CONSIA TRANSCRAFT

RAMBØLL NYVIG

Practical Guide for Improving Urban Bus Transport Systems

Volume 2

A Guide to High Capacity Modern Urban Bus Systems: Best Practice and Recommendations

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Content

One of the principal architects of the Curitiba Bus System, Carlos Ceneviva, has sketched out the worldwide question of urban mass transport in the following terms*:*

"There are currently about 400 cities with a population of more than a million – the vast majority in need of a mass transport system that will structure their future growth and minimize the time wasted on daily travel. These cities simply cannot wait for a so-called definite solution. An average trunk route scheme is about 20km in extension and costs between 2 and 6 million dollars per km to build, so many of the world's transport problems could be fixed for around US$ 40 billion – roughly the value of shares traded per day on the New York Stock Exchange. This would also create a world demand for about 20 thousand high-capacity bus units, spread over a period of several years – well within the existing production capacity of the world bus industry. Mass Transport is not a technical problem, nor is it a problem of capital or production – it is fundamentally a problem of policy." (Carlos Ceneviva)

Chapter I: Introduction

Volume 1 of this Practical Guide shows, through several case studies, how Modern Bus Systems have developed into a the new technology of High-Capacity BRT Mass Transit, which is now having an enormous impact on developing cities around the world.

Volume II of this Practical Guide draws on the experiences of the case studies and presents best practice recommendations for the design and implementation of high capacity, modern urban bus systems.

This volume describes the principle elements of modern bus systems, the costs and benefits normally associated with their implementation and the administrative and legal issues.

When international financing of a system is being sought, there are normally several stages of project development. This guide introduces recommendations for these project phases, focusing on the information needed and the level of detail to be achieved in each stage.

Chapter II: Sustainable and Affordable Mass Transport

There is a worldwide need for urban transport systems that can deliver tangible benefits and be built in a time frame compatible with that of most democratic governments.

Latin America is the most urbanized of the world's developing regions, with nearly 80% of its population classified as urban and most of these persons living in densely populated medium and large cities. This high density and increasing levels of car ownership has resulted in widespread congestion, elevated levels of air pollution and traffic accidents.

The problem of congestion has had a particularly adverse effect on the captive demand of public transport - in general lower income groups – as congestion means slower commercial speed for buses, which not only penalizes the user with longer travel times, but also results in higher fleet costs.

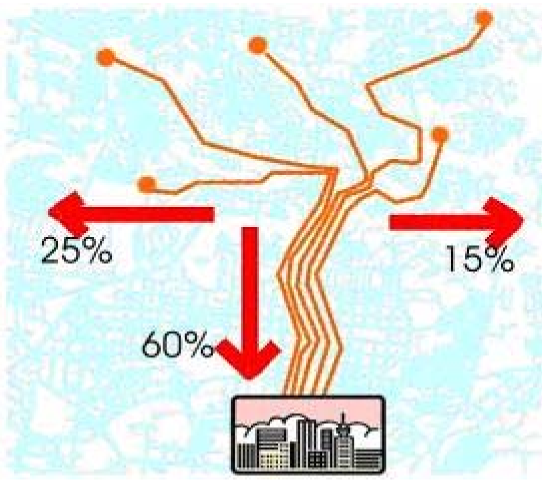
It is not widely understood by the general public – or even by policymakers - that in order to transport 10,000 passengers per hour at 10kph, instead of 20kph, transport operators will need to double the size of their fleet. This is additional fleet "congestion charge" is either transferred to passengers or to the city.

Source: Transcraft

Fig. 2.1 Bus Queues Crowding the Sidewalk, São Paulo

In the city centre, bus circulation (and their frequent stops) is added to general traffic, provoking further congestion and delays to the buses in the peak hours. During the evening peak, the sidewalks become blocked with thousands of bus passengers waiting for their individual bus units. Waiting conditions are uncomfortable, unpleasant and unsafe. The commercial areas next to these queues have their shop windows blocked and restricted access. Toilet facilities are a real issue.

Conventional bus services tend to be developed over decades and are largely radial, each residential district having a route going to the central area. In recent years, however, many jobs have migrated to new areas or mixed residential/commercial zones. As a result, public transport passengers have to take at least 2 buses – via downtown – to reach their destinations. In the example in Fig. 2.2 a district served by conventional routes has a potential demand of 25% going to the west and 15% to the east. At present only 60% of the potential demand can be captured on a single fare ticket, the rest of this demand is thus lost to other modes.



Source: Transcraft
Fig. 2.2 Potential Demand

If the routes become trunk and feeder, with an interchange offering new travel options, then some of this potential demand can be picked up. Overall travel time does not increase as the trunk routes are high frequency and the short feeder routes normally operate at shorter intervals than conventional routes.

Building an interchange can allow the bus services to be segmented into trunk routes, feeder routes and inter-district routes, offering new travel options and thus capturing some of this “repressed” demand.

This concept is the basis for the development of an *Integrated Urban Transport System,* which normally consists of the following basic elements:

Integration Terminals or Interchanges: Integrated Terminals serve as the primary tool for rationalizing the entire bus system in a way that allows for the provision of transport to be quickly and accurately adjusted to the real demand in each part of the bus network. The frequency and regularity of bus services on each of the routes that serve Integrated Terminals may be increased considerably in many cases, particularly within urban centres where there is the greatest concentration of riders. The consolidation of centre-bound trips at Integrated Terminals can significantly improve the flow of buses in the central area, while reducing the inconveniences often associated with boarding, alighting, and waiting for buses.

Through optimising the use of the bus vehicles, both in terms of capacity and efficient scheduling, the overall costs of providing transport can be reduced, and likewise the total capital investment required in fleet.

The concentration of various routes at Integrated Terminals can further permit the implementation of a coordinated user information system whereby public transport passengers, both everyday riders and those (such as tourists) who are new to or unfamiliar with the system, may be able to easily and accurately plan their trips. Finally, the concentration and consolidation of passenger activity at Integrated Terminals strongly encourages the consolidation of commercial sub-centres at these locations.

Trunk Routes: The trunk routes in an Integrated Urban Transport System share several common characteristics. First, they operate at high frequencies (normally less than 6 minutes) along the main transport corridors of the city, connecting them with the Integrated Terminals. Second, the trunk routes feature enhanced traffic signalling, geometric and/or bus priority measures, and stations at intervals compatible with increased operating speeds (generally not more than 500 meters, often less in concentrated commercial areas). Lastly, the bus vehicles used on these routes must be of sufficiently high capacity to comfortably carry the consolidated traffic loads that will transfer to the trunk routes at the Integration Terminals. This normally requires the use of articulated units and enhanced passenger boarding.

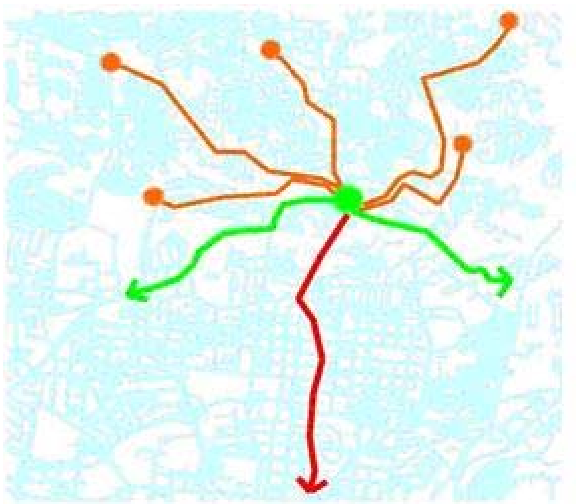
Apart from these shared characteristics, three slightly different types of trunk routes may be used:

- "Direct" trunk routes are those that follow a course leading generally in a direct path from one Integrated Terminal to another;

- "Circular" trunk routes also follow a course from one Integrated Terminal to another, but unlike the direct trunk routes they serve outlying corridors, without entering the central business district;

- "Radial" trunk routes that serve important transport and commercial corridors that lies outside a main bus way.

Feeder Routes: Most of the bus routes that serve (or "feed " into) the Integrated Terminals are conventional routes that serve mainly the outskirts of the city or system. Once at the Integration Terminal, the feeder route passengers are offered access to the entire Integrated Urban Transport System, including the variety of trunk lines described above as well as all of the other feeder lines that converge there - without having to pay another fare. Feeder routes use conventional buses at intervals selected to both minimize passenger waiting times and passenger crowding.



Source: Transcraft

Fig. 2.3 New Travel Options at a Terminal Facility

When the Curitiba network was being developed, the stated objective was to build a system that: "worked like a subway". However, unlike fixed rail systems, the infrastructure costs of modern bus systems – even including pedestrian and road improvements – are normally within the lending capacity of the major development agencies and these infrastructure loans are again within the repayment capacity of most cities.

Again, unlike urban rail networks – which are usually operated by the public sector, or by a public company – there is a clear and well-established role for the private sector in modern bus systems. Given the incentives and organization, private bus companies can finance the bus fleets and cover operating costs through adequate fare collection. No subsidies are needed. No expensive state-companies need to set up.

The economic benefits of modern bus systems are indisputable:

a) These systems favour lower–income groups. Most urban road projects tend to favour higher-income car owners. In

developing cities public transport normally has a captive or potential demand of low-income passengers. These benefit directly from investment in bus systems;

b) Travel times are drastically reduced on public transport. Passengers are often forced to spend several hours a day stuck in an overcrowded bus, facing traffic congestion, long waiting and boarding times and sinuous routes. Direct, high frequency, rapid transit can cut this lost time to a minimum;

c) Safety – is improved at both the waiting areas and in the units themselves;

Source: Transcraft

Fig. 2.4 Central Area Waiting in Curitiba

d) Road accidents tend to drop as pedestrian access is improved and units are separated from the traffic;

e) Emissions are drastically reduced;

f) As passengers gain new options of accessibility and reduce their travel time the city gains in competitiveness.

Chapter III: Principle Elements of Modern Bus System Technology

3.1 Basic Concepts

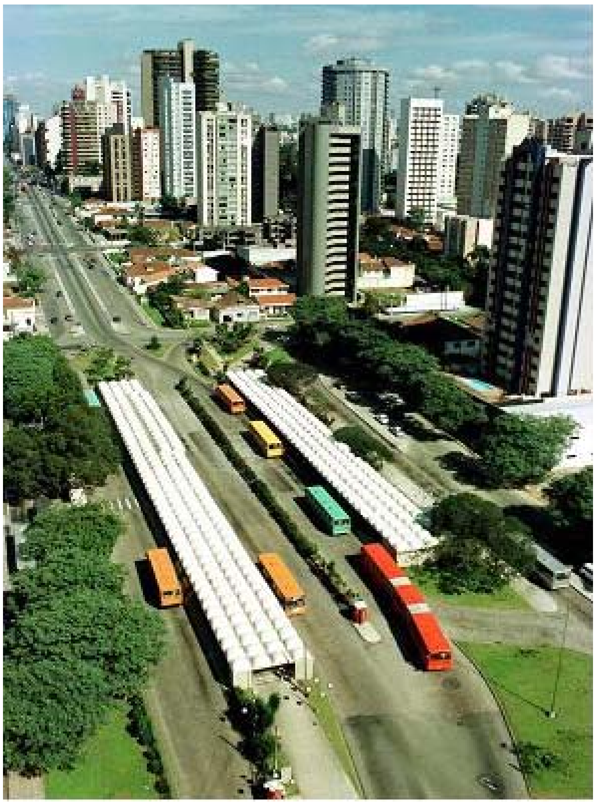
Most Latin American Modern Bus Systems share several basic concepts:

a) The designation of valuable city space for public transport in the form of bus-only streets, lanes or infrastructure for trunk routes.

A busway is normally considered to be a segregated stretch of road, with a minimum width of 7m (for a 2 way busway) or 14m for a 4-lane busway. A bus-only street is restricted to bus traffic, but would normally allow access to residents and special vehicles. Buslanes are normally 3.5m to 4m in width (per direction) and operate by road signs rather than physical segregation, and may permit access to private vehicles or to turning movements.

Source: Instituto de Pesquisa e Planejamento Urbano de Curitiba

Fig. 3.1 The Av. Sete de Setembro Busway in Curitiba



Source: Instituto de Pesquisa e Planejamento Urbano de Curitiba
Fig. 3.2 Santa Quitéria Integration Terminal, Curitiba

b) The concentration of passenger demand at integration terminal "hubs" and the rationalization of supply in terms of trunk and feeder routes.

These hubs offer new travel options in order to capture potential public transport demand. This infrastructure is normally called an *Integration Terminal* or *Interchange* and should be located in relation to the present transport demand as well as the planned development structure of the city. Examples of Interchanges can be seen in volume 1, Fig. 3.25 and Fig.5.1. Interchange design considerations are also covered in this Volume, see for instance Fig. 3.8 and Fig 3.9 and section 6.2.8.

This allows passengers in the city centre to generally take the first arriving trunk unit without waiting for a specific route number, which reduces the waiting queues. The waiting/station areas needed on the central area trunk sections are therefore relatively small.

c) Full accessibility to the entire system for a single ticket – or at least to the core urban zone. This means that passengers can

change from one route to another without paying an extra fare. From the 70´s to the 90´s, this meant using a “closed” system, with physically closed Interchange areas. With the current availability of smartcards, that allow unlimited travel, by zone and per time limit, Interchanges can now be designed to be fully integrated into the urban fabric.

d) Stations on the trunk routes set at longer intervals than conventional bus stops, typically 400-500 metres, preferably offering at-floor level, pre-paid boarding (as in a subway) to minimize loading times. The concept of pre-paid access implies that all passengers buy their tickets, and have them checked, before getting on the bus, thus saving valuable operating time as well as improving passenger journey times. At-floor boarding implies that instead of trying to make the bus as low as possible in order for passengers to only have a small step, the station is already at the same height as the internal floor of the bus – thus there is no step. Examples of this technology and the effect on boarding times can be seen in Volume 1 (chapters of Curitiba, Bogota, Quito, and Joinville). These stations are normally named and given a characteristic system design, rather than being simple bus stops[1].

e) The use of high-capacity units on the trunk routes, with high-frequency services operating at about 20kph. The unit that is most widely used in the 18m articulated bus. A sample specification is given in Volume 1, Chapter IV, on the Bogotá system.

[1] Examples of station design are shown in the AutoCAD files on the CD annexed

Source: Transcraft

Fig. 3.3 Interior Layout of a 25m Bi articulatedUnit in Curitiba

f) Electronic ticketing, preferably using contact-less smart cards. The use of smart cards is discussed in Volume 1, Chapter I and Chapter VIII in the description of the Joinville transport system.

g) Private sector investment in fleet and operation, with a professional administration of the concession. This approach was developed in Brazil and has been supported by the Brazilian Development Bank (BNDES). Although some systems have used a public sector company for trunk route operation (such as El Trole in Quito), this model has been adopted by most cities in Latin America. Examples of this are presented in Volume 1 in several of the case studies for instance in the description of the integrated transport network of Curitiba (Chapter III) and the presentation of city transport systems in Quito and Bogota (Chapter IV and VI).

h) System design and building associated with civic improvements for pedestrians and general traffic. Some examples of these improvements can be seen in Volume 1, for instance in Chapter III in the description of the development of the transport network in the city of Curitiba and specifically in the AutoCAD designs of the Curitiba Metropolitan Corridor that accompany the description in Chapter III, section 3.2.5.

Modern Bus Systems tend to be successful because their appeal has extended outward from the "captive" demand to a significant portion of the middle class. They look and perform much like modern metro systems, and there is no stigma attached to riding in them. This is essential for getting political, media and middle class support behind the transport project.

Source: Transmilenio
Fig. 3.4 The Tunal Terminal Access in Bogotá, Colombia

The expansion of public spaces (parks, sidewalks, bikeways), as well as conveying a sense of identity to the city, can enhance the general aspect of a system. Well-designed bus systems can bring real added commercial value to properties bordering the busways.

3.2 The Difference between Conventional and Modern Systems

Modern Busway Systems have sometimes been described as "closed" systems – as the passengers, once within the system area/units, can go anywhere within the network. However the Brazilian term "*Integrated",* is more appropriate as all sections – or even modes – operate as a single system.

On the other hand, open systems simply offer road space to existing bus routes, thus partly avoiding general traffic congestion. This is illustrated in the figure below; on the section marked in yellow, the conventional units enter a buslane or busway, avoiding traffic congestion. This is the most common form of bus priority in use, however, at high levels of passenger of

demand, units on open systems need space for overtaking in order to avoid units queuing for the stops. If only a single buslane is used, then the delays on all units are significant and the efficiency and overall travel speed drop.

Source: Transmilenio
Fig. 3.5 Conventional Units Converging on a Busway

A typical example of this form of bus priority is Oxford Street, London. Queues of buses at stops and signals are lengthy and the average travel speed on this "open busway" is only about 10kph – even during the off-peak.

Source: Transcraft
Fig. 3.6 An Open Busway In London

In order to examine the relative merits of both forms of bus priority, it is worth examining some case studies of high-volume public transport busways of the "open" type, the problems that have arisen and the strategies being adopted to address these issues.

3.2.1 International case Studies

a) Santiago, Chile

This situation has been experienced in several Latin American cities where "open" busways have been used for bus priority. The specific case of Santiago was shown in Volume I, Chapter X, section 10.2, and shows that the current "open" bus priority system requires 2 lanes in the centre – and that even then loading at stops is confused and dangerous. This has prompted the City of Santiago and the Chilean Government to propose a radical change in the bus network, transforming most corridors into trunk and feeder systems.

