97
Total		US$637.3m		46.8

25 Annualised capital cost; 6% interest and loan repayment over lifetime of element. Last column line 24 above: $46.8 million

26 Annual operating costs: (unit costs from Annex IV. Table 1 (US$))
Daily distance cost: car-km x 1.20 = 63,000 x 1.20 = 75,600
Daily time cost: car-hour x 9.00 = 3,464 x 9.00 = 31,200
Daily route cost: route km x 230 = 25 x 230 = 5,750
112,550 p day
x 350 = 39.4 million p.a.

27 Total annual cost 46.8 + 39.4 m = 86.2 m

28 Annual passenger km 500,000 x 6 km x 350 days = 1050 million

29 Cost per passenger-kilometer 86.2 million ÷ 1050 million = .082

30 $\frac{\text{Annual capital cost } 46.8 \times 1.3 = 60.8 \text{ plus operating cost } 39.4 = 100.2}{\text{passenger-km } 1050 \times 0.7 = 735} = 0.14$

TABLE IV. 6. Busway Transit (Example C)

1.	Type of system: exclusive busways: double lanes, 75% of route grade-separated, priority at intersections		
2.	Route length	25 km	
3.	Spacing of stops/stations	500 m	
4.	Operating hours/day	18	
5.	Operating days/year	350	
6.	Average trip	6 km	
7.	Journey speed	18 kph	
8.	Length of Peak Period	3 hrs	

Demand

		Peak	Off-Peak
9.	Passengers, average working day	500,000	
10.	Average hourly boardings, both directions (peak 12% of daily)	60,000	21,000
11.	Heaviest flow in one direction (i.e., on busiest section)	24,000	12,000

Vehicle Requirements

		Peak	Off-Peak
12.	Hourly capacity assuming 90% loading	27,000	13,000
13.	Headway seconds	16	32
14.	Frequency: buses per hour	225	113
15.	Capacity per train	—	—
16.	Capacity per bus	120	120
17.	Cars per train	—	—
18.	Buses per hour	225	113
19.	Round trip (50 km) time including stopover time of 15 mins	3 hours	3 hours
20.	Fleet size, assuming 85% availability	800	
21.	Bus-km per day	118,500	
22.	Train operating hours per day	—	
23.	Bus-hrs per day	7,110	

Costs (US $ million)

24.	Total capital costs	US$187.5 m	
25.	Annualized capital costs		15.37 m
26.	Annual operating costs (excluding (depreciation and interest)		44.5 m
27.	Annual total costs		US$60.00 m
28.	Annual passenger-km		1050 million
29.	Cost per passenger-km		US$0.06

30. With capital cost overrun of 30% and patronage shortfall of 30%, cost/passenger-km = $0.09

TABLE IV. 7. Calculation Sheet: Busway Example (C)

(These calculations are based on the Busway in Annex IV.(C)).

Lines 1 to 6, 8, 9, 13: Based on typical characteristics of various existing systems

Line 7 Journey speeds from Annex II. Table 5 lower end of range

10 Daily boardings: system as a whole - passenger trips

	Total = 500,000 (assumed)	
(peak)	3 hrs x 60,000 = 180,000 (assumed)	
(off peak)	15 hrs x 21,333 = 320,000 (balance)	

11 Heaviest flow: assumption based on survey of typical systems; usually occurs over the busiest downtown section of the system.

12 $24,000 \times \frac{100}{90} = 27,000$

14 $\frac{60}{16} \times 60 = 225$; $\frac{60}{32} \times 60 = 113$

15 (not applicable)

16 Bus capacity assumption based on surveys (rounded for convenience), i.e. $27,000 \div 225 = 120$

17 (not applicable)

19 Round trip time = 50 km $\div$ 18 Kph = 2.77 hrs + 15 mins (.25) stop-over = approx 3 hrs

20 Fleet size, based on vehicles required to meet heaviest flow (225 buses/hr) assumed to be sustained for at least as long as the round trip time (3.00 hrs), i.e., 225 x 3.00 = 675.

To provide for maintenance and repairs, assume availability of 85%, then fleet size required approximately 800 cars.

21 Bus-kilometers per day

(peak) 225 buses per hour for 3 hours = 675 x 50 km each = 33,750
(off peak) 113 buses per hour for 15 hours = 1,695 x 50 km each = 84,750
118,500

22 (not applicable)

23 Bus operating hours per day

(peak) 225 buses per hr for 3 hrs = 675 round trips/day
(off peak) 113 buses per hr for 15 hrs = 1,695 round trips/day
Total = 2,370
at 3.00 hrs per trip: 2,370 x 3.00 = 7,110 hrs

24 Total capital costs (US$million)

Element	Unit Cost	Cost	Life	Annual Cost
Segregated roadway (25 km)	3.0 km	75	40	5.0
Stops (50)	0.05 ea	2.5	40	0.16
Yards (2)	5.0 ea	10	40	0.66
Workshops (1)	20 ea	20	40	1.32
Buses (800)	0.1 ea	80	15	8.24
Total		US$187.5m		15.37

Line:25 Annualized capital cost; 6% interest and loan repayment over lifetime of element. Last column line 24 above: 15.37 m

26 Annual operating costs: (unit costs from Annex IV. Table 1 (US$))

Daily distance cost: car-km x 0.35 = 118,500 x 0.35 = 41,500
Daily time cost: car-hour x 12.00 = 7,087 x 12.00 = 85,000
Daily route cost: route km x 20 = 25 x 20 = 500
127,000 p day
x 350 = 44.5 million p.a.

27 Total annual cost 15.37 m + 44.5 m = 60 m

28 Annual passenger km 500,000 x 6 km x 350 days = 1050 million

29 Cost per passenger-kilometer 60 m $\div$ 1050 million = 0.06

30 $\frac{\text{Annual capital cost } 15.37 \times 1.3 = 20.0 \text{ plus operating cost } 44.5}{\text{Annual passenger-km } 1050 \times 0.7} = \frac{64.5}{735} = 0.09$

Annex V.

Bus Services:

Key Indicators of Performance

1.	(a) Passengers carried per bus per day (single deck)	1,000 - 1,200
	(b) Passengers carried per bus per day (double-deck)	1,500 - 1,800
2.	Kilometers per bus per day	230 - 260
3.	(a) Total staff employed per bus	3 - 8
	(b) Administrative staff per bus	0.3 - 0.4
	(c) Maintenance staff per bus	0.5 - 1.5
4.	Light or dead mileage as a percentage of total mileage	0.6 - 1.0
5.	Accidents per 100,000 bus kilometers	1.5 - 3
6.	Breakdowns as a percentage of buses in operation	8 - 10
7.	Availability: buses in service as a percentage of total fleet	80 - 90
8.	Fuel Consumption: liters per bus per 100 kms	30 - 50
9.	Pits/ramps/lifts per 100 buses	8 - 10
10.	Spares consumption per bus per year: % of vehicle cost	7 - 12
11.	Operating Ratio: revenue to operating cost (including depreciation)	1.05:1 - 1.08:1

Notes

The indicators of performance given in this Annex have been chosen because (a) they assist in providing a basic assessment of the efficiency of bus services, and (b) they are based on data that should be readily available.

The range of values are for reasonably well-managed bus companies in developing countries and take into account varying conditions that may prevail.

Notes on each indicator are as follows:

1. The figures are based on single-deck buses with a total crush capacity of 80 passengers and double-deck buses with a capacity of 120, and assume the exclusion of buses not put into service.

2. The figures assume the exclusion of buses not put into service.

3. (a), (b) and (c). Where labor costs are low, the higher end of the range can be expected, and vice versa.

4. Light or dead mileage (i.e., mileage that is not revenue earning) will depend on the location of night parking and maintenance in relation to routes.

5. The level of accidents will provide an indication of the standard of driving and maintenance but will be greatly influenced by traffic conditions, in particular the volume of pedestrians. A comparison should therefore be made with the general traffic accident rate for the city.

6. This indicator is based on breakdowns that require assistance from a mobile outside repair unit or repair at the depot.

7. Fleet availability is calculated by dividing "total buses running during the a.m. or p.m. peak period" by "total fleet size excluding buses scrapped or cannibalized."

8. Fuel consumption will depend on size of vehicle, engine type, and gradients and traffic encountred en route.

9. Sufficient pits, ramps or lifts will be required to cover all scheduled maintenance, unscheduled repairs, and overhauls.

10. The figures given assume that similar conditions apply to the procurement of buses and spares. Where special tariffs apply to one or the other, these need to be taken into account.

11. The operating ration is calculated by dividing total revenue by operating costs (including depreciation).

Annex VI.

Examination of High Capacity Transit Options:

A Checklist

This checklist comprises a number of important questions which need to be answered but which are sometimes overlooked.

1. High capacity transit systems, in particular RRT, are often justified on the basis that no other system will meet forecast demand. Are the demand forecasts realistic?

   [Patronage of new systems is frequently overestimated, and often does not adequately take into account the competition from other modes, the effects of higher fares, the need for passengers to interchange between modes to use the new system, or the low value that commuters sometimes place on time.]

2. Is demand excessive because of low pricing?

   [It may be possible to reduce demand by removing direct or hidden subsidies, such as low bus fares and low fuel prices.]