Source: Transcraft

Fig. 3.7 Confused Boarding on the 2 Buslanes in Santiago

b) Shijiazhuang, China

The city of Shijiazhuang in China operates a short but very successful open busway with 23 routes. According to the local authorities, however, there are several serious problems:

"***Few routes penetrate the residential areas and thus it is too far to get to the stops on foot.*** Some lines have poor headways, leading to long waiting times. With the growth of traffic, the road space is getting more crowded and public transport lacks sufficient priority.

Vehicle delays at intersections. Only 5 units pass the traffic signal per cycle. This is due to the waiting times of all units to get to the loading area and finish loading/unloading during the green time.

Queues at Signals. Similarly, as all stops along Zhongshan Road are located within 50m of the intersection. Long bus queues form on the approach lanes, blocking access of units to the loading areas.

Too Many Public Transport Routes on the Busway. As there are 23 routes on the bus lanes, all with differing bus types and speeds, the average speed on the busway is determined by the slowest unit. Boarding and alighting is also confusing at stops."

All these problems are typical of "open" systems operating at high volumes and frequencies. Some of the problems can be visualized in Fig. 3.8, such as the long queue of buses waiting to cross the junction and reach the loading area. The city is now in the process of analysing alternatives to these problems, such as limiting the

number of routes that use the busway; creating a parallel busway; making some routes into “feeder” or “branch” routes.

Source: Transcraft
Fig. 3.8 The Shijiazhuang Busway showing Excessive Queuing

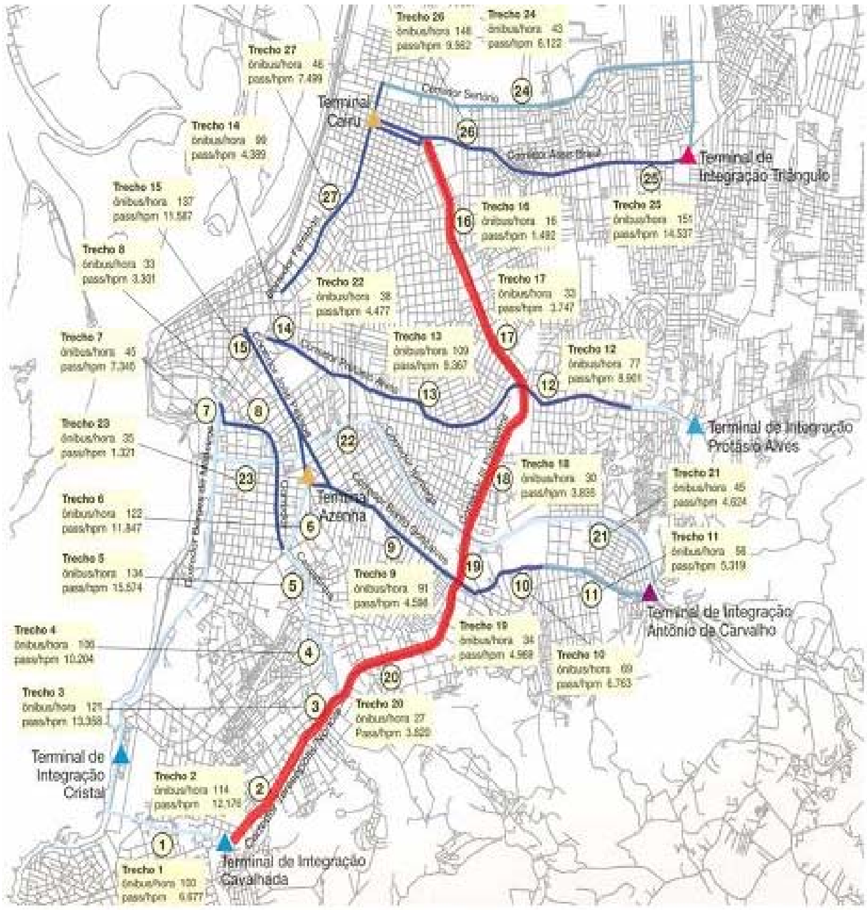
c) Porto Alegre

Another interesting case study is the Brazilian city of Porto Alegre. An early attempt at integration, using an interchange facility set extremely close to the city centre, was carried out in the late 70´s. This Interchange, Azenha, can be seen in fig. 3.9, and offered little in the way of new services or travel options but simply imposed a penalty on passengers in order to limit the volume of buses in the city centre; the result was a popular backlash that has limited the use of integration technology during decades.

Busways were introduced to give a measure of bus priority and by the 80´s, very high capacities were being registered. A report on several busway systems was produced in English by the TRRL (Transport Road Research Laborator) in 1991 (Gardner,G. Cornwell

P. and Cracknell J.). This showed that passenger flows of about 20,000 pax/h/d were being obtained on some of the main corridors in Porto Alegre, though the report does mention that high-flows; " are at the cost of extensive bus queuing and crush loading, and that without special operational measures, the maximum sustainable throughput is likely to be about 11,000 – 12,000 pax/h/d – or 15,000 with larger buses".

The spread of integrated technology in Latin America during the 90´s has led the city of Porto Alegre to revise it's transport strategy, as laid out in the Transport Master Plan of 2001. This document is a consequence of the City Master Plan (required by Brazilian Federal Law), and shows how the existing corridors can be upgraded to form an integrated network.



Source: Empresa Publica de Transporte Coletivo, Porto Alegre

Fig. 3.9 The Passenger and Bus flows on the Porto Alegre System

The passenger and bus volume figures given are for the morning peak hour and show that the crush volumes of the 80´s have now been reduced and are closer to the values estimated in the TRRL

report; the highest estimated volumes being on link 25 – nearly 15,000 pax/h/d – with 150 units/h after integration.

According to the city's EPTC (Public Traffic and Transport Company), trip destinations are no longer concentrated in the city centre, but are dispersed to the new commercial districts spread throughout the city. A home-interview survey carried out in 2003 showed that only about 20% of trips now end in the traditional centre. Of greater concern is the steady loss of passengers from the system: over 5% per month.

A summary of the 2004 system data shows a fleet of:

- 1594 municipal buses with an average age of 5.2 years;
- 297 units have air-conditioning;
- 112 are low floor;
- 117 have been fitted with a wheelchair elevator;
- 415 have an automatic gear box, and
- 681 units are still front engine.

The total number of passengers (transformed into equivalent-passengers, considering the fare reductions for students) is 20, 200,000 per month, for a total of run-out mileage of 9,455,000 km. This gives a Passenger Index per Km (IPK) of 2.14. The municipal system also has some 400 small vans ("lotação") registered as a complementary system.

Unlike Curitiba, the system only covers the municipality of Porto Alegre (a population of about 1.5 million) and operates with a flat fare of RS1.55 or about US$0,50. In September 2004,The inter-municipal fares were all over RS2.00, with an average of about US$0,70.

The change from the traditional "open" system to an integrated network is based on current Brazilian best practice: trunk routes, feeder routes, interchange facilities with new travel options and smart-card technology. The term "closed" is not appropriate as some conventional routes (and inter-municipal routes) will still have access to the busways; also the interchanges are not "closed" as the intention is to let passengers use smart-cards to transfer from one unit to another within a 2 hour time period. This will cause delays at some interchanges, so a form of pre-payment in closed areas may be introduced as the system develops.

Construction of one of the principal terminals, Triângulo, is nearly completed and the city has requested BNDES financing for the

ticketing system – both in terms of funding for the city and for the private operators. The BNDES also financed the “perimetral” Avenue, built during the 90´s, which has a central busway and links the main radial corridors through integration platforms at the intersections.

Source: Transcraft

Fig. 3.10 The New Interchange Terminal at Triângulo

Source: Transcraft

Fig. 3.11 The Interchange facilities on the Perimetral Avenue

Source: Empresa Publica de Transporte Coletivo, Porto Alegre
Fig. 3.12 Aerial View of the Grade Separated Passenger Link in Porto Alegre

According to the EPTC directors, the principal reason for changing to an integrated system is the need to maintain passenger levels. To do this, costs have to be rationalized to avoid fare increases, and accessibility and travel times improved. Specifically, the current problems are:

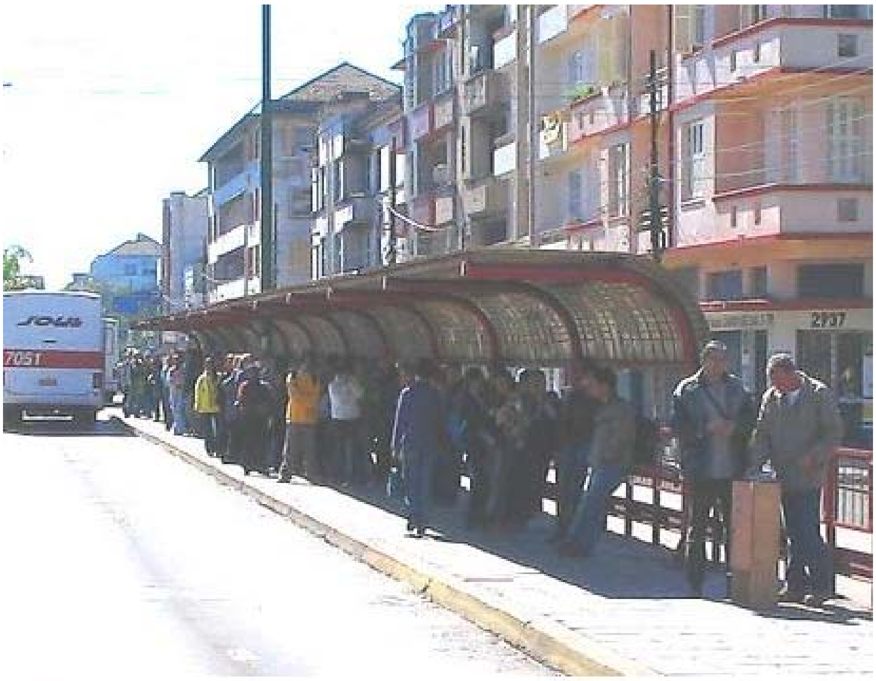
1) ***Cost***. The rationalization of long routes to the outskirts, using trunk and feeder routes, will reduce fleet size (capital costs) and overall mileage (operating costs). This will avoid increasing fares due to the current "vicious circle" of passenger loss > higher fares or lower quality > more passenger loss.

2) ***Lack of busway capacity***. With up to 300 units using the Farrapos busway per direction per hour, station capacity is at the limit. In the peak hours, running speeds in the busway can be lower than the general traffic lanes. To extend the "lifecycle" of the system, the bus units are operated as "ordered convoys", so that the sequence of units arriving is the same as that of the passenger waiting areas at platforms. This involves the use of "marshaling" areas at certain points along the corridors, again increasing overall travel time.

3) ***Frequency of routes on the outskirts***. During the peak hours, the main routes are subdivided on the city outskirts into " Route xa" , "xb", "xc", etc. The frequency of each subdivision is thus about 20 minutes. This means that central area waiting times and overall passenger travel times increase. In the off-peak, the routes are shortened, leading to longer walking times. With

rationalization, these areas will be served by feeder routes with improved frequencies.

4) ***The need for high-capacity units on the trunk routes***. User perception studies show that the main passenger complaint is overloading during peak hours. This can improved using higher capacity units – a measure only valid for trunk routes. The use of smart-cards will improve overall accessibility, but all units are required, under a specific municipal by-law, to have bus conductors. High capacity units will thus also help to reduce labour costs.



Source: Transcraft

Fig. 3.13 The Farrapos Corridor; long platforms and large numbers of waiting passengers

The newest corridor to be put into operation is the “Sertorio” busway, which uses left-hand doors on the trunk section. This was adopted for several reasons:

- To reduce the loss of road capacity;
- Lower building costs (one station serves both directions);
- Increased passenger comfort (as the platform width is 4m rather than 2m).

Source: Transcraft

Fig. 3. 14 Left-hand access at the Sertorio Stations

d) São Paulo

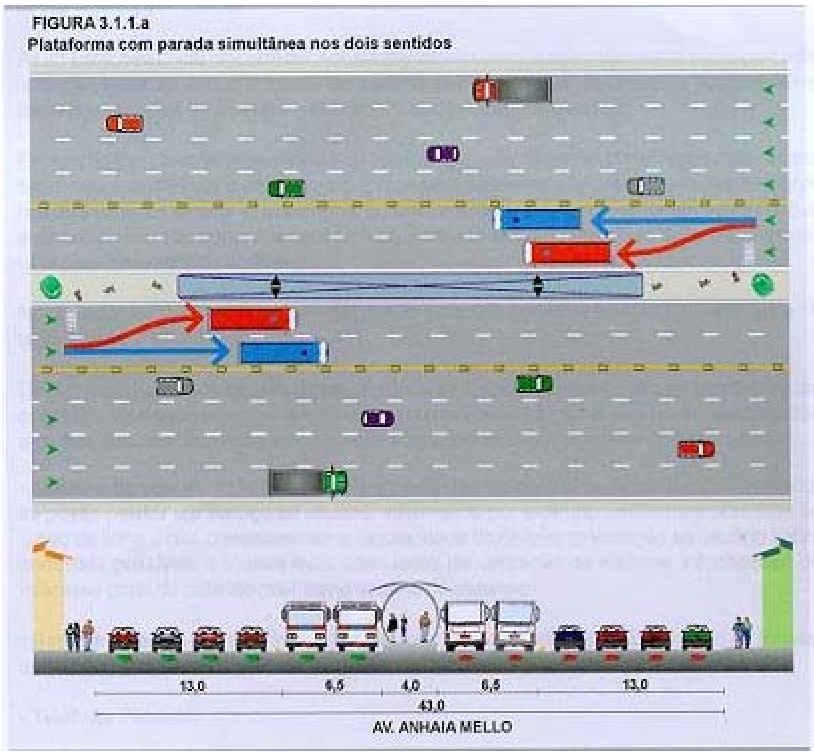
The Brazilian Metropolis of São Paulo has a metropolitan population of about 20 million and many decades of experience in operating buslanes. The public company, São Paulo Transportes (SPTrans), is responsible for the planning and operation of the municipal bus system of, about 10,000 units, operating over a thousand routes and distributed among more than 50 bus companies. There are 15 transfer terminals in operation, with a total of about 45 km of segregated busways, although the city also has 168 km of buslanes. There are points of integration with the Metrô, which allow for transfers using a magnetic strip card and paying an extra tariff of 20 per cent.

Busway technology during the 1970´s and 1980´s was heavily focused on maximizing throughput. The COMONOR project, for example, went to great lengths to organize bus queues and form convoys – or platoons – of units in order to obtain the maximum capacity of passengers. In 1991, for example, values of 20,000 pax/h/d were reported on the *9 de Julho* busway, for volumes of 230 buses per hour. Although efficient at moving people, the environmental and commercial impact of this volume of bus units is to create a 'wall to wall' queue of buses – especially near stops or junctions.

Source: SPTrans

Fig. 3.15 A Typical São Paulo Busway with Trolley and Conventional Units

The ambitious program of New Transport Corridors covers the construction of 93 new Integration Terminals, 350 Transfer Stations, busway construction and full electronic ticketing. The 23 de Maio Corridor, for example, is expected to handle 24 "structural" routes with a maximum demand of some 150 units/h and a maximum morning peak demand of 15,000 pax/h/d. At these volumes the units will have 2 dedicated lanes in each direction – to permit overtaking – and stations set in the central median.



Source: SPTrans

Fig. 3.16 A Typical São Paulo Corridor

In order to finance this project the city has obtained loans from the BNDES of R$247.3 million (approved in 2002) and another of R$ 494 million approved at the end of the first semester of 2003 (approximately US$200 million). Several corridors are already in the process of being built, as can be seen in the photograph below of the Av. São João in the central area (04/2004). The principal characteristics of these "structural" trunk busways are:

- Central stations with doors on the left;
- A reinforced pavement with reinforced concrete areas at the stations (high braking and acceleration);
- High-capacity bus units.

3.2.2 Bus Boarding and Waiting

In an open system passengers have to wait for their individual units, on average about half the headway, if the arriving units have available boarding capacity. This signifies that near the major bus stops there area large numbers of passengers blocking the sidewalks, without adequate protection or toilet facilities.

One of the advantages of integrated transport systems is the reduction in passenger waiting times in the downtown areas during the evening peak, which eliminates the confused, uncomfortable and often dangerous boarding as different route units arrive at the boarding sidewalks.

This can be illustrated by a simple example:

- If passengers arrive at the loading area at a rate of "q" = 1.5pax/s during the evening peak, this gives 5400 pax/h.

- On an Integrated or Closed system, if an empty, articulated radial trunk unit is arriving every 2 min, then on average there will be 1.5 pax* 120s = 180 pax: the load of the unit. The average pax waiting time will therefore be (headway/2) = 1min, and the average number of pax waiting will be = q * (headway/2) = 90 pax.

- For an open system with, say, 10 routes, each route would have to offer about 600 spaces/h (there is no rationalization of the corridor demand). For a 12m unit with a capacity of 100 pax, each route will therefore need a frequency of 6 units/h – or headway of 10 mins.

- Each passenger has to wait for his/her specific route, hence average waiting time is (headway/2) = 5 mins. The average number of passengers waiting at the area is therefore q* (headway/2) = 1.5*300 = 450 pax.

In general, for a given passenger demand, the number of passengers waiting at a stop is a function of the average headway of the routes arriving at this stop.