3. Can anticipated high demand be influenced in some way? Can it be dispersed or discouraged?

   [There may be opportunities to reduce the intensity of demand, particularly along radial corridors, by modifying the road network, pursuing city development plans that influence the pattern of demand, constructing bypasses and road links to disperse demand into other corridors, or by operating additional services along parallel routes.]

4. Have all the opportunities to improve the existing system been pursued?

   [Improve bus supply by liberalizing entry into the market, avoiding undue taxation or financial restraints on investment, improve cost-effectiveness and hence improve replicability of bus operations.

   Improve productivity of bus services through incentives, personnel policies, fare and route rationalization, etc. Provide off-street embarking and disembarking facilities. Reduce street congestion through restrictions on on-street parking, better traffic management, and above all else, by providing priority for public transport, exclusive busways, etc., and restraining the use of private cars.]

5. If demand is high, what other options have been considered?

[The capacity of a single lane of segregated busway is as much as 30,000 passengers per hour in one direction. If parallel routes on separate streets can be established, 60,000 passengers per hour can be moved, exceeding the practical capacity of most metros. Even in mixed traffic, if several lanes are available, volumes as high as 35,000 passengers per hour in one direction have been observed in a single street. See Annex II., Table II.5., "Transit Systems Characteristics."]

6. Has the decision to invest in transit systems been based on over-optimistic returns from enhanced land values or development opportunities?

[These returns are often miscalculated and misdirected. High capacity systems, by concentrating demand, may in fact reduce land values. But if land value increases are taken into account, it is important to determine the beneficiaries, who are unlikely to be the urban poor. Similarly, unless the transit operators control the land, it is unlikely that development profits from the existence of the system can be credited to the system's revenues. Also, revenues from development can be a very unreliable form of financing. Their contribution to the capital cost of the Hong Kong Island Line went down from 40% to 10% overnight when land values slumped.]

7. Has the capital cost of the system been properly estimated?

[Current costs (1985), including right-of-way, track, power, control, stations, depots, rolling stock, etc., for an RRT range from:

--US$45 million/km for segregated surface systems
--US$70 million/km for elevated systems
--US$125 million/km for underground systems.

A 25-km underground system would cost in the region of US$3,000 million.]

8. What fares are proposed for the new system, and how do these compare with existing public transport fares?

[Fares for RRT's are usually underestimated. Even on the basis of full capacity, the fares necessary to recover total costs are likely to be too high for most users. For well-patronized and well-run RRT's, total costs (operating costs, depreciation, and financial charges) are in the region of US¢15-25 per passenger/km (or US¢75 to US$1.25 for an average 5-km kilometer trip).]

9. If fare revenue is not going to cover costs, how will the deficit be financed?

[The implications of subsidies need to be clearly understood and taken into account. (See Urban Transport Policy Paper.)]

10. What has been the experience with fare increases in the past?

    [In many countries, government fare increases become nationwide issues, leading to more and more subsidies. This needs to be appreciated when governments become involved in costly transport systems.]

11. Has the impact on other public transport services been taken into account? Are proposals for integration realistic?

    [With a view to recouping the extremely high expenditure for an RRT, there is very considerable pressure for city authorities to maximize patronage and revenue by reshaping existing bus routes to provide feeder services and by curtailing competing bus routes. This inevitably will erode the viability of the bus services and may lead to both the bus and rail systems having to be subsidized.]

12. What fares are forecast for other public transport after integration?

    [These are likely to be higher for several reasons:

    a) the re-routing and curtailment of profitable routes and the loss of patronage to the new system are likely to reduce overall revenue and increase cost of bus service;

    b) pressure to increase bus fares in order to reduce the bus system's competition with the new system;

    c) the necessity for passengers to interchange between modes means that two or more separate fares are involved for each journey; rarely can fares on feeder services be reduced even if through ticketing is possible.]

13. Have other operators been made aware of the integration proposals, and has their reaction been taken into account?

    [Integration proposals may have a very dramatic effect on operators. Consultation may well indicate that the proposals are not feasible or that necessary cooperation may not be forthcoming. Integration proposals are often dependent on through ticketing. This may prove to be very difficult to achieve if revenue-sharing between public and private transit operators is involved.]

14. Has the reaction of the public to changes in travel patterns and fares been properly assessed?

    [Since high capacity systems can only be provided along main corridors this means that many passengers will be faced with the need to make additional interchanges. Also, they are very likely to react against higher fares. Low-income groups placing less value on time may shun the new system. Lower patronage means higher cost per passenger.]

15. Has the construction period been realistically estimated?

[Construction periods are usually greatly underestimated. The opening of the first small section of the Calcutta metro took eleven years. Typical was the construction time of seven years for the 17 kilometers of the Sao Paulo North line (mainly in tunnel).]