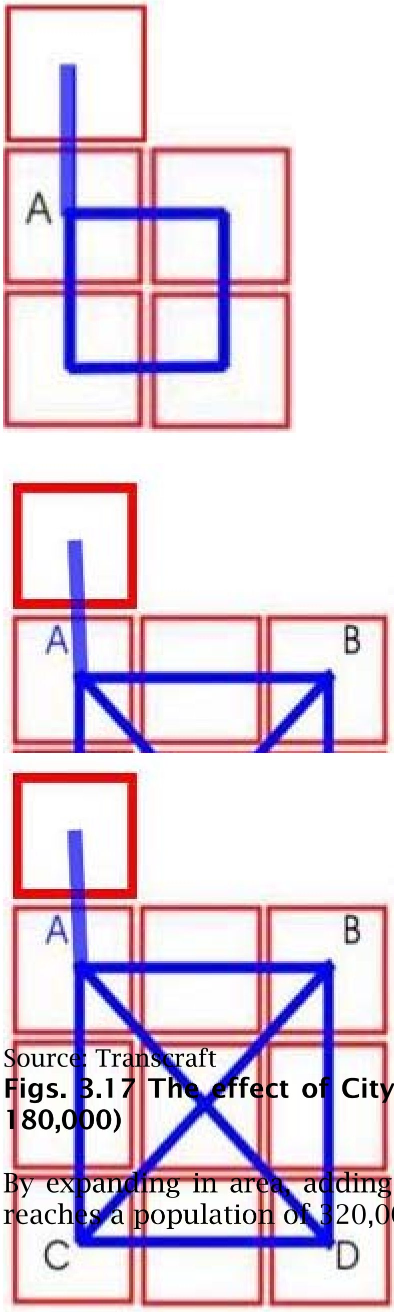
3.2.3 Comparison of Integrated and Open Systems as Inductors of Urban Development

The perception of public transport by many authorities in some parts of the world is still more in terms of a service that is aggregated to development, such as sewerage and electric power, rather then an inductor of urban growth. However, this view is seriously flawed: unlike other services which just require availability (electricity, water, drainage, etc.), public transport also requires accessibility – the means of traveling to different parts of the city.

As a city grows in size, the number of routes required to link all the different city areas grows exponentially. This is unsustainable and the consequences are a drop in service quality and/or a rise in costs.

For example, a simple model shows the growth of a city. The city is divided into zones of 1km square, each with a density of 200 inhabitants per ha, where bus passengers can reach a route by walking a maximum of about 500m.

For the first stage, of 80,000, one simple "square" bus route, as marked in blue, can connect all the zones. If a new zone is added, this route can simply be extended from A to allow access to the entire city. When the city grows to 180,000, 4 basic routes are needed: ABD; ACD; AD; and BC. Again, for a new zone, an extension of the 3 routes AD and ABD and ACD give full accessibility. This is illustrated in Figs. 3.17 below:

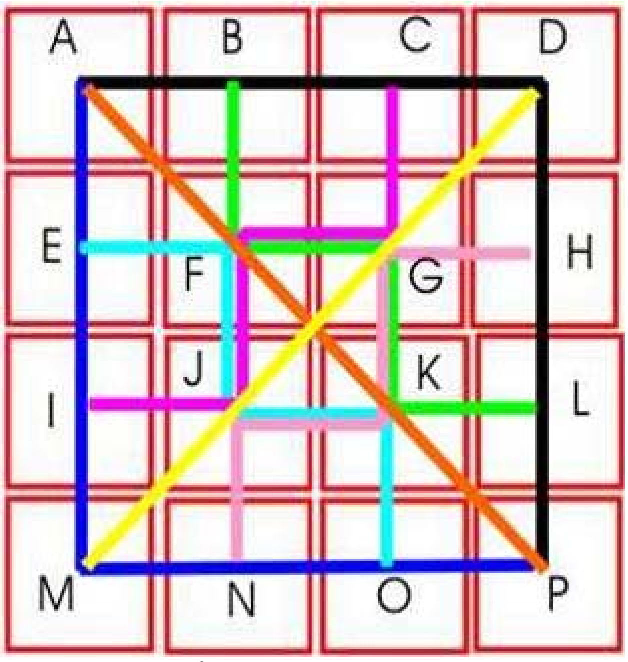


Source: Transcraft

Figs. 3.17 The effect of City Growth on Bus Routes (80,000 to 180,000)

By expanding in area, adding an extra 25% on each side, the city reaches a population of 320,000. The route network needed to link

the different zones starts to adopt the zigzag pattern typical of larger towns, and the routes have become longer – 5 to 6 km instead of 2 to 4 km.

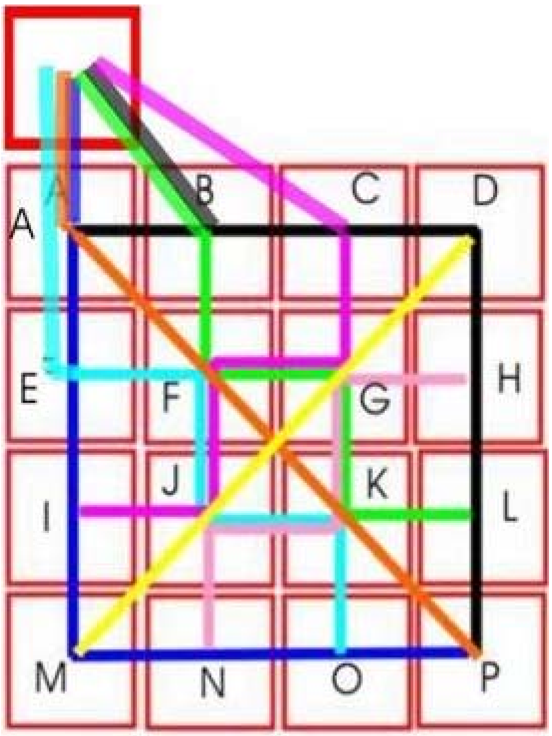


Source: Transcraft

Fig. 3.18 Routes on a Grid for a City of 320,000

Eight routes are now needed for all zones to be connected: AMP; ADP; AP; MD; BFGL; CGFJI; EFJKO; HGKJN. There are also several routes superimposed, with excess capacity - although this still leaves no direct connection between B and J; C and K; H and F; L and J; O and G; N and F; I and K; and E and G. Passengers between these zones must change buses and pay an extra fare.

A new zone added to this structure will require 6 extended routes, causing the routes to become 1km longer. Other typical problems of this “organic growth” are also shown: the purple route develops an irrational pathway; the black route has 2 variations (say“Black a” and “Black b”), which means that the frequencies at the end points are unsatisfactory; and there is an oversupply of capacity at the route endings.



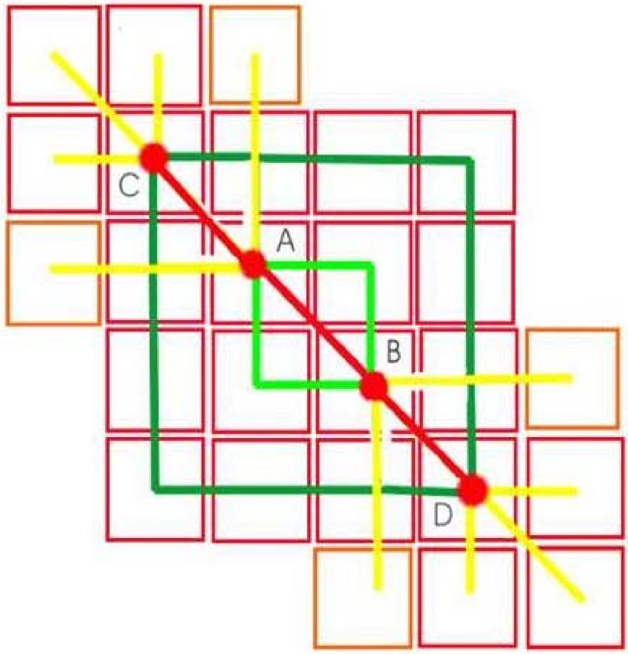
Source: Transcraft
Fig. 3.19 Extended Routes for an extra Zone

If the city plans to develop new districts, with 5 new zones at specific locations, each zone will need several new routes to reach the existing city areas, including a route that offers a direct link between the zones themselves.

The larger the city, the more routes are needed to give each new development zone full accessibility to the main destinations. If this is not available, the passenger either has to use another mode to reach a satisfactory route, take more than one route, or simply not use public transport.

At this stage, an option is to use the integrated approach. This allows the system to expand in order to meet the demands of planned city growth. Once the basic infrastructure is in place, access to the transport network thus becomes an essential factor in promoting the desired development.

The example below shows how expansion in 2 main corridors, north-west and south-east, can be included into the existing system by adding 2 new interchange terminals at C and D. The main trunk route becomes C to D, using high-capacity vehicles and some form of bus priority. The extra 10 zones –at the same density – would have an additional population of 200,000, taking the city to 520,000 inhabitants.



Source: Transcraft

Fig. 3.20 Expanded Integrated System on a Grid for a City of 520,000

In order to promote the occupation of the new development zones a city has 3 options:

1) Create several new, long routes, each route linking the main attraction centres of the city and all with frequencies that can attract passengers – these could eventually form part of an "open" priority system;

2) Maintain the current "status quo", in which some areas simply do not have public transport, thus decreasing the attractiveness and commercial viability of these urban developments and forcing all new residents to use private transport;

3) Building a convenient interchange, which can allow feeder routes to access these areas, and offering several travel options to different parts of the city at the interchange – including the high capacity trunk route.

The latter approach has been used for 3 decades by the planning authorities of Curitiba in order to direct rapid urban growth and the control of: land use, the road network and the public transport system are seen as the 3 pillars of urban planning in developing cities. According to the former Special Secretariat for Urban Development (SEDU – Presidency of Brazil, Priority for Urban Public Transport, 2002): "the development of integrated public transport is seen as an efficient strategy to promote the efficiency of urban development and economies".

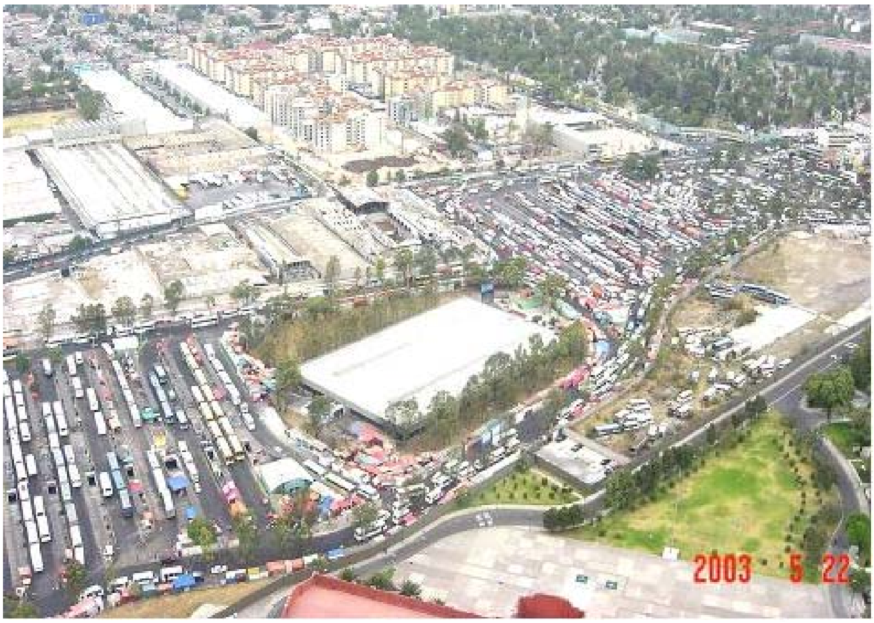
3.3 Modern Bus Systems as Extensions of Mass Transport

It is important to stress that modern bus systems can be implemented as extensions of other mass transport systems. Hence, the transport system of a city can be improved in a simple, low-cost and flexible way based on the existing system.

A Modern Bus System can be applied to a corridor that serves as an extension to high-cost infrastructure, such as a subway or overhead LRV (Light Rail Vehicle). This will consolidate the corridor and land-use plan, allowing for the future expansion of the high-cost infrastructure at a convenient later date.

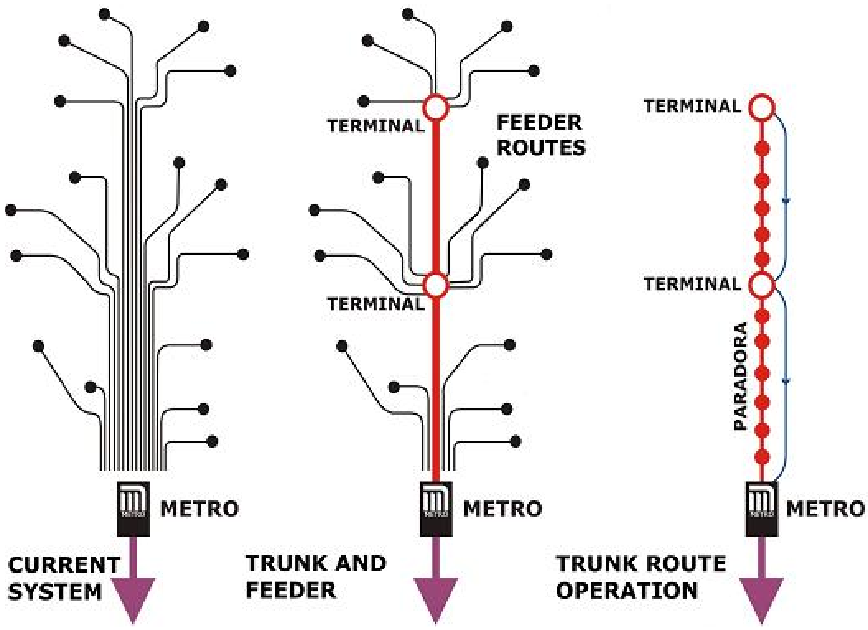
An excellent example of this use of bus technology is in Mexico City. The Administration of the Federal District is aware of the problems caused by the growth of the Metropolitan Region and the dependence of 81% of trips from the metropolitan area on poor quality public transport. The pollution levels caused by old vehicles is a major issue in Mexico City and several studies are being commissioned, such as the Conceptual Design of Strategic Axis 8 (South), by the Environmental Secretary *(Diseño Conceptual, Funcional, Operacional y Proyecto Ejecutivo del Corredor Estratégico Eje 8 Sur de la Ciudad de México).* This project is unusual as it is considered as part of the Air Quality Improvement Program for the Valley of Mexico *(PROAIRE 2002),* although the corridor is also included in the Integrated Transport and Road Network Program *(PITV).*

A conceptual design of another major corridor in Mexico City carried out in 2003 by the consultants *Jaime Lerner Arquitetos Associados* of Curitiba, indicates the scale of the problem of integrating large numbers of buses and passengers with a very high-capacity Metro. The figure 3.21 shows the morning peak bus flows around the Terminal of "*Cuatro Caminos"*. There is a swarm of buses – mostly small, old and highly polluting, around the terminal, forcing passengers to transfer in dangerous and uncomfortable conditions.



Source: Instituto Jaime Lerner
Fig. 3.21 The Cuatro Caminos Terminal

The proposal designed by the consultants would transform these small units into a trunk and feeder system, allowing an almost seamless transfer from the trunk routes to the Metro platform and improving the access for the passengers of the remaining bus routes which would still access the current transfer area. This conception can be seen in Fig. 3.22. The trunk routes are designed to operate with high capacity buses, on segregated busways and with at-floor, pre-paid boarding. Even operating as an extension, this would still be a very high-capacity system, requiring several hundred units.



Source: Instituto Jaime Lerner

Fig. 3.22 An Example of Metro Extension Rationalisation

3.4 System Capacity

3.4.1 Modern Bus Technology as Mass Transport

Mass Transport is a term loosely applied to high-capacity public transport - such as a metro, subway or transit system. At the high end are underground subway systems such as in Hong Kong, São Paulo and Mexico City that carry some 60-80,000 pax/h/d.

Overhead rail systems with no interference from junctions, such as the Manila Light Rail and Bangkok Skytrain carry about 20-25,000 pax/h/d. (See fig. 3.23) Other Light Rail Vehicle (LRV) systems with little interference at junctions tend to have capacity levels of less than 20,000 pax/h/d, such as the systems in Kuala Lumpur (Putra LRV, 10,000; Monorail 18,000).

Source: Bangkok Mass Transit System Public Company Limited

Fig. 3.23 Bangkok Skytrain

Theoretical estimates of bus systems have been published for many years, in some cases to show that this technology is not in the same "league" as rail-based systems. Modern Bus Systems have, however, similar carrying capacity as LRV Mass Transport, with registered capacities, as of 2003, of:

System	Highest recorded pax/h/d
Bogotá TransMilénio (articulated units on 2 lanes in each direction, including the overtaking of express/direct routes)	42,000 (1)
Bogotá TransMilénio (articulated units on 2 lanes in each direction, including the overtaking of express/direct routes)	34,000 (2)
Curitiba (7m busway, no overtaking, bi-articulated units at minimum intervals)	15,000
Quito (7m busway, articulated trolleybuses)	8,000

Source: Transcraft

1. Considering that this value was obtained on the special "no-car" day.
2. Normal week-day value

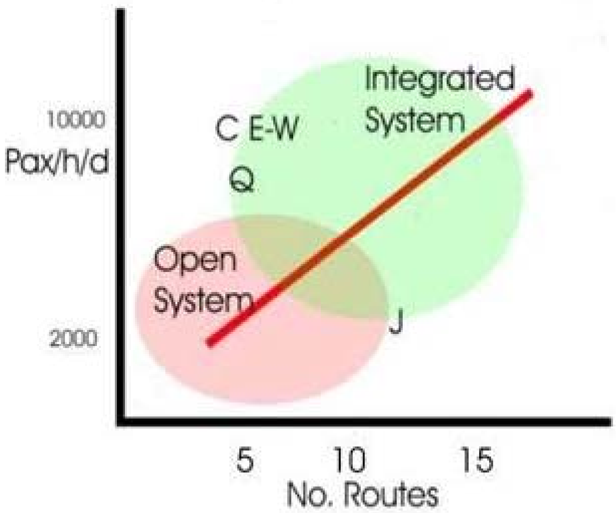
Table 3.1 Recorded Capacity Values: Pax/h/d on the most loaded section

The limiting factor for the system is the capacity of stations to handle the units. For a Curitiba type system, this value is around 60 units per hour/direction. For Bogotá a value of 80 units per station bay per hour/direction has been given by the Transmilenio management.

If no overtaking is allowed, and station infrastructure permits 2 units to dock at the same time, then the maximum system capacity for a 7 metre busway operating with bi-articulated units is probably about 18,000 pax/h/d – even with quite high volumes of cross traffic at junctions.

A rough guide to the use of "open and integrated" bus priority is that, integrated systems are more efficient when the number of existing or planned conventional routes that would use any corridor infrastructure is more than 5, and when peak passenger demand per direction reaches about 2000.

This is illustrated graphically in fig.2.24 below. For corridors that have characteristics in the pink zone, a simple "open" bus priority scheme will offer a better service. For corridors that lie in the green zone, the use of integrated technology will probably offer a more efficient service. The letters "Q, C E-W, and J" refer to the corridors of Quito, Curitiba and Joinville, respectively. (See Volume 1; page 56, 119 and 132)



Source: Transcraft

Fig. 3.24 A Comparison of Open and Integrated Technology

3.4.2 System and Capacity Upgrading

One of the enormous advantages of modern bus systems is the flexibility in adapting or upgrading the system. The useful working life of a high-capacity unit is normally considered to be about 10 years (in Brazil), thus there is always a “window of opportunity” for upgrading the system when the fleet is renewed. This also allows the physical installations to be modified, bringing in smartcard ticketing, left-hand doors, articulated units, etc. For more information on these specific upgrades see Volume 1, page 15, 30 and 210.

For example, the current maximum load on the trunk routes in Joinville is about 3000 pax/h/d on the main North-South Axis. This is the typical lower limit of the demand envelope for exclusive busways (about 50,000 passengers per day, both directions on the critical stretch) thus the city is now in the process of designing exclusive buslanes for the central area with pre-paid loading. The specifications for the new trunk route fleet also require articulated units.

The final operational data for the corridors of the Fortaleza program will be finalized in 2004, however, the initial modelling indicates a maximum flow on the critical stretch of some 4500 pax/h/d, corresponding to about 70,000 passengers/day (2007 estimate). Given the size of the city and current level of congestion, the program thus considers upgrading to exclusive buslanes/busway, using a fleet of articulated units and pre-paid, at-floor loading (Vol.1, Chapter IX).

The table below gives an indication of the technology needed for different corridor demands based on Brazilian and Latin American experience. Even at fairly low demand levels, there is a tendency in Brazil to opt for trunk/feeder systems due to the increased accessibility and rationalized costs. At higher demands, open systems present the problems already discussed and busways for trunk routes are recommended. At about 5000 pax/h/d the use of pre-paid, at-floor loading becomes an important factor. Above 10000 pax/h/d the stations may need to be increased allow for bi-articulated units or convoys of 2 articulated units. The only system operating above 18000 pax/h/d is TransMilenio, which has a 14m busway and semi-direct routes allowing for overtaking.

Pax/h/d	System Type	Indicated Technology	Trunk Units
< 1000	Open	Conventional	
1000 - 2000	Open/Integrated	Conventional/Trunk and Feeder	12m, 3 door

2000 - 3000	Integrated	Trunk/Feeder	Articulated 3 door
3000 - 5000	Integrated	Trunk/Feeder, Exclusive Busway	Articulated
5000 - 10000	Integrated	Trunk/Feeder, Exclusive Busway, Pre-Paid, At-Floor	Articulated 4 door
10000 - 18000	Integrated	Trunk/Feeder, Exclusive Busway, Pre-Paid, At-Floor, Convoy	Bi-articulated 5 door
18000 - 34000	Integrated	Trunk/Feeder, 14m Busway, overtaking, Pre-Paid, At-Floor	Articulated 4 door

Source: Transcraft

Table 3.2 Indicated Technology for Different Corridor Demands (pax/h/d).

3.4.3 The Effect on Performance of Boarding and Loading Technology

Experience has proven that in order to operate as Mass Transit, a bus system should have a segregated busway and pre-paid, at-floor loading. The role of low-floor or low-entry buses in Modern Bus Systems is still open to debate. As Modern Bus Systems have a strong private sector involvement in the purchase, operation and maintenance of the fleet, control of passenger numbers and fares is essential. In Latin America, even with the use of smartcards, this involves the use of turnstiles that can either be installed in the units or at terminals and stations. No other technology has been tested that can guarantee adequate levels of control.

One of the advantages claimed for low-floor bus technology is that station infrastructure can be simpler (less costly and with less encroachment on the sidewalk). In other words, the concept of stations with pre-paid, at-floor boarding can be abandoned in favour of conventional bus stops. In practice, this would transfer the turnstile to the bus. If passenger demand along the corridor is high, the bus loading times will thus be significantly increased and the units will suffer a drop in operating speed, reducing travel time benefits and increasing operating costs.

There are several urban transport proposals for BRT (Bus Rapid Transit) for developing cities, drawing on recent North American experience. However, it is vital for these systems to work that the huge differences in the scale of passenger demand be considered. Solutions, such as low-floor entry, that may work well for buses with 10-minute headways and 1,000 pax/h/d will be completely inefficient for demands of 18,000 pax/h/d.

Most conventional Brazilian buses operate with separate front entry and rear exit doors, a turnstile separating the compartments. A cash fare thus requires either a separate driver per bus, increasing costs, or the time consuming sale of a single ticket - leading to longer boarding times and slower commercial speeds.

The term *passenger boarding times* (i.e. the time taken to get on the unit from the sidewalk) is often confused with the term *passenger loading times* (i.e. the time needed to pass the turnstile). If the unit has a conductor to take fares next to the turnstile and there is a large accumulation area, then stopped boarding and loading times are equal to the time taken to step on the bus. During the peak hours at, say a school or in the city centre, when the number of passengers exceeds the waiting area, the stopped time is more a function of the loading time taken to pass the turnstile.

Tests were carried out in Joinville on high capacity units that have room for about 10 passengers in front of the turnstile. Average turnstile-times for cash paying passengers, single trip (magnetic strip) tickets and contact-less smart cards were measured. For cash paying passengers, this time involved paying the driver, getting change and moving past the turnstile. The results are given below in Table 3.2 along with data from the Curitiba and TransMilenio mass transit systems.

System	Average Loading Time/Pax (s)
Cash payment to the driver	Around 8 (*)
Single Ticket Joinville	4 (§)
Contactless Smart Card Joinville	2.5
Terminal Joinville (3 doors articulated)	0.3
Tube Station Curitiba (2 doors)	0.25
Tube Station/Terminal Curitiba (5 doors bi-articulated	0.1
TransMilenio Articulated Unit (4 doors)	0.08

Source: Passebus, TransMilenio and Transcraft (2003)

(*) Passebus (the ticket office of the operating companies) mentioned that this time varies according to the fare and the change that has to be handed back.

(§) They also mention that magnetic strip tickets have a failure rate of about 1 in 1000, which causes great loss in time. This is negligible for smart cards.

Table 3.3 Average Passenger Loading Times for Different Systems

In peak hours, the stopped time of units is more a function of loading times than boarding times. The lower the stopped time, the faster the trip for the passenger and the lower the capital cost for the operator.

Hence it is clear that, in peak periods, the major operational gain for one-man operated buses is going from a cash payment to pre-paid smart cards.

Pre-paid loading at terminals and “tube” style stations is the next most important step, with a gain of about 2 seconds per passenger.

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Chapter IV: Benefits and Costs

4.1 Benefits

The economic benefits of modern bus systems are recognised as being:

4.1.1 Travel Time Benefits

Travel times are drastically reduced on public transport. Passengers on conventional systems are often forced to spend several hours a day stuck in an overcrowded bus, facing traffic congestion, long waiting and boarding times and sinuous routes. Direct, high frequency, rapid transit can cut this lost time to a minimum. (See Volume 1, Chapters IV and Chapter VI)

4.1.2 Safety

One of the advantages of pre-paid access is that passengers can wait in more comfortable surroundings, relatively free from the action of pickpockets or muggers. A survey carried out in 1992 on the first Tube Stations on the Boqueirão line in Curitiba (Transcraft, 1992), showed that the level of perceived safety was much higher, specifically among women passengers, leading to high approval ratings of the new system when compared to the previous standard articulated buses stops.

Public Perception of the Boqueirão Biarticulated Route in Curitiba

77% thought the service had improved;

84% considered the Bi-Artic to be more comfortable;

81% believed the system to be safer;

87% preferred the new boarding access;

93.5% found the Bi-Artic more spacious,

80% found it quieter and

92% considered the design to be more attractive.

Source: Transcraft/Volvo do Brasil 1992 (unpublished)

Table 4.1 Public Perception of the First Biarticulated Route in Curitiba and the Pre-Paid Tube Stations

This higher perceived level of safety was also felt in Bogotá, where the crime rate on the Avenida Caracas section dropped drastically. (See Volume 1, Chapter IV)

Safety and comfort can be further enhanced by having on-line CCTV (Closed Circuit Television) at boarding platforms, integration terminals and stations. This dedicated infrastructure also allows for an "emergency or panic button" to be installed together with the CCTV, so that passengers that feel threatened, can be seen and contact by voice the control centre. This system already exists in several subway systems – such as the Underground in London – and is programmed for the new Metropolitan route in Curitiba.

Road accidents tend to drop as pedestrian access is improved and units are separated from the traffic, though this is difficult to predict. The before and after data from Bogotá indicates that this benefit can be quite substantial (Volume 1, Chapter IV, Section 4.2.6).

4.1.3 Emissions

The rationalization of the route system and the introduction of new, low-emission units running on uncongested busways, allows for a more efficient use of fuel and consequently, less pollution in the central areas or on major transport corridors. This is not the case for "open" systems, which simply increase throughput of the existing fleet. (See Volume 1, Chapter III and Chapter VII). The data from Quito and Bogotá shows that there is a substantial reduction in emissions from the public transport system. (See Volume 1, Chapter VI and Chapter IV).

4.1.4 Accessibility and Competitiveness

In many cities, passengers, especially from the low-income districts on the outskirts, are forced to take one bus into the downtown area, and pay another fare to reach their final destination. This is currently the case in San Salvador, where the average number of fares paid per trip is 1.4. (See Volume 1, Chapter X)

The new options of travel available through integration - for the cost of a single ticket - offer passengers new alternatives of work and commerce. Lower travel times and better local access increase the chances of a city attracting new investments in manufacturing or commercial centres. This has been part of the planning strategy of Curitiba, for example (See Volume 1, Chapter III)

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4.2 Potential Disadvantages of Modern Bus Systems

The effects of a system on other road users will be both positive (the elimination of turning movements, bus stops, bus units, overtaking buses, irregular stops, etc.) and negative (the possible elimination of one or more lanes used by traffic). Each system requires a specific traffic analysis to determine the before and after capacity levels.

In Quito, the overall effect on traffic was found to be positive (See Volume 1, Chapter VI). In Curitiba, the planning of the busways was prior to any major congestion; in the case of the Western busway, this was a green-field site when originally built. (See Volume 1, Chapter III)

The policy of some cities when retro-fitting a busway, such as Jakarta, is now to "take away and put back", in other words, remove a traffic lane during construction of the busway, but add a new traffic lane (even if narrower) when the system starts operating.

4.2.1 Special Access Needs

In Latin American bus systems there are 2 main methods for handling special access needs:

1) By bringing the entire system up to full accessibility; and

2) By offering auxiliary services.

Part of this discussion is the delicate question of citizenship – the right to be treated as a normal citizen with full access rights, versus the cost to society in general. For example, fitting every bus unit with a wheelchair access lift, which requires the driver to get out of the bus, offers full access but at an enormous cost in equipment, in time and extra fleet and is incompatible with the aim of offering low-cost Mass Transit. Most modern bus systems thus try and allow special access needs to be incorporated into the system through modified infrastructure.

The simplest form for trunk routes with at-floor boarding is to use ramps for passengers to reach the station or terminal platforms. In some cases the design is extremely poor – as in Goiânia (See Volume 1, Chapter V, Section 5.4)

The "tube" stations on Curitiba's mass transit system have a special lift, which permits wheelchairs to rise to the at-floor platform. The extra wide doors allow for easy access to the bus unit and a special zone is reserved in each unit for passengers with wheelchairs (See Fig 4.1) These elevators require frequent

maintenance thus involving extra cost. In the case of malfunction passengers with special needs will have no option to access the platform. Where space is available, ramps still offer the best low-cost solution.

Source : Transcraft
Fig 4.1 The Platform Elevator

For the city zones that do not have the trunk routes there is a special dial-up taxi service that can accommodate wheelchairs, partly subsidized by URBS. For passengers with visual deficiency the stations in Curitiba also broadcast the trunk routes arriving and on each trunk unit, a recording gives the next tube destination.

Curitiba also pioneered the SITES service, which is offered free to students with special needs (Vol. 1, Chapter III, section 3.2.2). This service has a pick-up route of all special needs students per specific catchment area and that can use a conventional bus unit. These buses then converge on a special terminal, where each student then takes his or her bus to the educational establishment that caters for each special group. This reduces the overall transport cost and travel time.

In Joinville the bus companies offer an adapted mini-bus dial-up service that is paid for with a smartcard, each registered user being able to purchase 50 trips per month for the same cost as 50 bus fares. (See Volume 1, Chapter VIII)

In several other cities in Brazil, municipal by-law requires that at least one unit per company has a special lift, such as Campo Grande. In practice the timetable of these units is not readily available so the service is of marginal use. In São Paulo there Is a

large fleet of vans that offer a free dial-up service to registered users – the cost being borne by City Hall.

Similar access is offered by the Quito and Transmilenio systems on their trunk routes, as can be seen in fig 4.2 below.

Source : Transmilenio

Fig. 4.2 Wheelchair Access in the TransMilenio System

For passengers with visual deficiencies the stations in Curitiba also broadcast the trunk routes arriving and on each trunk unit, a recording gives the next tube destination.

4.2.2 Affordability and Sustainability in operating

Both terms of affordability and sustainability refer to the financial analysis of any proposed system. If proposed fare levels are in the same range as current fares then a system is affordable; if the fares cover all the operating and financial costs, a system is sustainable.

Experience in Latin America, now confirmed by systems such as TransJakarta, Indonesia, has shown that passengers will pay a premium fare for a better service. In many cities a sizeable part of the daily demand also has to pay more than one fare per trip. Often this involves getting another bus in a crowded and, some times, dangerous downtown area. For these passengers a new integrated fare may actually be cheaper.

Operating costs will vary according to import duties, the local costs of fuel and manpower, taxes and the structure of any proposed system. If there is a high turnover of passengers along a short trunk route the system will be cheaper to run than a longer route with most of the loading at the end terminal.

A useful rule-of-thumb, based on projects carried out in Latin America, Asia and Africa, indicates that: If fares are lower than US$ 30cents, then it is difficult to equate the financial engineering – the system will thus not be financially sustainable. On the other hand, if the majority of passengers are only paying about US$ 12cents per trip, then a new system will probably not be financially affordable.

4.3 Costs

4.3.1 Capital Costs: System Infrastructure Costs

Each city has its own structure and needs. Only a pre-feasibility study will determine if a Modern Bus System is a viable proposal and how it can physically be inserted into the city. This is a process that requires experience and vision: the existing road network may not be adequate, however, new roads, the use of one-way "couplets" or the redesign of a blighted central area may create the space needed.

This new infrastructure may also allow for redevelopment or the improvement of pedestrian and cycle facilities. Urban design, open spaces, commercial enhancement and overall land-use are all factors that should be considered.

The examples given in the chapters on case studies show that Modern Bus Systems – like all transport networks - tend to be built up over time. A typical project would involve one or two corridors that would be transformed into some 20km of exclusive busways, with at-level stations every 400 metres and several major integration terminals for feeder buses. There would also be new road works (partly to offset any loss in traffic capacity and minimize any new congestion) and improvements in urban design, green spaces, pedestrian and cycle facilities. This is sufficient to radically transform a city.

However, a common error in the pre-feasibility stage is to add the costs of a few terminals to some busway paving and present the result as the cost of a Program. This will sub-estimate the real costs and lead to budgetary problems when the full costs are determined in the feasibility study.

The table below gives an idea of the scale of some recent or on-going projects and the agencies involved. This table tends to confirm the statement made by Seidel (See Chapter III) that for a city of say 2 to 3 million there will be a need of between US$ 50 – 200 million to finance infrastructure.