16. Have the effects of construction on traffic and utility services been taken into account?

[The cost of disruption to traffic can be very considerable due to the need to excavate in roadway and to cart away large quantities of material. Similarly, utility services can be seriously affected and may require very costly relocation.]

17. Has the need for training in new high technology been taken into account?

[New systems often involve a high level of sophistication and technology that is often quite new in developing countries. The ability of local staff to handle this and the track record of operating and maintaining such equipment needs to be assessed. Staff training programs for completely new systems may take several years.]

18. Has the environmental impact of the system been considered?

[This applies particularly to surface and elevated systems. As well as air pollution, both visual and noise intrusion need consideration.]

19. Have climate conditions been taken into account?

[In hot and humid conditions, it is vital that there are back-up ventilation systems; in crowded vehicles stopped in tunnels without ventilation, temperatures can rise to fatal levels within a short period. The cost of flood protection also needs to be assessed.]

20. Has the effect of highly concentrated demand generated by a high capacity system been taken into account?

[The concentration of high demand may have considerable impact on other urban services in the corridor; it may be very costly to increase their capacity in line with increased development arising from the new transit system. As well as concentrating demand, heavy transport investment generates more demand--when, for example, an RRT is fully utilized it may be prohibitively expensive to provide additional capacity. The construction of a high-capacity system may retard the development of other areas which may be less costly to service.]

Annex VII.

Brief Case Studies

of Transit Systems

Abidjan: A Comprehensive Approach to Transport Improvement

The Government of the Ivory Coast has adopted a comprehensive approach to improving the transport system in Abidjan. This approach, which is being undertaken with the assistance of the World Bank, comprises the following:

(a) the adoption of various traffic improvements, including the creation of one-way streets, the installation of integrated traffic signals, signs, and road markings in the central business district, and the extension of traffic management programs throughout the city;

(b) the introduction of traffic management measures to improve the movement of pedestrians and buses in high-density, low-income communities;

(c) the improvement of pedestrian facilities, including construction of footbridges;

(d) the construction of a bus-way and reserved bus lanes in the central business district;

(e) the creation of a high-speed express bus network, made possible by the construction of new road links;

(f) the upgrading of bus terminals and bus stops and construction of a bus depot;

(g) the construction of primary roads to improve public transport access to low-income areas.

Before the project began, key sections of the city's road network were seriously overloaded, and downtown congestion lasted for as much as twelve hours each day. In neighborhoods in other parts of the city, there was strenuous competition for road space as buses, cars, taxis, and parked cars competed with pedestrians, market customers, and street traders. As population and motorization rates grew, traffic congestion began to have an adverse effect on the entire national economy.

Considerable all-round improvement has occurred as a result of the project. The running times for buses crossing the central business district have been halved, and the elimination of congestion caused by the loading and unloading of buses has benefited other traffic. These improvements have been achieved even though rush-hour traffic has increased by roughly 20 to 30%. By making better use of the existing road network and other transport facilities, Abidjan found it possible to delete or defer several expensive infrastructure projects and to reduce planned investments between 1981 and 1984 by US$120 million or more.

Bangkok Bus Lanes

Faced with widespread and growing congestion in Bangkok, the Thai Government embarked in 1978 on a comprehensive urban transport scheme. The project, supported by the World Bank, was designed to strengthen urban transport management, increase the capacity of the road network, and improve public transport. Extensive priority bus measures were an important element of the project. At the time of project appraisal, the speed of bus trips during peak periods in the central area was as low as 10 km/hr, while cars were able to maintain only little better than 12 km/hr. More than 60% of all personal trips on main roads in Bangkok were made in buses and minibuses, which together accounted for only 6% of all passenger vehicles. Private cars, which made up more than half of traffic (57% of all vehicles), carried only 26% of commuters. Both types of vehicles were constantly caught in traffic snarls. Then, in 1980, 145 km of traffic lanes were set aside for exclusive use by buses.

Surveys carried out by the Asian Institute of Technology on behalf of the Transport and Road Research Laboratory showed that as a result of the comprehensive measures both bus and car travel times improved significantly in almost all cases. In areas where the most success was achieved, bus and car mean travel times were reduced 25 to 30%. On none of the streets surveyed did bus or car travel times worsen.

Observed bus flows were very high, with up to 250 standard buses and 150 private minibuses using a single bus lane during an average peak hour. All told, these vehicles had a carrying capacity of about 18,000 passengers an hour. Such intensive utilization of a single traffic lane highlights the efficient use that can be made of limited road space by introducing priority measures.