City /Project	Population	Overall Cost	Proposed

	(Million)	(US$ million)	**Financing**
Metropolitan Corridor Curitiba BID II 3		133.4	IADB
Transmilénio Bogotá (Phase 1)	6	213	Local
Quito El Trole (Phase 1)	1.5	57	European Credit
Guayaquil	2.1	80	CAF
Lima (LimaBus)	8	126	WB/IADB
San Salvador/Transfuturo	2	26.4 (*)	IADB
Santiago/Metrobus	4.8	209	Undetermined
Fortaleza BIDFOR	2.1	142	IADB
São Paulo	10	385	BNDES

(*)first year only
Source: Transcraft
Table 4.2 Summary of Project Costs

This level of cost can be compared to other forms of Mass Transport systems as quoted in the TransJakarta Busway Project, Technical Review, presented below in table 4.3

Line	**Capital Cost/Km (US$ million)**	**Actual capacity (passengers/hour/direction)**
Hong Kong Metro	$ 220	81.000
Bangkok Skytrain	$ 74	25.000 – 50.000
Caracas Metro	$ 90	21.600 – 32.000
Mexico City Metro	$ 41	19.500 – 39.300
Kuala Lumpur LRT	$ 50	10.000 – 30.000
Bogota TransMilenio	$ 5	35.000 – 45.000

Curitiba Busway	$ 2	15.000
Quito Electric Trolley Bus Rapid Transit	$ 5	9.000 – 15.000
TransJakarta	$ 1	8.000

Source: TransJakarta Busway Project, Technical Review, ITDP, Institute for Transport and Development Policy. December, 2003.
Table 4.3 Level of Transport Costs

4.3.2 Operating Costs

Modern Bus Systems – (or High-Capacity BRT) use bus technology in amore effective manner, hence operating costs tend to be similar to conventional bus systems. In Latin America, nearly all BRT bus units are bought, operated and maintained by the private sector and run on infrastructure provided by the public sector.

In Curitiba, for example, the cost per passenger of the feeder units from the Metropolitan outskirts is much higher than the costs of the municipal integrated network, as was made clear in 2003 when the municipal fare was reduced to R$1,60 (about US$64 cents) from R$1,90 (US$76 cents). (See Volume 1, Chapter III)

The El Trole in Quito is the exception to the rule and does not include the capital cost of the fleet in the fare calculation. However, the new route, Ecovia, operated by a private sector consortium, uses the same fare of US$25 cents, which covers depreciation, maintenance and operation of a fleet of articulated buses.

The IPK (passenger per kilometre index) is a much-used guide to bus system performance in Brazil and Latin America. In general, an efficient system has an IPK of about 3. The aim of the El Trole system is to have an IPK of 6; the goal of Transmilenio is to maintain a value of 6.4 and the IPK value of the biarticulated units on the Southern Line in Curitiba is higher than 11.

The fare-box ratio gives a reasonable idea of how Modern BRT systems compare with Light rail and Metro. As shown above, most BRT systems have a fare–box ratio of more than 1, in other words, fares cover all trunk route operating costs and, in some cases, feeder route costs as well – including depreciation of the units. El Trole in Quito and new systems such as TransJakarta have fares of US$25 cents in 2005 that do not include fleet depreciation.

For Metro systems, a study by the GTZ in 2003 revealed that the fare box ratios for most Metro or Light Rail systems vary from 0.25 to more than 2, depending on the fare charged and excluding

all capital costs – including the depreciation of the rolling stock (See table 4.4).

Fare Box Ratios, selected rail MRTs.

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

Source: Sustainable Transport: A Sourcebook for Policy-makers in Developing Cities, GTZ, March 2003

Table 4.4 Fare Box Ratios

The World Bank Report, Cities on the Move, 2001, indicates that operating costs per passenger for Metro systems range from US$61 cents in Hong Kong to US$19 cents in Santiago.

Chapter V: Administrative And Legal Issues

5.1 General Characteristics

The transport sector in many Latin American cities often presents similar characteristics: large quantity of small operators that offer their services in a disorganized fashion and route networks that have grown up in a "spontaneous" manner, without little formal planning apart from the commercial initiatives of the transport sector. The owner-drivers of one or two units are their own individual managers, normally without any form of organization or formal association. Fares are usually collected and kept by the units in operation, causing any other bus on the route – or part of the corridor – to be perceived as the competition.

Even though many transport laws and regulations have been drawn up, this extreme atomization has stayed fairly constant over the decades. Indeed, regulation in many Latin American cities allows transport services to be run by individuals or merely formal commercial societies, without any true managerial content or capitalization. Quite often these "companies" do not even have the operating fleet registered in the name of the company.

This situation has many very negative consequences for the transport systems, as the private sector is blocked from credit sources due to a lack of counter-guaranties, often forcing the state to offer some form of subsidy. This context of individual operation also imposes on operative costs, as the benefits from certain economies of scale, inherent to the exploitation of services of this nature, are lost; such as in purchasing or in the more rational use of personnel assigned to the companies.

The same extreme atomization of operators leads to the absence of any form of control in terms of passengers carried or fares paid. On the one hand this encourages fares to be pocketed by drivers or conductors, on the other hand, no true idea of taxes to be paid is given. The lack of data on fare collection also contributes to the ignorance of real demand mobilized by the system, both on the part of the companies themselves and at City Hall. This in turn leads to the lack of indispensable basic information necessary to guarantee that the essential public service of urban transport is adequate to meet the mobility needs of the population, in terms of frequencies, capacity, planning and the general administration of a system, by nature, extremely dynamic.

Another element in most Latin American systems is the high number of obsolete or extremely old units in operation: a major cause of congestion, pollution and traffic accidents. This situation is made even more serious due to the non-existence of obligatory

mechanical revisions in many cities and absence of a culture of preventive fleet maintenance within the companies.

In all cases, these scenarios of urban transport impose a heavy costs on society. In some cases there is even an explicit cost as a result of direct public subsidies of fuel or units. Both types of subsidy lead to market distortions and a simple increase in the units in operation in order to “farm” the subsidy.

5.2 Institutional and Management Aspects

The public authorities, national, state or municipal, normally possess a limited capacity to conduct an adequate control of such an essential public service as urban transport. The technical level of available staff prevents a successful structural change of the system and, too often, key data is missing for adequate decision making, such as the supply of capacity, the demand of passengers and the operating costs of the services.

Another common problem is the lack of a modern Transport Code, which defines the necessary technical rules for the development of services, the rights and obligations of operators and specifies the level and mechanisms of intervention of the public authority.

Government inactivity of the face of these factors, or the partial and slow intervention in certain aspects of the services, only makes the system go from bad to worse, condemning the transport system to be unsustainable in the medium term. These problems are most obviously manifested in the makeshift offices dedicated to transport in the back yards of the general security forces, or in administrations that have been openly co-opted by the transport sector.

This is a scenario, which often plays out as follows:

- Unemployment forces more people into the transport sector;
- Oversupply of bus units keeps fares artificially low and increases operating costs, especially during the off-peak;
- New buses are not feasible, so older units are acquired and added to the existing fleet;
- The higher and more visible pollution levels attract public attention;
- The old fleet becomes unsafe, buses crash and people get killed or injured;

- Renewing the fleet becomes a public and political issue; age controls for the fleet are introduced;

- As the industry has not been able to make any provision for fleet depreciation, the sector has little capital for new investment;

- To avoid losing their livelihood, the sector goes on strike. The very nature of the sector – with hundreds of individual owner/drivers – means that negotiations are extremely complicated. The results can be bitter as the sector has little to lose;

- An agreement is eventually reached, fares go up, a few units are removed and the main problems are simply pushed into a distant timeframe.

During this process there is often an additional phase of calling for new, radical or fanciful transport solutions, such as urban trains, electric trams, etc. This phase is attractive to desperate mayors, seeking to avoid dealings with the transport sector and is also favoured by the smarter members of the transport lobby as these high-cost solutions are known to be unrealistic and guarantee the "status quo".

This scenario is only reversible if there is decisive intervention of the public administration in order to radically transform the sector.

5.3 Regulation

The transformation and modernization of public transportation represents an important challenge for cities and international experience over the past decades recommends that public transport be given the character of a regulated service. The maintenance of regulatory policy in relation to technical and economic questions, even in countries with a strong neo-liberal national economic policy, is necessary due to at least three basic considerations (for example, see Vol 1. Chapter 9, section 9.2.1 and the Chapters on Bogotá, section 4.2.1 and Quito, section 6.2):

- Public transportation uses a good of limited capacity (the roadway) and its operation impacts decisively on traffic circulation, on the environment, on travel times and the general level of accessibility within the city – as well as the competitiveness of the city within the region;

- The need to guarantee acceptable levels of public safety (minimizing the number and severity of traffic accidents); and

- The high inelasticity of public transport demand, especially work-based trips.

The decision to regulate the urban public transportation system in a modern and efficient manner, guaranteeing long term sustainability, is an important step as it implies a redefining of the relationship between the State and the operators:

- The Administration has to transform a passive attitude into an active role that can guide the private operator's behaviour, following strategic objectives in order to arrive at the common good.

- The operators need to evolve from an informal, backyard industry into a new, professional sector within a formal business environment.

In some cases, as in Argentina, regulation of public urban transport has not only meant the economic regulation of the activity, but also an intervention of the State in this field, more complete and diverse than in other areas of the economy.

Indeed, the regulatory framework establishes a complete sector regulation, taking into account the following aspects:

⇒ Fixation of transport policy objectives.

⇒ Establishment of subjective requirements of the companies that will perform the services (most of the requirements demanded of the urban transport concessionaries are established with more detail according to the bases and conditions of the public procurement that must be carried out for the selection of the concessionary).

⇒ General regulations applicable to the activity in itself: this is the nucleus of the regulation and includes:

- Legal Declaration on the activity of urban passenger transport as apublic service, that is, with characteristics of continuity, regularity, obligatory nature, majority and uniformity.

- Limitations and prohibitions to observe in the exercise of the activity.

- Regulating norms of anti-trust competition and rules destined to prevent unfair practices in a regulatory atmosphere.

- Rights and obligations of the parts concerned.

- Procedures for implementation.
- Norms on the technical quality of the services (many appear in contract and others are delegated to the regulatory unit).
- Principles that govern the system of fares.
- Norms referred to the aims and powers of the regulatory unit.
- Norms that govern the procedures and the jurisdictional control (for example, public hearing), sanctions in case of breach of any contractual clauses or violation of the regulatory norms.

5.4 Costs and Financing

Latin American cities tend to be highly congested; they have little available public space, a lack of capital for investment in costly road works and often experience difficulty in managing expropriations.

The political authorities responsible for city transport have to weigh the advantages and disadvantages of choosing a certain transport system and the necessary complementary infrastructure, since the difficulties of making projects an attractive investment in the eyes of the private sector increase in proportion to their cost.

The question of the cost and the financing should thus occupy a central role in any analysis: should it be public, entirely private or public-private?

The fare levels that can reasonably be charged for public transport in developing countries are far too low to sustain high, short-term capital investment, specifically over the normal time period of a transport concession. Nowadays, it is very rarely questioned that the infrastructure costs of a major Mass Transport project should be thus met by the public sector. The private sector tends to play a role limited to an operating concession – hopefully covering operating costs.

Consequently, the investment of public resources in infrastructure of a modern bus system should be considered in the same fashion as rail based mass transport: the public counterpart costs of a major transport concession. This is a model that is being adopted in several cities with systems in operation, such as Curitiba, Bogotá, Quito, Joinville, Fortaleza and Guayaquil (see Volume 1, sections 3.2.6, 4.2.1, 6.5, 8.2.5, 9.2.1 and 10.1.3), where international agencies invest in infrastructure loans for busways,

integration terminals and feeder road paving; allowing the city to spread this financial cost over a longer timeframe. The private sector invests in the modern fleet and garages needed to operate the system under concession. The advantage of this model is that some agencies recognize the private investment in high-capacity, specially adapted vehicles as local counterpart funds, again minimizing the financial burden on cities. As these units can also be financed over several years, the initial local capital outlay for a modern bus system can be quite small when compared to the total cost.

Although the public sector can operate public transport, this often presents a series of problems: overstaffing, lack of investment, political pressure to keep fares below a sustainable level, cannibalisation of units, etc. Once the state is removed from the responsibility of day-to-day management, it can take on the inherent tasks of acting in the common good: choosing the most appropriate form of operation the services, and regulating and monitoring the development of the concessions.

Before any delegation to the private sector can take place, it is necessary that the public authorities involved – both elected officials from the city and eventual lending agencies - evaluate the accuracy and realism of the results of the economic-financial feasibility studies of the project. These studies should define at least:

- The amount of investment that would be left in private hands;
- How the public and private linkage would work;
- The individual characteristics of the project in terms of regulation and contractual rights and obligations.

5.5 The Distribution of Risk

The regulation that is adopted for a modern bus mass transport system should guarantee:

- The successful administration of the system;
- The appropriate inspection of the execution of contractual clauses;
- The full observance of the rules and conditions regarding safety/security imposed on the operator;

- The means of guaranteeing the quality of services to the passengers;
- The equal distribution of inherent risks as a condition for sustainability.

This last point involves outlining the risks involved and the scale of the costs, as well as any incentives or penalties that may be imposed. These factors are of such importance that any indefinition, or a wrong approach, can seriously damage the concession. A good example of an incentive is, for instance, the bonus given by Transmilenio to the operators that have the highest public acceptance scores; an example of a serious in definition is the current problem faced by the Curitiba system in relation to the control of inter-municipal services.

In this sense, a project cannot simply be considered sustainable when the projected cash flow reimburses invested capital and financial cost, there must also exist guarantees regarding technical quality and the legal standing.

The risks associated with the delegation of public transport to the private sector are multiple and varied in nature. Some are inherent to the operation of services, such as: a lack of revenue due to the fall in passenger demand; an over-projected future demand; a significant increase in operating costs, insurance costs or uninsured damages, etc.

However, some operational risks that are not normally identified can, in fact, become quite serious, such as; the inactivity of the state, allowing the growth of unfair competition (informal transport), un authorized vehicles using the busway with the complacency of the State, or the need for investment in new technologies that were not foreseen at the beginning of the concession.

Other risks are not necessarily operational, such as; the political risks due to a change in government or in their strategies, the risk of abrupt alterations to the exchange rate, rampaging inflation or a drastic change in the prevailing tax regime, the risk of new regulation or legal challenges to the activity, and the risks of acts of violence or force.

Risk – as an unknown quality – has an associated financial cost. Keeping risks low can be a policy to guarantee accessibility to low-income groups through low fares – in turn guaranteeing the maximum use of public investment in infrastructure.

Risks are sometimes partly undertaken by the state, including explicit contractual clauses on economic or political guarantees to the private operator, covering legislation, fiscal, or even the exchange rate. In Brazil, for example, the laws governing

concessions already offer a guarantee on financial and economic sustainability.

Another form of minimizing private sector risk is to offer public land or construction to the private concessionaire, such as office space, garage and maintenance areas, thus reducing their initial exposure. This is the case, for example, in Transmilenio (see Vol 1, section 4.2) .

5.6 The Inspection and Control of Services

Another essential element of regulation is the treatment given to the inspection and control of the concessionaires. It is fundamental that there be put in place bodies with technical staff, with a minimum of bureaucracy or political interference.

The application of correct inspection policies allows the state to:

- Assure the conditions of safety and quality of the services;
- Correct any distortions or undesirable behaviour of the operators in time, through the application of appropriate penalties; or, if necessary;
- Recuperate the concessions through contractual rescission, re-conferring to new operators, thus guaranteeing the continuity of the services.

It is also of supreme importance that the states licensors undertake to carry out all their obligations in relation to the concessionaires, either through the imposition of contractual clauses or under the applicable regulation. This avoids any future difficulty derived from the loss of authority.

5.7 The Institutional Question

Although many of the points raised refer to a “ general model of urban transport in Latin American”, in certain cities there are examples of exceptional experiences in the institutional handling of public transport. Among others: the Integrated System of Curitiba, the TransMilenio system of Bogotá and the “El Trole” and Northeastern Corridor “Ecovía” systems of Quito (see Volume 1, sections 3.2.2, 4.2.1 and 6.5).

In many other Latin American cities, there are projects for modern urban transport systems that will transform the regulatory framework and that are in different stages of development, such as the Metrobus system of San Salvador, El Salvador, the Integrated Transport System of Guayaquil, Ecuador or the LimaBus project of Lima, Peru (see Volume 1, Chapter 10, sections 10.4, 10.1 and 10.3). Although these experiences present technical

differences in relation to each other, they have all been inspired by the common denominator of giving priority to public transport, at the same time using transport as an agent for the planned urban development of the city.

There are many institutional alternatives for managing public transport. The adopted solution will depend, among other variables, on the constitutional and legal frameworks in each State, the mode of transport considered and the powers of each institution involved. Experience has demonstrated that the exploitation of services is best left to the private sector, as in nearly all cities in Latin America; although there are exceptions to the rule, such as El Trole of Quito, run by a municipal company. However, feasibility plans have been made for the privatisation of this system.

a) The Integrated System of Curitiba

The experience of Curitiba (see Vol 1, section 3.2.2) is frequently used as an example of management technology in the administration of urban public transport and is the result of decades of uninterrupted and coordinated effort between urban planning and transport policy: not a very frequent circumstance in other cities of Latin America.

Unlike the traditional outline of public companies, the case of Curitiba constitutes an example of a successful association between the private sector and the municipal government. Local government manages and plans the system through the municipal company URBS - Urbanization of Curitiba S.A. Also it calculates and sets fares, monitors operations, checks on passenger complaints and is responsible for the quality of the services.

The URBS maintains that it is the concession holder, and as such, can delegate to private companies the operation of services under the regime of granted permits.

The traditional operators were organized, by the request of the Municipality, into selective and exclusive operating areas, being endowed with due security in order to make the necessary investments of private capital. The companies assume full operational responsibility of the system, invest in the purchase of the units and hire the operative personnel.

b) TransMilenio

The TransMilenio (see Vol 1. section 4.2.1) system began operating in 2000, and although different to Curitiba, it also represents a successful institutional experience of a public-private association in the administration and operation of urban transport.

The public Company of Transport of the Third Millennium-TRANSMILENIO CORP. is commercial shareholding with public funds, constituted in the sphere of the Municipal Government of Bogotá by other public entities of the District Capital. The company is endowed with a legal entity, administrative autonomy and independent capital, and it acts as the regulator of the TransMilenio system. Its managerial structure allows it to carry out the tasks of operative planning, administration and control of services, also using a fiduciary administration of resources.

TRANSMILENIO S.A. sets the guidelines required for operations by the private concessionaires. In this, the legal framework is unusual as in many Latin American countries a state-company would be the concessionaire and not capable of offering legal concessions itself.

The following table gives an outline of the main features of each public-private association:

Feature	**Curitiba**	**Bogotá**
1. Controlling Agency	URBS	TRANSMILENIO S.A.
2. Type of Institution	Public Municipal Company	Public Municipal Company
3. Company Type	Commercial shareholding	Commercial shareholding
4. Functions	Operational Planning, Management and Control	Operational Planning, Management and Control
5. Strategic Planning	Municipal Government (IPUCC)	Municipal Government
6. Operators	Private Companies	Private Companies
7. Legal basis	Permits	Concessions
8. Fare Calculations	Cost variation according to contract	Cost variation according to contract
9. Financial Administration	URBS	Fiduciary contract
10. Fare collection	URBS	Prívate conrtact
11. Payment to	By km and bus	By km and bus type

Operator	type	
12. Penalties	Contract	Contract
13. Control	URBS	TRANSMILENIO S.A.
14. Enforcement of Penalties	URBS	TRANSMILENIO S.A.
15. Breach of Contract Control	Municipality	TRANSMILENIO S.A.
16. Infrastructure	Public funds	Public funds
17. Unit ownership	Private operators	Private operators

Table 5.1 Comparison between Urban Transport Operation in Curitiba and Bogotá

These observations show that it can be affirmed that the systems have few substantial differences. Both examples of public-private administration show:

i. The functions of regulation and strategic planning are handled directly by Local Government;

ii. The management, control of services and day-to-day planning are the responsibility of the public management companies (URBS and TRANSMILENIO S.A.);

iii. The operation of the services is handled by private companies.

Nevertheless, there are differences, as in items 7, 9, 10 and 15. The different solutions adopted do not represent fundamental changes, however, they tend to give the TransMilenio a more advanced operational model, as this has:

- The more solid legal format of concessions rather than the simple emission of operation permits; and,
- The fiduciary constitution, which allows fare collection to be handled by the private sector, facilitating the financing and minimizing bureaucracy.

c) The Proposed Model for Guayaquil

Within the framework of public-private organization of urban transport, the proposals for Guayaquil go even further in stressing the private nature of the overall management. The city has opted to build a Modern, Integrated Bus System along with the streamlining of the legal and institutional system – a necessary

aspect of the project given the current complex structure involving various agencies.

The proposal is to create a Regulating Agency for the management of the transport system, considered as a "foundation"; a civil corporation under Ecuadorian law. This is similar to the administration of other infrastructure projects in the country, such as airports or housing, and represents a feasible, local solution for developing the city and promoting the interests of both the passengers and operators.

Thus the functions of administering the system and its incomes will be undertaken by a private, autonomous, non-profit entity, with a social and civic "raison d´être". The objective is to keep this body free from political pressures associated with public bodies: overstaffing and political appointments.

The founding members will be: the Traffic Commission for the Province of Guayas; the municipality of Guayaquil, Ecuador; the Chamber of Commerce; local Universities; The Chambers of Tourism, Industry, Construction, Banks; etc. Most of the services will be contracted – the "board" of the foundation being charged with guaranteeing the transparency and efficiency of the tasks. This is fundamental, as the revenue of the system will be managed by the foundation: the sale of all smart cards and the payment of the operators.

5.7.1 Institutional Aspects

Institutional questions have an enormous impact on the transformation, modernization and rationalization of urban transport systems and can be seen as a driving force, along with the elements of design and technology. Regulation, investment and financing have to be dealt with, however, governments must also possess an exact understanding of the implications of the institutional question, which will have an vital role in the success of the project.

From the **operational** point of view, the most common problems are:

- Excessive offer of services (capacity) in an open competition environment (competition **on** the road and not **for** the road), with an excessive number of operators..

- Increasing tendency towards the miniaturization of the fleet

- Excessive number of routes without any articulation

- Routes mainly converging onto the downtown region, leaving out other areas with little or no coverage at all

- Buses are trapped in traffic congestion without any specific infrastructure that allows the services to run smoothly.

From the **organizational** point of view, the main common problems are:

- Little or no control of the services

- No articulation between the services.

- The awarding of routes does not respond to a structured process or technical planning.

- The different modes (buses, trains, vans, etc.) respond to separated or nonexistent administrative institutions , creating a fractious form of organization.

- It is common to see in a number of cities where the development or transformation of the transport system is being undertaken, a very strong emphasis being placed the albeit important questions, such as: planning and design of the new network; which modes of transport will be used; what large-scale infrastructure work will be needed; the financial model; and even the formulation of new regulation for the sector – even including the sort of operating company desired. Nonetheless it is of great importance to design and envision a transition process that allows the gradual elimination of the distortions that characterize the existing systems. This transition process should try to diminish the social, urban and political impacts.

It would be rash for a government to build a segregated busway without having first resolved which traditional operators could be involved and how they could be able to operate this corridor. Nor would it be prudent to ignore the social impact of replacing the owner-drivers if new operators are invited to participate. And with on which human and material resources will the operators be able to count on?

5.7.2 Continuity of the Existing Operators

In many cases it may be convenient to offer some form of priority to current operators of the restructured services, in order to minimize the resistances of these groups to the proposed changes - as well as of diminishing the social and labour impacts of a massive withdrawal.

Evidently, this historical interest has its limits in the collective wellbeing of the community, and in which the city intends to invest considerable resources: the city cannot be held hostage by the interests of a single group.

As such, it is important that the traditional operators demonstrate an economic and organizational capacity compatible with the scale of the projects under consideration. As part of this process, it may be necessary to introduce a temporary or "bridging" form of regulation that maintains their route permits while establishing a new relationship between the sector and the state. Given the extreme atomization of much of the transport industry, this temporary regime should establish the consolidation of companies in order that the desirable economies of scale may be achieved and basic private infrastructure acquired – garages, workshops, etc.

This may not be possible in some countries, such as Brazil, as the laws governing concessions do not allow local businesses to be favoured. This is, however, less of an issue in Brazil as the consolidation of the transport industry was largely achieved in the 60´s. But for new corridors in other countries, this incentive to the local transport industry may not only be possible but also desirable.

Certain minimum conditions should, though be met:

i. The constitution of the operator as a capitalized company, registering the units in the name of the company and as company patrimony;

ii. The demonstration of basic centralized management skills;

iii. The provision of expertise, by means of the transfer of technical experience as regards the operation and administration of urban mass transport systems, from a local or foreign operator, to a level that satisfies the Municipality;

iv. Guarantees of Execution of the Contract.

5.7.3 Strategies for the Insertion of the Local Operators

The transport sector tends to be highly conservative worldwide. Many traditional operators in Latin America perceive any change as a threat that should be stopped. The example of Quito is common: the authors have all had experiences of patiently explaining the benefits of new proposals only to see the whole city brought to a standstill a few hours later by a transport strike.

Many of the problems, defects and negative aspects surrounding the sector and local operators have to do with the insecurity, lack of minimum care for the passengers and the nature of its predatory behaviour; that is to make a living in a context of very little opportunity cost. However, the present limitations of traditional operators does not necessarily mean that they be exclude from the process of change – even though this be very tempting for both the city administrators and the consulting team. It is indispensable that the development of new strategies contemplates the advantages that can be gained by both the operators and the community.

Other chapters in this book give examples of how this insertion can be made, such as in Guayaquil and Bogotá (see Vol. 1, sections 10.1.3 and 4.2.1). Other examples, such as San Salvador, have shown how an existing system can be rapidly transformed from an almost informal state to a regulated environment: the first step towards a modern bus system.

Just as the concept of Integrated Systems rapidly spread to Brazilian towns during the 90´s, as the bus industry learned more about the associated benefits of rationalization and the potential capitalization of their companies through BNDES (National Bank of Economic and Social Development) financing, so the transport sector in Latin America has had its eyes opened during the current millennium by the experiences of Bogotá and Quito. The authors can safely state that, given the right approach, a modern bus system is now seen by some traditional operators as more of an opportunity than a threat.

In this sense, a possible Plan of Action could include the following:

a) Creation of an Advisory Group.

This group would offer permanent advice on matters linked with organization, accounts, legal and technical questions related to the demands of the tender process.

b) Clear Presentation of the Project to the Transport Sector as well as the Press and the Public. These would normally involve:

The benefits for the passengers:

- Improvements in the quality of travel; timesaving, comfort, modern units, better and safer waiting areas, etc.;
- Improved safety as "on-route" competition is eliminated (the one-cent war);
- Rationalization of frequencies, better regularity of services and better spatial distribution.

The benefits for the operators:

- Reduction in the global costs due to economies of scale;
- Rationalization of routes and resources;
- Reduction of operational costs due to less accidents;
- Control over the fare-box, improved revenue flows;
- Capitalization of the company; a real increase in value;
- Access to new and more efficient forms of financing.

c) Programmed Meetings.

The meetings would be carried out with the credited representatives of the transport operators, along with their designated professional aides in the technical, legal and accountancy fields. These meetings would pursue the following objectives:

i. Technical debates about the characteristics of the project;

ii. Exchange of ideas about the adaptations managers would have to make in order to guarantee the participation of local companies in the restructuring of the system of transport;

iii. Debates about the timescales involved to carry out the necessary changes in the legal and financial nature of the companies;

iv. Orientation regarding the mechanisms for forming Consortia or Transitory Unions of Companies that can be adapted to the requirements of the tender process.

d) Seminars

This step consists of the organization of Seminars for exhibition and debate of the project, reaching a wider audience than just the selected representatives, although the representatives would have to be at a stage where they were fully aware of the advantages and costs of the project. These seminars would also include groups such as professional bodies, etc.

E) Visits to Other Systems

This step is always important and allows the transport industry to have direct contact with the operators of modern systems. During the early 90´s in Brazil, it was common to hear operators from the other, lower-income, regions claiming that: “this sort of system

works well in Curitiba, but not in the culture of the Brazilian North-East”. After the success of the systems of Aracajú and Fortaleza this comment was dropped.

In the late 90´s, operators from other countries would say that this integrated system technology was: “very good for Brazil, but will not work in the Andean region”. Now, thanks to the experiences of Bogotá and Quito, all Latin America is well aware that this technology can be applied to big cities, once the political decisions have been taken.

Briefly describe the difficulties, fault and errors encounter on the different experiences. Miscalculations, over budget and pricing, planning and implementation deficiencies.

Chapter VI: Modern Bus System Planning and Design

6.1 Pre-Feasibility Study

In order for a city to seek international financing of a Modern Bus System, there are several stages of development. A crucial stage is that of project conception, or pre-feasibility, when city authorities consider building a system as part of the city strategic plan. At this stage the information available on bus systems tends to be restricted to material supplied by the industry and specialized web sites.

A pre-feasibility study, carried out by experienced professionals, can quickly identify and quantify principal travel demands and determine if a Modern Bus System can be adapted to this demand and the city's structure and land-use plan. This stage will in average last about 2 to 3 months. Experience and vision are, however, essential: if the initial conception is a mistake, then subsequent work and even the final project can be irrevocably impaired.

This pre-feasibility study will give a much clearer idea of how a Modern Bus System could work, where it would run, who would benefit, how it could be operated and what other road works or urban design improvements should be incorporated into the project.

Ideally, this work should also be part of a wider urban plan, the mass transit system being an essential mechanism for directing city growth and structure, along with the road network, the zoning plan, the preservation of green areas and the recuperation or recycling of degraded areas. The chapters on Curitiba and Joinville in Volume 1 are good examples of how city growth and the transport system have been planned over the past decades. Brazilian law now requires that all cities with a population of more than 500,000 have both an approved Master Development Plan and a Transport Plan (Statue of the Cities), hence the relationship between any transport system and city planning will become clear and transparent. In other parts of the world this relationship is not so clear or formalized. The terms of reference for a pre-feasibility study should therefore make it clear that the city development plans should provide the basis for any operational evaluation of a corridor or city. And the consultants should use their experience and judgement in bringing to the attention of the city any complementary measures required to enhance a proposed system.

Based on the basic elements involved, estimates can also be made on how much the infrastructure will cost, how many bus units will be needed and what would be the operating cost. From this data,

an estimate can also be made on the level of fares needed to cover operating costs or the level of subsidy required to reach the intended demand.

In Latin America most systems are operated by the private sector without a direct subsidy. In other regions, a public policy goal may require a substantial modal shift from the private car (or motorbike) in order to reduce pollution and congestion. This may require passenger fares to be kept at a level that is competitive with, say, the user cost of a motorbike and involve a direct subsidy (to a public company) or an indirect subsidy to a private company (in terms of garage areas, refunded diesel cost, etc.). The pre-feasibility study will determine what the public cost would be in obtaining such goals.

The city authorities can then decide if this project can be incorporated as a policy goal and contract a definite feasibility study. In the following section, nine recommended steps for further planning is presented.

6.2 Step by Step Planning

There are no hard and fast rules - or "tool box" - for designing a Modern Bus System of the Latin American type. Each city is always a separate case study with its own characteristics and needs.

Experience has shown, however, that there are certain basic steps that have to be carried out in any pre-feasibility study.

Step 1: City Structure

The first step is common to all projects: A close examination of the city's structure. This involves an on-site investigation of: the street layout, the location of residential, commercial and industrial areas; the general behavior of the traffic; the scope of the current public transport network, the quality of road paving, sidewalks, urban design and the scale of the city in terms of density, buildings. This information is normally noted on maps and in digital photographs. At this stage the professional team should be keeping an open-mind and simply form a mental picture of the urban area and the immediate surroundings.

Step 2: Base Data

The second step is again common to all projects and involves the collection of data on: the current public transport system and its recent history (fares, new routes, etc.); population/census figures and income levels; development (Master) plans and proposed short-term highway/road projects; existing studies on similar systems (light rail, guided bus, etc.), as well as obtaining good maps of the urban area – preferably updated and in digital format

– and aerial photographs – preferably at the 1:8000 scale.If recent O/D data available, this can assist in determining the basic city trip matrix, preferably by mode, in order to confirm that the main transport corridors conform to the main desire lines.

A general rule for busway planning in Latin America is to “design short-term, think long term”, i.e., use the existing demand data (all modes, but preferentially from the public transport system) as a basis for design, but check that these designs are compatible with the longer term planning strategy.

Step 3: Identify Existing Demand Constraints

The third step is to check on the existing demand constraints for any modern busway-type system. These can expressed in terms of a viable passenger demand envelope, which for a 7 metre, 2-way busway, with stops every 400-500m, is about 30,000 (minimum) and 200,000 (maximum) pax/day (both direction) on the most loaded stretch. This corresponds to minimum peak headway for articulated units of about 5 minutes (greater headways are difficult to justify and to enforce the dedicated road space); and a maximum headway of about 60 seconds (below which the operation of the station platforms becomes complicated).

The corridors should also, ideally, have linear commercial development, so that there is a high “turn-over” of passengers along the route, leading to a high Passenger/km Index and better commercial return. This can best be achieved through integrated urban and transport planning, such as in Curitiba (Volume 1, Chapter III, Section 3.2)

Step 4: Examine Physical Constraints

The fourth step is to examine the physical constraints of the city road system in terms of width; continuity; turning movements; accessibility; available land; interchanges; parking; lateral access; pedestrian access; etc. Conventional bus priority tends to be restricted to the existing road network or even the existing one-way systems. Planning a modern busway, on the other hand, requires more “lateral thinking” in terms of the use of city space and other options, such as railway right of way, river valleys, private land, street markets etc. A short stretch of a bus-only street in Joinville, for example, was built through a market – which was transferred to a side street (Vol. 1 section 8.2.1). The system proposed for San Salvador would simply replace the wooden shacks of the street market by an iron “Victorian” overhead market – a solution that would be a lot cheaper than putting a mass transit system underground (Vol.1 section 10.4.2). The figure below shows a stretch of the downtown busway in Curitiba built in the mid 90´s on private land. Planning permission was granted for a commercial building, including compensation for allowing the 7

m busway to go through both the land and the building block (Vol.1 section 3.2.4).

Source: Instituto de Pesquisa e Planejamento Urbano de Curitiba
Fig. 6.1 Busway and Private Development–Downtown Curitiba

Step 5: Examine Existing Public Transport Network

The fifth step is the examination of existing public transport (bus) routes to see if these can be “rationalized” into a common trunk route section and additional feeder routes. Depending on the scope of the assignment and/or the size of the city, this step would be for any corridor and catchment area under study or for the entire city or conurbation. An interchange at a convenient location near this point would allow passengers from the feeder routes to change to the trunk route, as well as to other options of travel. The areas chosen for interchanges should thus create trunk route corridors with high passenger loadings (within the demand envelope) as well as good access for other route options, specifically interdistrict routes that link several corridors and important destination zones, without going through the city centre.