The initial regulations did not permit buses to leave the bus lanes. This increased bus bunching and therefore caused some congestion at bus stops. This drawback, however, was usually not sufficient to offset the general improvement in bus running times. Subsequent relaxation of the regulations, which allowed buses to pass one another, resulted in further reductions in bus travel times. Car travel times were made somewhat greater by this modification but remained substantially less than before the bus lanes were introduced.

A follow-up survey in 1981 showed that bus travel times on important bus lanes had been reduced by 38% and car travel times by 20% as a result of the priority measures. According to a study of bus lane violations, some 20% of the vehicles in priority bus lanes were illegal users, mainly slow moving non-motorized vehicles. This was an indication that strengthened enforcement might lead to even better results.

The overall success of the project illustrates the high value of priority bus lanes. The cost of the project was less than US$1.5 million, yet it has provided substantial benefits to the majority of Bangkok's road users, particularly bus and minibus passengers. (A full report is contained in The Performance of High-Flow Bus Lanes in Bangkok by N. W. Marler, TRRL Supplementary Report No. 723.)

Hong Kong's Wide Range of Bus Services

Transport demands in Hong Kong are met by a wide range of modes, including buses, trams, ferry boats, and taxis run by private enterprise, and both surface and underground rapid rail systems operated by government corporations. All of these transport modes function within a framework of limited government regulation designed to stimulate the provision of cost-effective, efficient, and safe services.

Buses account for by far the largest number of trips in Hong Kong. The two main franchised bus companies together carry about 3.4 million passengers daily on some 3,000 double-deck buses. Fares, which are set by the government, range between US10¢ and US20¢, depending on route distance.

The Kowloon Motor Bus Company operates 160 routes in Kowloon and the New Territories, carrying about 2.6 million passengers in 2,000 buses. The China Motor Bus Company operates 102 routes, mainly on Hong Kong Island, carrying about 0.8 million passengers daily on 1,000 double-deck buses. The two companies also compete on 15 routes that run through the cross-harbor tunnel. Most of the buses have a capacity of 120 passengers and generally operate throughout the day at high frequencies and high load factors. Both companies are making increasing use of super-large double-deck buses developed specifically for Hong Kong that can carry up to 170 passengers. These are used on routes where demand is heavy enough to run almost fully loaded buses frequently throughout most of the day.

At the other end of the scale are 4,350 "public light buses" (PLBs). These are 14-seat minibuses, mostly individually owned and free to operate almost anywhere at whatever fare they decide to charge. These PLBs, which ply for hire in direct competition with bus and tram services, carry more than 1.5 million passengers daily. PLB passengers are guaranteed a seat and pay fares that may be as much as double those charged on the large franchised buses, particularly during peak periods.

Some 800 PLBs, termed "maxicabs", have been franchised to service routes that are not suitable for service by double-deck buses, either because demand is not sufficient to sustain high frequency of service or because the routes are too hilly or too tortuous for large buses. Maxicabs operate on fixed routes and at fixed fares that are slightly higher than those of the large franchised buses.

To meet the needs of people living in new residential developments where service was inadequate, premium "residential coach services" were introduced in 1982. These services are run by private operators under contract to either the developers of these residential areas or to associations of residents. Although these services are regulated to avoid conflicts with the terms of franchise of the main bus companies, the fares are not fixed by the Government. Most of the residential coach services use medium-size buses, usually air-conditioned, that have a capacity of about 50 passengers, all seated. The privately owned residential coach services, and similar services for transporting factory workers and school children, utilize about 3,500 buses and 1,600 minibuses.

Hong Kong now has a total bus fleet of some 12,000 vehicles, ranging in size from the 14-seat minibuses to the 170-passenger double-deck buses. This comprehensive bus network is able to meet a wide variety of demands for transport at different levels of quantity and quality of service.

Bombay: Publicly Owned Bus Undertaking

Greater Bombay, with a population of about 8 million, has one of the largest and most efficient bus services in India. The operator, the Bombay Electric Supply and Transport Undertaking (BEST), is a semi-autonomous subsidiary of Bombay Municipal Corporation (BMC), itself an autonomous authority that provides municipal services in Greater Bombay. BEST has a high degree of financial and operational independence, but increases in bus fares require the approval of BMC and are subject to maximum limits prescribed by the state government.

BEST has an exclusive franchise for scheduled bus services within Greater Bombay and in 1984 had a fleet of 2,325 large buses operating on 198 routes with a total length of 2,423 km. The system serves over 4 million passengers each day and has a staff of 30,000 in the bus segment of its operation.