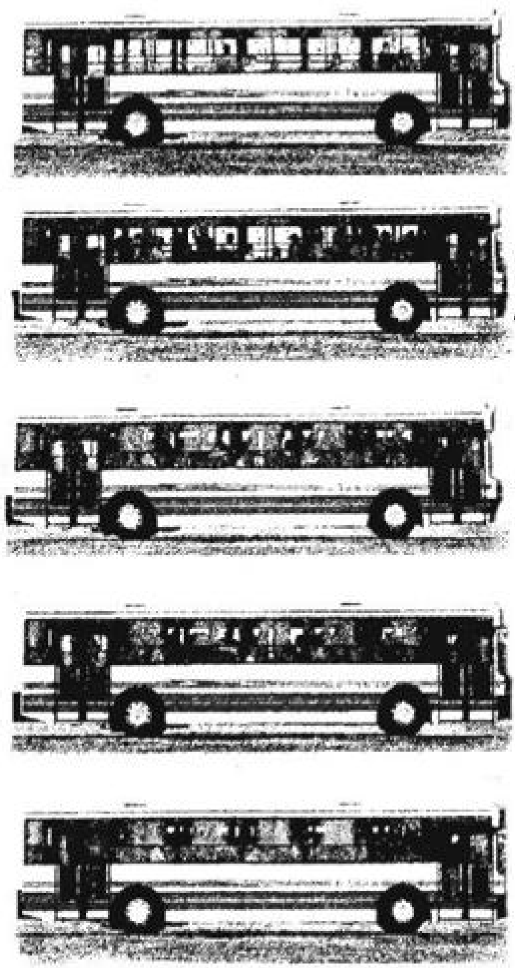
This process is shown in Vol. 1, figures 2.1, 2.2 and 2.3. Simulation studies can also help to predict the overall corridor demands. However, this design step requires experience and a level of insight on how the city will develop and the impact of the proposed interchange on land-use. A small interchange, for example, such as those used in Curitiba or Quito (Vol. 1 Chapters 3 and 6) will not only attract large numbers of passengers, but also commercial development around the interchange. A large interchange with garage facilities attached, such as in Transmilenio, may have a lesser impact. The use of Terminals for bus parking, as in Fortaleza for example (Vol. 1, section 9.1), has had a clearly negative effect on the surrounding land use.

It is common to hear that these Interdistrict Routes – because they do not already exist – will have “no demand”. In practice, such new circular routes have proved to be highly popular in cities of Brazil such as Curitiba, Fortaleza, Campo Grande , etc.

Step 6: Compare Physical Constraints with Corridor Demand

The sixth step is to compare the physical constraints with existing high corridor demands. Where the two coincide, a modern busway system may be feasible in terms of space and demand. If the existing “captive” demand element is of major importance, as is the case in bus systems in Latin America, the basic corridor demand can be obtained through a survey of passenger loadings at intervals along the corridor. A survey can be made of boarding and alighting inside the bus, taking a representative sample of units during peak and off-peak hours. When overcrowding and/or irregular bus stops makes these surveys impossible (such as in Andean, African and some Asian countries), then the survey can be of the “visual loading” type, counting the units by type and allocating an indication of their load at each counting station. These counts would typically be carried out on the most loaded stretch of the corridor (close to the centre) and slightly downstream from the point designated for the Interchange.

An example of a visual survey sheet for a 12m unit is shown in Fig. 6.1.



Source: Transcraft
Fig 6.2 A Visual Demand Sample

At each survey point an outside observer notes the number or code of passing routes, the time the units passed and the load level. Each type of unit has its own load chart according to local characteristics, such as Van, 10m, 12m, 18m; or Mini, Midi Conventional, etc.

Step 7: Examine Other Constraints on Corridor Development

The seventh step involves an examination of other constraints such as green areas, historical (listed) buildings and other environmental factors. Part of this process should also consider problems related to urban blight, abandoned or wasteland sites, and redevelopment policy. Modern BRT planning should take a broad view of the city and consider the possibilities of: using new infrastructure, opening up new corridors, using bus-only streets or including busway infrastructure in new city redevelopment. The

Curitiba School of Urban Planning calls this approach having a "global or holistic vision" of the city, and more creative options for a mass transit busway can usually be found. The incorporation of green areas, parks and cyclepaths into busway projects has been a major feature in the success of both the Curitiba and TransMilenio systems.

Step 8: Identify Planning Considerations for Bus Interchanges

The eighth step is a check on how the interchange facilities will interact with the city land use plan and its desired future growth. New housing areas can be serviced from the interchanges by extending a new feeder route - without adding a new route for this development (thus overcrowding the city centre and other major destinations, nor extending an existing route and thus creating a huge oversupply of capacity on the last few kilometres).

The question of waiting times and waiting areas, specifically in the evening peak, is often worth examining in detail. If the city policy is to increase public transport use and an "open" bus priority system is also being considered, an estimate of the number of passengers entering the system, by link, can be obtained from a transport model (Vol. 2, section bus boarding and waiting).

When some of these passengers reach the interchange terminal, they will have to wait for their respective feeder units, but in these facilities space and comfort are available. In the digital video annexed to this report, the morning peak loading at the Southern Terminal of Pinheirinho can be seen. This shows the 2 platforms, one for alighting and the other for boarding. According to the operating company, URBS, these handle a peak load of about 9.000 pax/h/d.

Step 9: Define the Busway System

The ninth step is to determine the integrated busway system. Conventional transport planning often considers several simplified options, evaluated by means of modeling techniques.

The designs made by the Curitiba School normally present a "best case" option, which for a busway, implies the routes, the public works, the fleet and the institutional arrangements. This concept can be, and often is, modified during the final design. This approach has been used in all successful Latin American busways.

6.2.1 From Feasibility Study to project proposal

Appendix A covers the description of the various phases of modern bus system projects. The appendix aims at establishing an overview of the information required and theproject phases are:

- Feasibility Study;
- Functional Design;
- Development of Executive Project;
- Budgeting;
- Economic Evaluation;
- Financial Evaluation;
- Environmental Impact Analysis;
- Social Impact Analysis and;
- Safety Audit.

6.2.2 Typical Objections to Bus Systems

Once a functional/operational design has been agreed upon, this concept has to be presented to the actors involved - and also to the public. At this stage a series of objections is often made, and these have to be addressed as part of the planning process.

Some “classic” objections to a central lane, left-hand access systems, together with respective answers are:

a) ***The traffic will get worse.*** In some cases the traffic flow will actually improve, as bus units will no longer be stopping in the street, sometimes several metres from the curb. This was documented in Quito (See Volume 1, Chapter VI, Section 6.4). Conflicts are eliminated and pedestrians will be able to cross the road more easily.

b) ***Passengers using central busways have to cross to the middle of the road.*** All passengers on conventional buses already have to cross the road, either on the way in or coming back. At the stations, passengers will have better protection. Adequate pedestrian protection is always required, either by signals, islands or overpasses, as in Curitiba, Bogotá and Quito (see Vol. 1, sections 3.21 and 3.2.5, 4.2.2 and 6.3).

c) ***The busway will present an ugly “wall-of-buses”.*** Maximum headways are about 1 minute per direction. Modern busways in fact not only reduce bus flows and emissions, they can even present a

much calmer and more attractive environment. This is achieved by the use of the higher standard engines used by high-capacity units, running at optimum speeds and the removal of an excess supply of old buses stuck in traffic jams (see Vol. 1, sections 4.2.6 and 6.4).

d) ***The commerce along the busway will be affected.*** Commercial value and rents have actually improved on the corridors in Curitiba and Bogotá. This is not the case when large numbers of units are operating as an "open" system, as noted in São Paulo (See Volume 1, Chapter III, Section 3.2.4).

e) ***The system forces passengers to walk too far.*** Most subway systems accept that passengers will walk 500m to the station and 800m in the city centre. A map showing the proposed coverage and the population benefited (from census or O/D data) is a useful tool. It is important to stress that there are no bus stops on the trunk system, only Mass Transit stations.

f) ***The system excludes passengers from certain areas.*** All systems expand over time as the city expands. Major demands can be met in up-coming phases by adding new feeder routes or even new corridors. Building a High-Capacity BRT Mass Transport system is an on-going process as is shown in Volume 1 by the examples of Curitiba, Bogotá, Quito, Joinville, Fortaleza and many other cities.

Chapter VII: Best Practice Design Recommendations

Experience in the design of Modern Bus Technology, as developed in Latin America over the past three decades, has shown that there are many "best-practice" options that can be adopted, which will simplify the design process and avoid the more common pitfalls. The key words are in italics and underlined so the reader can check the references in the context of the case studies presented in Volume I.

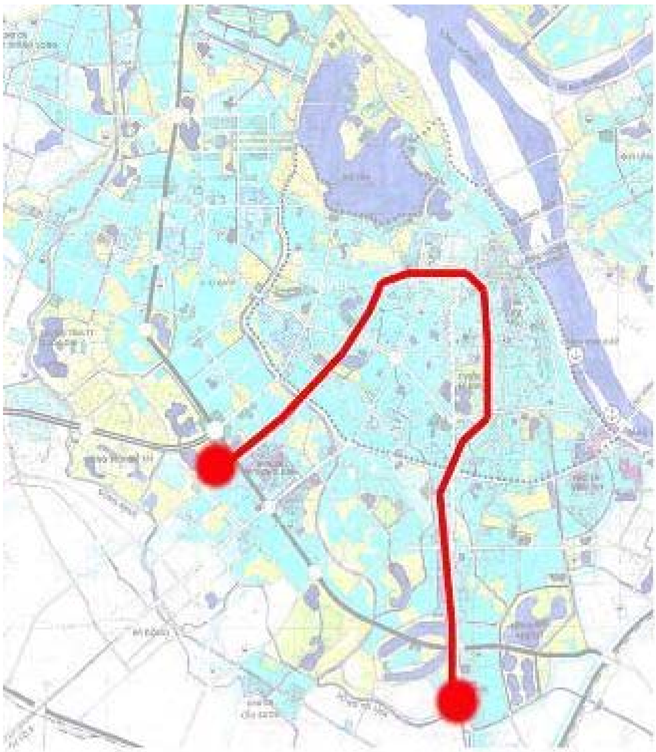
1. ***Type of Bus Unit:*** On exclusive busways, only adapted, high-capacity units should be permitted (such as 18m *articulated buses*). The use of existing units is a mistake and damages the mass transit image of modern bus systems. The existing fleet, which complies with minimum standards, however, can be used on feeder routes, where there is no specific busway infrastructure;
2. ***System Rationalization:*** If an exclusive busway is not feasible, then the option of *rationalizing demand (see Volume 1, Chapter 2)*, fleet and city centre platform space with ordinary high capacity units, using bus lanes and mixed flows can be considered;
3. ***Flat-fare System:*** The entire system should operate on a basic flat-fare, preferably using *contact-less, smart card technology*; Imbalances can be corrected through zonal fares that charge slightly more on in-bound trips smart-cards also allow for temporal integration during a given time period and the possibility of charging off-peak lower fares.
4. ***Passenger Access***: Passenger access to buses should be *pre-paid* and preferably *at-floor* level;
5. ***Distance between Stations***: The *stations* should be set about 400 - 500 m apart on corridors with mixed residential/commercial use. In lower density sections, or where the corridor is being used to induce growth, this distance can be increased. Multiples of 400-500m can thus be subdivided when necessary (such as on the Metropolitan Corridor in Curitiba).
6. ***Direct Services***: If the busway corridor has a high proportion of long trips (typically from the outer interchange terminals to the city centre) then *direct routes*, with very few stops can greatly increase overall system efficiency and reduce travel times and costs – specifically during peak hours. *Overtaking lanes* require additional width – either 2 bus lanes per direction as in Av. Caracas, Bogotá, or having stations set back as on the Autopista Norte, Bogotá. Pedestrian access has to be strictly controlled to avoid the risk of accidents. An option in

less congested cities is for Direct Services to use the existing streets for most of the trip.

7. ***Balancing Routes***: Trunk routes should be preferably diametrically arranged, going from one interchange on the outskirts to another. In order to have "balanced" fleet sizes on each "arm" of the corridor, the demands on the critical stretches of these trunk routes should be similar. If this is not the case, other travel options can be offered, using a central area turn-round as a last resort. This measure:

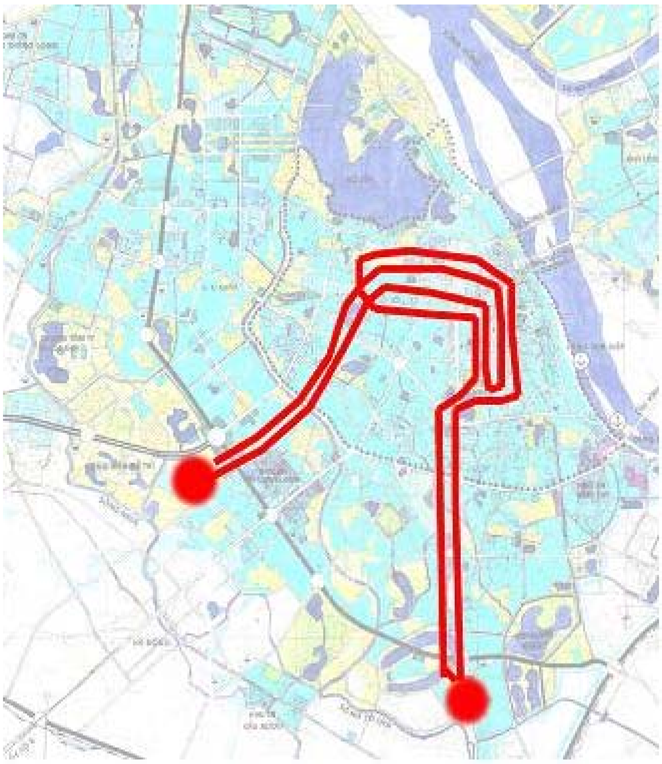
    - Allows greater accessibility to the city to passengers without the need for a transfer; and,
    - Reduces overall operating costs (mileage), as the units do not have to make long, slow "loops" in the downtown area in order to cover the main destination zones before returning.

As is shown in Fig. 8.1 a single trunk route operating on 2 radial corridors offers better coverage for a much lower cost than a solution with 2 separate radial routes. The number of feeder routes at each main interchange can also be managed to maintain the correct "balance" on the individual trunk sections.



Source: Transcraft

Fig. 7.1 Single Balanced Trunk Route



Source: Transcraft
Fig. 7.2 Option with Two Radial Trunk Routes

8. ***Implementation Risk Management***: To keep the element of risk to a minimum, the first phases of the system should have a low initial infrastructure cost, with minimum *relocation/resettlement;*

9. ***Operation Risk Management***: Again, to minimize public sector *risk*, the fleet should be operated and owned, at least in part, by the private sector, under a *concession* compatible with the working life of the units. This is normally around 10 years;

10. ***High Quality System Design***: All *design* should be of high quality. Modern busways should operate and look like subways: normally the world reference for high-quality mass transit. Interchanges, the livery of the units, and the designation of a system logo are all important factors. The first contact the passenger has with the system is at the stations, which have to be comfortable and safe. All designs should be tested to check that they have adequate capacity for the predicted demand (at a maximum of 6 passengers/sq.m.) and that internal temperatures do not become uncomfortable;

11. ***High Quality Urban Design***: All physical interventions should be accompanied by high-quality *urban design*, not simply concrete "New Jersey" blocks. This reinforces a positive image to the new system. Other elements of good urban design

should also be part of the system, specifically, better sidewalks, the restoration of green areas and parks, lighting and street furniture, etc.

12. ***Busway Construction.*** Construction costs can be kept to reasonable levels as articulated buses can handle ramps of up to 10% and turn on a minimum internal radius of 12 metres. (There still exists the myth that articulated units cannot go round corners, although, with a shorter wheel base than 12 metre units, their turning radius is actually less.) Station design for pre-paid, at-floor boarding requires that the platforms be set about 80 cm above the pavement level. At junctions and stations the pavement should be in reinforced concrete (40cm, including a base of crushed stone) in order to support the repeated loads of braking and accelerating. If the busway is a completely new pavement, then a rigid concrete option is recommended.

13. ***Position of Bus Doors***: The bus units can have *doors* on the left or right. In Latin America, traffic drives on the right, hence all the following observations are only valid for cities that have traffic on the right. Normally the best option for an articulated unit is 4 doors, 110 cm wide, on the left, for the following reasons:

    - The road median can be used as part of the station area with a minimum of road works

Source : Transcraft

Fig. 7.3 Contra Flow Buslane in London with pedestrian barriers

- One station can serve both busway lanes, hence the overall road width needed for the busway is less;
- Station infrastructure and maintenance costs are thus less, as are staffing and security costs;
- There is no conflict with parked cars or loading/unloading vehicles;
- There is no conflict with vehicle access/garage curbs;
- Potential conflicts at openings of the median can be eliminated by closing these gaps or banning left turns;
- Pedestrian and 2-wheeled conflicts can be minimized by using either a high curb on the median or by a fence.

14. ***Traffic Management***: All traffic management measures can be considered to be secondary to the public transport network. In other words, the network and its operational needs are established and the necessary traffic management is then arranged to fit the network. This policy has to be established openly to avoid local political pressures, such as requests to change street direction or keep a conflicting median gap open for a local "authority"; Conflicting left-hand turns should be eliminated where possible, using "P" type traffic management to handle these movements;

15. ***Traffic Control at Intersections:*** All intersections should be controlled by *traffic signals*, preferably with *priority* for units using the busway. At highly conflicting sites, these controls should be enforced by traffic police in order to minimize the risk of units being involved in accidents. This does not imply that traffic police can override the signals. These signals should be programmed for minimum passenger and pedestrians delay as well as vehicle delay and, if spaced less than 300-400m, should offer synchronization for the trunk routes;

16. ***Segregation of Bus Lanes***: To keep the public transport lanes free from private cars and motorbikes, the lanes should be physically *segregated /separated*, with adequate drainage, such as in the use of road studs and concrete barrier in Bogotá as presented in Fig. 7.3 (See also Volume 1, Chapter IV, Fig. 4.5).