The undertaking pursues prudent management and financial policies and strives for improved efficiency and viability. The bus services are subject to comprehensive monitoring and a detailed costing system. An important reason for BEST's success is its provision of bonuses to staff members who improve their performance. Bonus payment amounts are based on revenue gains and savings resulting from higher bus utilization and better fare collection. Over the years, BEST has consistently achieved a high level of output at low cost. Because bus maintenance activities are effective and well-scheduled, BEST is able to keep more than 90% of its fleet in service on a regular basis and has a breakdown rate of less than 5%. Despite heavy congestion, each bus averages about 220 km and carries about 1,800 passengers each day. Although it has a comparatively high staffing level of 14 employees per bus, productivity is good, and costs, at approximately US6.5¢ cents per passenger, are particularly low.

In 1976 the World Bank provided BEST with a loan for the purchase of new buses, the construction of new depots, workshops and terminals, and management training. This undoubtedly helped the corporation, and for short periods of time BEST has been financially viable. Most of the time, however, BEST has recorded small deficits and has had to be cross-subsidized by surplus revenues from its electricity undertaking. BEST's deficits have occurred because the Government has consistently held bus fares down. In 1984, for example, the average fare was US6¢. In addition, investment for expansion has been denied from time to time. Service is generally maintained at a Spartan level, with substantial overloading and long waiting times, particularly during peak periods. Given the authority to establish appropriate fares, there seems to be little doubt that BEST could achieve total financial viability and proivde better service.

Bus Expressways in Porto Alegre

Exclusive busways in Porto Alegre have met the demand for high passenger flows in the central business district without the high investment required for elevated or underground systems. In 1978 the City Administration, in an agreement with the World Bank and the Brazilian Company for Urban Transport (EBTU), designated 30 km of exclusive busways. These expressways have been paved, bus stops erected, and signs posted, at a cost of US$500,000 per km. The right-of-way has been made exclusive by way of curbs or low, reflecting markers.

The narrowness of the designated expressway precludes passing at bus stops, and buses were often held up by those stopped ahead. The solution to this problem, implemented in Sao Paulo as well as in Porto Alegre, was the bus convoy, or COMONOR. At the beginning of a corridor, buses are coordinated in a fixed sequence according to route, forming convoys of up to six buses. The buses travel together, stop simultaneously, board their passengers, and depart in a queue or convoy. At each bus stop, a passenger awaits his bus at a "sub-group" bus stop placed according to his bus's location in the convoy. Because buses are operated privately in Porto Alegre, a convoy may be composed of buses run by several operators.

A convoy can almost double busway capacity in congested areas. The combined use of the bus expressway and bus convoys has achieved peak-hour one-way passenger flows of 28,000 passengers on 260 buses, at a speed of 19 km/hr in the most heavily traveled corridor.

Higher speeds (with lower flows) have been achieved on other bus-expressways in Porto Alegre with the use of another innovation, the transfer terminal. It was found that unnecessary congestion resulted when feeder routes overlapped in the downtown area. This problem was solved on one expressway with the building of two transfer terminals, where passengers transfer between the smaller buses serving feeder lines and larger, articulated buses serving the bus-expressway. This system resulted in 20% higher bus speeds and corresponding fuel savings.

Hannover Light Rail Transit

The Ustra system in Hannover, Germany, embodies the main characteristics attributed to light rail transit. At most stations, passengers board from the road surface or from a low platform. At some underground stations, and at some of the suburban stops, passengers board the train from high-level platforms. Because of these different boarding levels, the vehicles used in the system are equipped with folding steps. Trains usually are composed of two double articulated cars, each car with a capacity of 250 passengers. These vehicles have a top speed of 80 km/hr. The network is 69 km long, with 96 stops and 14 underground stations. About 80% of the system operates on an exclusive right-of-way; the remainder is within or adjacent to the roadway.

Headways (i.e., the intervals between trains) of 90 seconds are possible on the exclusive right-of-way, but in practice the headways are at least 2 minutes. This would make it possible to carry about 15,000 passengers per hour in each direction, but in practice peak passenger volumes are about 8,000 per hour/per direction.

Passengers may buy either single or multi-ride tickets from ticket machines at stations and at other locations. Cancelling machines are located on the vehicles. Since passengers are responsible for paying the correct fare, and since inspection of tickets by officials is infrequent, passenger honesty is important.

The system has evolved over a number of years, so it is difficult to calculate its full capital cost. The 1983 price for the double articulated cars was US$800,000.

Fares are charged according to zone and in 1983 ranged from US60¢–US$1 per trip. In the same year the system's operating costs and interest were US$80 million, while annual revenue was US$52 million. This left an operating loss of US$28 million, which was covered by a subsidy from the local government that represented US17¢ per passenger. Sixty percent of capital expenditure is covered by the federal government, 25% by the state government, and 15% by local agencies.

The original intention was to upgrade the light rail system to a rapid rail subway in stages as ridership increased but, due to stagnation of demand and financing problems, conversion is now unlikely. Instead, the existing system is to be extended, and more tunnelling is planned.