17. Penalties for using this reserved space should be high, as this will minimize invasion by other users. Good design, such as in Bogotá (see Vol. 1 Chapter IV) can reduce invasion and simplify police enforcement. When using a binary corridor approach (2 one-way streets), with the busway/lane on the left, pedestrian and 2-wheel access (and hence risk) should be kept minimum

by using a low fence, preferably with a "green zone"- a strip of grass/bushes. A simple form of separation used in Curitiba is a double yellow 20cm line, spaced 40cm apart, with "tachões" or studs at 2m intervals. This not only separates the flows but also provides a "refuge" for pedestrians, while allowing limited vehicle access. Note that the busway is entirely paved in concrete.

Source : Transcraft

Fig. 7.4 Road Studs used to Separate the Busway in Curitiba

18. ***Interchange Design***: *Terminal Interchange design* also has to be of a high standard, with good pedestrian access, using covered platforms of at least 6m in width, preferably with the most used routes operating on both sides of the platform to minimize walking distances. When moving from one platform to another, passengers should either use a subway (for large volumes) or a 4m wide pedestrian crossing (normally raised to almost the height of the platform as a traffic calming device).

    The system should offer new travel options at interchanges. In all the Latin American systems examined, passengers thus see the interchange as a benefit (greater accessibility) rather than a transfer penalty. This is valid even if different modes are used on the corridors. In Quito, for example, both articulated buses and *trolleybuses* use the same trunk route interchange facilities.

    A useful rule-of-thumb based on the dimensions of the Interchanges operating in Curitiba is to estimate a total interchange area of 360 sq m for each route using 12m units,

500 sq m for routes using 18m articulated units and 600 sq m for 25m biarticulated trunk routes.

Some examples of terminal interchange design are given in the case studies on Bogota, Goiania and Joinville in Volume I (See Volume 1, Chapter IV, V and VIII). For more detailed information on modern bus interchanges, the reader is invited to examine the AutoCAD digital files annexed, which give the working dimensions of several examples from Curitiba, Fortaleza, Quito and Bogotá.

19. ***Platform Dimensioning*** The operational aspects of Integration Terminals consist in determining the access and circulation of vehicles and passengers, areas of passenger accumulation, layout of *platforms* and mechanisms of operational control. Normally platforms are dimensioned taking into account the intervals and the layover time of each route. Bearing in mind the need for future expansion, reserve platform areas should also be provided.

To obtain of the number of platforms, the average arrival interval is considered for all routes. Normally 5 minutes is sufficient for the off loading and embarking of passengers. To provide a better distribution of routes for available platforms in the terminals in this stage, a minimum of one platform for each feeder route should be adopted, thus allowing a greater level of comfort inside the terminal, facilitating the identification of the routes and allowing the formation of orderly passenger queues.

Chapter VIII: Concluding remarks

Based on the experiences drawn from the case studies, and the recommendations from best practices, it is clear that an comprehensive planning process and the gathering of adequate information is crucial to ensure successful implementation of modern urban bus systems. This does not only consist of a support in the design process but it is also expected to help policymakers to formulate specific projects and to seek financial support for the project in international donor and lending agencies.

This design process is also necessary for an adequate formulation of transport planning policy and the initial support of international lending agencies. When a more detailed examination of a bus transit system is needed, the planning process will normally require a pre-feasibility study that covers the steps indicated in Chapters 6 and 7. Once a system has undergone public consultation and become part of government policy, the next requirements often involve a feasibility study, including a certain level of full executive projects. As there may be differences in the interpretation of what these tasks involve, the following appendix covers the main points in relation to the development of modern integrated bus transit system.

Appendix A – Project Phases

Feasibility Study

A feasibility study can be considered an extension and detailing of the previous work, including further travel demand studies, pre-design of the corridors, terminals and other infrastructure, addressing the administrative and legal issues, preparing cost estimates, environmental and cost-benefit analyses.

If O/D data is available, this will become essentially the main input needed to help in the estimation and forecasting of the travel, demand, if not, the corridor demand could be estimated roughly from available traffic counts. It was mentioned previously that the inherent flexibility of bus transit systems, and the direct link between travel demand and costs, permits a wide margin of correction, as infrastructure is tends to be a fixed public investment and operating costs are closely linked to the fleet size. Hence, if no O/D data is available, a modern integrated bus transit system could be designed at this feasibility stage for cities with a population of 2-3 million, with no need for an expensive, time-consuming O/D survey. The feasibility study should then take about 6 additional months to prepare.

During this stage, the city – or the state– may wish to procure financial support from international agencies. Negotiating a loan contract is a procedure that varies according to agency culture, but will normally require final detailed engineering design of at least some major works. The feasibility study should guarantee that the following are included: the geometric road designs and basic specifications; the identification of utilities to be relocated; the layout and program of the terminals and depots; and the availability of green and open public spaces. This should permit local companies to be able to develop final engineering drawings. The financial, economic and environmental analysis will also have to be developed to a level that satisfies both the lending agency and the local legislation.

Feasibility Study tasks would normally cover the following points:

a) Urban development

- Location of the corridors and their importance in the urban context;
- Determination of the area of influence of the corridors;
- Characteristics of the population and land use in this area of influence;

- Characteristics of the business activity and intensity in the area of influence;
- Plans and programs of urban development, including zoning. building incentives, and other transit-supportive land use policies;
- Review of previous transport studies;
- Existing and proposed pedestrian-friendly and other non-motorized travel facilities (i.e., bikeways).

a) Road Infrastructure

The information on infrastructure would be collected by homogeneous sections, which will be determined before carrying out any activity in field. The information would normally cover the following points:

- Length of the road;
- Geometry of the section: number and width of lanes; sidewalks;
- Physical state of the pavement;
- Traffic circulation;
- Localization of traffic lights and their phases;
- Inventory of vertical signs;
- Inventory of horizontal signs;
- Bus stops and infrastructure;
- Geometry of intersections.

c) Traffic, 2-wheeled vehicles and pedestrians.

The information obtained for each corridor and for a normal workday would be:

- Traffic flows and composition on the roads where the new bus transit system will operate;
- Traffic flows and composition on main roads and/or secondary roads that influence the operation of the new bus routes;
- Flows and composition at conflicting intersections;

- Flows of bicycles;
- Flows of pedestrians;
- Journey times and respective traffic speed for different origins and destinations along the corridors where the new bus mass transit system will operate during peak and off-peak periods;
- Identification of major delays (congestion levels) and bottlenecks on the main roads.

d) Information on traffic accidents registered in the last two years in the area of influence of the corridor should be collected, in order to assess strategies in localized conflict points aimed to reduce the risk of traffic accidents with the operation of the new bus transit system.

e) Characterization of the transit supply services. The data needed to characterize the transit routes and fleet operating in the area of influence of the corridors where the new system will operate are:

- Routes' length, frequency/headway at each critical stretch the route, by direction and in peak and off-peak periods;
- Routes' span of service;
- Number of daily trips;
- Routes' journey times (peak and off-peak) from terminal to terminal;
- Major delays and bottlenecks, indicating location, times and causes;
- Average stopped times at terminals;
- Average dwell times at stops;
- Average passenger waiting times at stops.

A description of other characteristics of the route network on the corridor should also be made, covering, sinuosity and spatial distribution. In addition data should be presented on:

Fleet

- Number of vehicles in operation on each route, classified by type and nominal capacity;

- Average age of the fleet;
- General description of the seat layouts, number and width of doors, internal circulation, wheelchair loading, ticket collecting mechanism, handrails, type of propulsion, noise (internal and external) and emissions levels, etc.

Institutional Arrangements

For each organization the following information should be collected:

- Association type;
- Administrative structure;
- Legal instruments;
- Operational structure;
- Participation by type of service and vehicle in the total corridor demand;
- Coverage (by route or area);
- Fare collection and distribution;
- Operational costs;
- Maintenance costs.

The operational and maintenance costs will be needed for the economic and financial evaluation of the project. These costs will be determined for the types of vehicles that operate currently in the corridor and they will be compared with the respective costs of the new vehicles.

f) Characterization of transit demand

- Daily demand per route;
- Daily demand on each section of the corridor and estimate of the annual demand;
- Demand per route in the peak and off-peak periods;
- Average distance and trip time for each user type (by gender if a regional issue);
- Average walking distance for each user type;

- Turnover indexes per route;
- Transfers (if more than two units are needed to make the trip or if a major transfer facility is involved);
- Areas of trip origins on the corridor;
- Areas of trip destinations on the corridor;
- Desire lines on the corridor;
- Distribution of trip purpose per route.

The sources for some of this data can be:

- Visual occupation surveys;
- Boarding/Alighting surveys;
- Origin /Destination surveys.

A public opinion survey of the total passenger demand (workday) on the corridor is needed to identify the basic socio-economic groups. This opinion survey should also show how users perceive the services in terms of general quality of service, waiting times, physical state of the vehicles and treatment by drivers. The sample size can be determined by fixing the confidence limits required and by knowing the general size of the passenger "universe" to be tested. .

g) Information for the calculation of emissions of global and local pollutants.

h) Travel demand modelling. If the data is available modelling of the base year can be done (normally by any commercial package modelling under the four-step approach). The model can be calibrated and validated using real survey data. The Chapter on Curitiba (See Volume 1, Chapter III, Section 3.2) stresses that expensive modelling techniques are not necessary for bus system planning. However, if recent data exists and the planning process involves projections for the short, medium and long terms, (typically 5, 10-15 and 20-25 years), a corridor model can give a useful notion of future demand and possible capacity restrictions.

i) Modelling at the micro-level. The objective of the microsimulating traffic conditions is to evaluate the performance of mixed-use lanes if an exclusive busway is being designed. This can then be used to simulate the mitigation of negative impacts and the improvement of the

proposed circulation. This is often carried out using the TRANSYT or SYNCHRO models.

Functional Design

The Feasibility Study will produce a Functional design. This will normally be prepared in CAD format at 1:1000 scale. If this database is not available, then maps on the same scale, based on aerial photographs can be used. This design should show how all routes on the corridor will connect to other transit modes and also include the following information:

a) Determination of types of service and operation parameters

- Types of service: Ordinary, express, feeder, and convoy;
- Types of routes: trunk, feeder, conventional, complementary, etc.;
- Types of vehicles;
- Journey cycle times of the routes;
- Operational speed;
- Method of payment.

b) Description of the following items:

- Relationship between the operational design and the corridor demand;
- Method used to calculate maximum and minimum frequencies, journey cycle times per route, operational speed, and nominal capacity of the vehicles;
- Analysis of the peak and off-peak periods;
- Level of service offered to the users during different periods of the day.

c) Design of itineraries, describing any major differences in relation to current routes.

Stop Location, Design and Spacing

- Bus stop or station spacing for the new bus transit routes. Bus stop spacing has a substantial impact on the

performance of operations, affecting both access time and line-haul time, and therefore the demand for the service[2];

- Bus stop or station location (near side, far side, or mid block and over the median or in the curbside).

d) Localization of transfer stations and terminals.

e) Design of internal transfer stations or terminals, showing:

- Internal circulation of vehicles;
- Passenger circulation;
- Flows entering and leaving the station or terminal;
- Points of control of vehicles and users;
- Connection points with other modes.

The stations and transfer terminals should include facilities for special needs, parking for bicycles and/or private vehicles.

f) Unit Specification

The ideal or most adequate vehicle for each route should be described, along with the reasons for each choice. Normally these would be:

- Chassis type and nominal capacity;
- Transmission (automatic on trunk routes and all busways);
- Suspension (air suspension is preferable and obligatory on all busways with at-floor loading in order to maintain the exact height of the unit in relation to the concrete pavement);
- Specification of environmental contamination with reference to EPA or similar standards;
- Number of doors, width and location;
- Type and dimensions of seats;
- Corridors circulation;

[2] In particular, there will be a tradeoff between closely spaced stops (with shorter walking distance but more time on the vehicle) and stops spaced further apart (with longer walking distance but less time on the vehicle).

- Disposition and height of handrails;
- Special access mechanisms;
- Fare collection mechanism (if used);
- Useful (working) life of the vehicle.

Traffic design priority and passenger information

- Signal priority consist of using ITS technology and sophisticated algorithms for controlling traffic signals based on real-time bus transit schedule adherence and traffic volumes. Adjusting signals have a large effect on bus travel time, both its mean and its variance;
- Automatic vehicle location systems can be used to provide real-time data on next vehicle arrival times. Providing information can be done at stops, on board vehicles, and away from the system through remote access of customized transit information.

g) Detailed public presentation. Any modern bus transit scheme will have a radical impact on the lives of thousands of city inhabitants. The functional design should also include the elements needed for a professional public relation presentation. Geometric designs and maps are often incomprehensible to the general public; architects´ perspective drawings and digital animation can be useful tools.

Executive Project

Based on an approved functional design, an executive project of the new bus transit corridors can be developed.

a) Construction. The Executive Project will contain all the necessary detail for the construction or reconstruction of infrastructure works and the installation of the services, such as:

- Exclusive Busways, bus lanes and lanes for mixed traffic;
- Transfer Stations or terminals;
- Stations along the busway;
- Estimated relocation works for public utilities;
- Intersections, considering turning movements;

- Access facilities (pedestrian under and overpasses, park and ride, bike parking, etc.), functional open/green public spaces and ancillary urban landscaping.

- Access to neighbouring construction.

b) Operational Design of the Transit Services. The operational planning of the new bus transit corridors determines the level of service offered to the users. This will include the detailed scheduling and programming of the services for each route, such as:

- Estimated number of vehicles for both trunk and feeder routes;

- Define frequency of service or headways for each route and for peak and off-peak periods;

- Design of route scheduling and bus driver programming;

- Estimated number of reserve vehicles;

- Procedures for real-time control of schedule adherence.

c) Operational Design of Traffic. The operational design of the traffic in the corridor consists in detailing all the proposals in the functional design, including signal timings/phasing, specifications of traffic management measures and materials, etc.

d) Topographical Information. The topographical survey should consider all adjacent properties to the corridor and cover all items in CAD format at 1:500 scale. This should include land use, public utilities (water, gas, sewerage pipelines, and telephone and electricity lines) that could be affected by the design of the project and other interventions than in the future could have an impact in the project.

e) Pavement reconstruction, rehabilitation or maintenance, and complementary roadway works.

f) Signalling.

g) Illumination.

h) Drainage.

i) Urban landscaping, urban furniture and the recuperation of green/public areas. This aspect has been included in many successful projects of modern bus transit systems and deserves special attention in this final phase.

j) Projects for traffic diversions. The construction of a modern bus transit system will often require the temporary diversion of traffic, with additional congestion and other associated externalities . It is important that this question is resolved at the executive level.

k) Transition plan from the current operation model for the proposed.

Plan to mitigate negative environmental impacts

Transition plan for the current bus transit operations and enterprises

l) Outline information to the user.

m) Design and implement visual and signage information for the station, bus interiors and terminals.

n) Elaboration of tender documents.

Budgeting

The work program should consider the following costs:

b) Costs of infrastructure of the corridor – based on unit costs as far as possible;

c) Costs of maintenance of the infrastructure;

d) Fleet investment/renewal program and maintenance costs;

e) Equipment maintenance program;

f) Costs of facilities - stations and terminals;

g) Maintenance costs and operation of the facilities - stations and terminals;

h) Costs to mitigate environmental impacts;

i) Costs to cover possible social impacts and to generate appropriation of the work;

j) Resettlement of housing, trade and facilities;

k) Complementary services, illumination, safety, special access, etc.;

l) Complementary works – cultural, parks, historic buildings, etc.;

m) Consultancy and research.

Most systems will require a cost-benefit analysis, comparing - in economic terms - the resulting situation of implementing the project, with the do-nothing case.

The costs considered above should be evaluated against the benefits in operating costs, travel time, safety, etc., excluding items such as taxes, using market prices as far as possible.

The results would normally be expressed in terms of:

- Internal rate of return;
- Net present value;
- Cost-benefit ratio.

A sensitivity analysis and risk analysis may also be required – especially if large changes in demand or modal shift are predicted.

Financial Evaluation

At the executive project level, a decision will have been made in relation to the operation of units. This report has shown that a recommended working model would involve – or delegate through a concession – the operation of units to the private sector. The financial and risk analysis of operating the system would thus be carried out by either the bidders or the concession holder.

Environmental Impact Analysis

The environmental impacts of the proposed works on the corridor will require a plan of environmental mitigation, as well as monitoring in order to identify future possible negative impacts. This task involves the following activities:

a) Evaluation of the direct environmental impacts caused in the construction stage, as well as those during the operation of the corridors;

b) Development of the measures of mitigation of the impacts on pedestrians, drivers, passengers and neighboring properties in the area of influence;

c) Recommendations to the engineering projects from the environmental point of view;

d) Estimate of costs of these measures and designation of the responsible body for their execution;

e) Specific environmental proposals for:

- Potential factors of risk - erosion, riverbanks and flood plain reduction;
- Green areas and parks – as well as major changes to vegetation, required for the execution of the works;
- Tourist, archaeological and historic sites of particular interest along the corridors;
- Land use and occupation within the area of influence, specifically near places like hospitals, schools, markets, etc.

Social Impact Analysis

This analysis would typically cover:

a) Identification of the type and characteristic of the organizations that would be displaced by the introduction of the new services in the corridors, defining:

- Displaced workers (chauffeurs and other);
- Small proprietor-operators (man-vehicle);
- Informal workers (without formal labour relationship or legal protection);
- Large operators.

b) Evaluation of the effects on properties (expropriation needs, damages, etc) and preparation of a program designed to mitigate these problems on the affected population groups.

c) Estimate of the impact on productive activities and services.

d) Resettlement of squatters, low-income housing or subsidised dwellings.

Safety Audit

This is needed to guarantee adequate levels of safety on the corridor for all users, specifically pedestrians, 2 wheeled users,

passengers and other road users. This task is best handled by a specialist and should cover both the work plan and final operations.

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