Osaka's Surface Rapid Railway

The Hankyu Railway System is one of the many privately owned and viable rapid rail systems in Japan that run mainly on the surface and provide efficient service. The Hankyu system serves the urban areas of Osaka and Kobe and connects with Kyoto and Takarasuka. The railway carries more than two million passengers each day on three lines with a total length of 140 km and 84 stations. Passenger volumes of up to 63,000 per hour per direction have been recorded.

The system was established at the turn of the century, when much of the area was lightly or moderately inhabited. The system was then greatly extended during a period when the surface right-of-way could be provided with comparative ease and at low cost.

The Hankyu Corporation has been very responsive to increasing demand and has continually expanded and improved its services while taking advantage of the most recent developments in technology.

The corporation also has constructed a number of multi-purpose buildings and housing projects close to its stations. Particularly significant is the 32-storey building housing offices, shops, restaurants, and transport interchange facilities at the Umeda terminal.

Fares are charged according to distance, and season tickets can be purchased at a substantial discount. In 1982 the average fare was 90 yen (US40¢); for season ticket holders the average fare was less than 60 yen.

Although these are comparatively low fares, the rail operations shows a profit. The 1982 profit was 10,708,127,000 yen ($48 million); the operating ratio (revenue divided by cost) was 1.18. The corporation also made a large profit on its other operations, and thus was able to make substantial interest payments while also paying dividends to shareholders.

Sao Paulo Metro

The decision to construct an underground rapid rail system in Sao Paulo was made in the late 1980s, at a time when demand for transport was growing rapidly, and it was thought vital to relieve pressure on the road network.

In 1982 the metropolitan area of Sao Paulo had a population of over 13 million. Transport trips amount to nearly 20 million daily. Since Sao Paulo has 2 million private cars, 38,000 taxis, and 12,000 buses, most of the main traffic corridors are close to total saturation for long periods of the day. By contrast, the metro provides a rapid, convenient, and safe means of transport.

The system's North-South Line began service in 1974; the East-West Line was opened in 1979. The system's trains are capable of travelling 100 km/hr and have a capacity of 2,000 passengers each. Very high frequencies are maintained during peak periods. Trains operate at about 2-minute intervals, and the system is able to carry up to 58,000 passengers per hour in each direction. Average daily ridership exceeds 1.2 million, making the 24.5 km system one of the most intensively used in the world.

At 1983 prices, the total cost of the system was US$2,338 million, or $96 million per km. Considerable use was made of commercial loans and supplier credits from both local and foreign sources; the Sao Paulo City and State governments, and the Federal Government provided substantial capital subsidies.

The system's fares are set at a level allowing recovery of at least 70% of operating costs (excluding depreciation, amortization, and financial expenses). In 1982, however, operating revenues covered only 62% of operating costs, resulting in a loss of US$26 million excluding depreciation and interest charges. This was covered by a subsidy equivalent to US7¢ per passenger trip.

Current plans call for the expansion of the system from 25 km and 26 stations to 95 kms and 80 stations. Although 16 km of new line and 11 new stations are under construction, further expansion has been postponed because of difficulty in arranging financing.

Caracas Metro

The plans for the Caracas Metro railway call for the construction of three lines with a total length of 40 km and 35 stations by 1990. Most of the system will be underground.

The first phase of the first line, comprising 12 km and 14 stations, was opened in 1983. The cost was US$1.4 billion. Extensions of 28 km are under construction and are due to be completed in 1990. The rest of the system is still in the planning and design stages.

Caracas is located in a valley between mountain ranges that constrain the outward growth of the city. The shortage of land available for development, and the high cost of building on hillsides, have resulted in an extremely high population density along the valley.

These generic factors favor the construction of rapid rail systems and in this case led city planners to select an underground Metro as the best solution for meeting heavy demand and overcoming severe traffic congestion. The decision was made on grounds that an underground system would eliminate the need for considerable enlargement of the capacity of the road network, a costly alternative that would have required substantial demolition of existing buildings. The expectation of the planners was that Metro users would save a great deal of time and that non-users would benefit from reduced congestion. The scheme was also justified in part on the ground that the large numbers of poor people living at the western end of the metro line would benefit from greater mobility and access to job opportunities in the center-city. But studies have shown that demand for travel by bus (a demand that comes almost entirely from low-income groups) is concentrated in the center of the city and that there is little demand among the poor for the longer trips that could be taken on the Metro. The travel patterns of the city's minibuses, which are favored by middle-income groups, conform more closely to the routes that would be served by the Metro. It should also be noted that the same flat fare on the Metro for both short and long trips would favor commuters from distant high-income suburban areas. By contrast, most of those in low-income groups take short journeys and are thus disadvantaged by the Metro fare policies. The authorities have in hand measures that may to some extent overcome these disadvantages of the system.

The Caracas Metro is expected to cause greater development along the corridors it serves, thus increasing population densities in the city. This would run contrary to the declared policy of spatial and economic decentralization to the suburbs. These increased densities would intensify current problems in providing urban services. Since Caracas has no plans to place restraints on the use of private cars, the Metro's effect on road congestion will probably be short-lived. It seems clear that the existing congestion has suppressed some of the demand for road use and that any road space freed by the diversion of commuters to the Metro would quickly be occupied by new motorists.

Finally, it has become evident that the cost of the Metro will be several times the original estimate. This makes it likely that the costs will be well beyond the means of many users, particularly those in low-income groups. Hence, heavy subsidies will be needed, placing a considerable and continuous burden on the city's financial resources.

While the decision to construct the Metro was promoted by an earnest desire to deal effectively with congestion, insufficient consideration was given to alternatives and less costly solutions, such as demand management and improved bus service, including the creation of exclusive busways and other forms of priority for bus services.

Annex VIII.

CAPITAL RECOVERY FACTOR—
Annual payment that will repay a $1 loan in X years with compound interest on the unpaid balance.

Year	1%	3%	5%	6%	8%	10%	12%	14%	15%	16%	18%
1	1.010	1.030	1.050	1.060	1.080	1.100	1.120	1.140	1.150	1.160	1.180
2	.508	.523	.538	.545	.561	.576	.592	.607	.615	.623	.639
3	.340	.354	.367	.374	.388	.402	.416	.431	.438	.445	.460
4	.256	.269	.282	.289	.302	.315	.329	.343	.350	.357	.372
5	.206	.218	.231	.237	.250	.264	.277	.291	.298	.305	.320
6	.173	.185	.197	.203	.216	.230	.243	.257	.264	.271	.286
7	.149	.161	.173	.179	.192	.205	.219	.233	.240	.248	.262
8	.131	.142	.155	.161	.174	.187	.201	.216	.223	.230	.245
9	.117	.128	.141	.147	.160	.174	.188	.202	.210	.217	.232
10	.106	.117	.130	.136	.149	.163	.177	.192	.199	.207	.223
11	.096	.108	.120	.127	.140	.154	.168	.183	.191	.199	.215
12	.089	.100	.113	.119	.133	.147	.161	.177	.184	.192	.209
13	.082	.094	.106	.113	.127	.141	.156	.171	.179	.187	.204
14	.077	.089	.101	.108	.121	.136	.151	.167	.175	.183	.200
15	.072	.084	.096	.103	.117	.131	.147	.163	.171	.179	.196
16	.068	.080	.092	.099	.113	.128	.143	.160	.168	.176	.194
17	.064	.076	.089	.095	.110	.125	.140	.157	.165	.174	.191
18	.061	.073	.086	.092	.107	.122	.138	.155	.163	.172	.190
19	.058	.070	.083	.090	.104	.120	.136	.153	.161	.170	.188
20	.055	.067	.080	.087	.102	.117	.134	.151	.160	.169	.187
21	.053	.065	.078	.085	.100	.116	.132	.150	.158	.167	.186
22	.051	.063	.076	.083	.098	.114	.131	.148	.157	.166	.185
23	.049	.061	.074	.081	.096	.113	.130	.147	.156	.165	.184
24	.047	.059	.072	.080	.095	.111	.128	.146	.155	.165	.183
25	.045	.057	.071	.078	.094	.110	.127	.145	.155	.164	.183
26	.044	.056	.070	.077	.093	.109	.127	.145	.154	.163	.182
27	.042	.055	.068	.076	.091	.108	.126	.144	.154	.163	.182
28	.041	.053	.067	.075	.090	.107	.125	.144	.153	.163	.182
29	.040	.052	.066	.074	.090	.107	.125	.143	.153	.162	.181
30	.039	.051	.065	.073	.089	.106	.124	.143	.152	.162	.181
35	.034	.047	.061	.069	.086	.104	.122	.141	.151	.161	.181
40	.030	.043	.058	.066	.084	.102	.121	.141	.151	.160	.180
45	.028	.041	.056	.065	.083	.101	.121	.140	.150	.160	.180
50	.026	.039	.055	.063	.082	.101	.120	.140	.150	.160	.180
100	.016	.032	.050	.060	.080	.100	.120	.140	.150	.160	.180

$$\text{Annual capital cost} = \frac{\text{Principal (capital cost)} \times \text{interest rate}}{1 - (1 + \text{interest rate})^{-n}}$$

where n = the useful life of the cost element.

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