CURITIBA, BRAZIL

BRT CASE STUDY

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SUMMARY

Curitiba's bus system was developed as an integral part of an overall master plan whose basic objectives included radial expansion of the city along five corridors (structural axes), integrating land use and transport, and protecting the traditional city center. The median busways in each corridor are in the center of a "trinary" road system (busway, local street, one-way arterial). Development densities are greatest within this system as compared with other parts of the city.

Curitiba's busways are viewed as a model bus rapid transit (BRT) system. They are widely recognized for their many innovative features. Trunk and feeder bus lines routed through terminals allow convenient fare-free transfer. Bi-articulated five-door buses and tube stations with off-vehicle fare collection and floor-level boarding facilitate passenger access. Finally, direct express service and tube stations are provided along parallel, one-way arterial streets.

The overall system is the result of many incremental decisions aimed at improving service quickly, pragmatically, and affordably.

The bus system includes about 60 kilometers [37 miles] of median busways and carries about 2 million people per day. The system carries up to 11,100 passengers one way on the busiest busways in the peak direction during the peak hour. Bus speeds average 20 kph [12 mph] along the busway and about 30 kph [19 mph] on the "direct" express routes. Development costs have been estimated at $1.5 million (U.S. dollars) per kilometer [$2.4 million per mile].

About 70% of Curitiba's commuters use the bus system even though Curitiba's automobile ownership and per capita incomes are significantly higher than the national average for Brazil.

CITY CONTEXT

Curitiba is the capital city of the State of Parana in Southern Brazil. The city is located about 250 kilometers [150 miles] southwest of Sao Paulo near the coastal mountain range. Current data (mid-1990s) shows a population of some 1.6 million distributed within city limits of about 430 square kilometers [165 square miles] and a total metropolitan area population of some 2.2 million[i]. The city has a thriving economy with the gross domestic product reported at $7,827 (U.S. dollars) per head in 1997, among the highest of any city in South America. Automobile ownership has been variously reported: it was between 295 per 1000 in 1997[ii] and perhaps 500 per 1000 in 1999.[iii]

During the 1960s to early 1980s, Curitiba grew at a rapid rate, with a population growth rate of approximately 4% per year. Although a city plan had been prepared in the middle of the 1940s, the plan failed to recognize the issues raised by the need to deliver urban services to a rapidly increasing demand caused by population and economic growth, within a realistic level of investment. Thus, in 1964, Curitiba prepared a new plan, the Preliminary Urban

Development Plan, which evolved over the next 2 years to become the "Curitiba Master Plan," and which has guided city development for the last 30 years. Parallel with the evolution of the plan, in 1966, Curitiba created a planning institute, the Instituto de Pesquisa e Planejamento Urbano de Curitiba (IPPUC), to develop, supervise, monitor, and continually update the Master Plan.[iv]

The Curitiba plan follows an integrated approach to development of transport and land use. Key directions are the following:[v]

- Promotion of a linear urban city growth by integrating public transport, road network development, and land use along key, "structural axes";
- (Traffic) decongestion of the city center and preservation of the historic central city core;
- Management and control of land use citywide;
- Provision of economic support incentives to urban development to realize land use aims and to assist employment generation; and
- Improvement of infrastructure.

In addition to the land use-transport sector, Curitiba has also followed enlightened policies on housing, environment, waste recycling, social matters (particularly for the young), and other initiatives.

Curitiba's transport system is known throughout the world as an example of a pragmatic, integrated, cost-effective, and efficient transport system. A system of median busways along five "structural axes" is complemented by "direct" express service on parallel arterial roads, and by an extensive feeder bus network.

This case study presents an overview of the Curitiba busway transit system and suggests important lessons relevant to U.S. conditions.

BASIC STRUCTURE OF THE CURITIBA TRANSPORT SYSTEM

The transport system in Curitiba is founded on an integrated land use and transport policy along the major radial corridors of the city or linear, structural axes. Each of the structural axes was developed as a "trinary system" comprising three roads. Figure 1 gives an overhead perspective of this trinary road concept. The central road of the three roads contains a center-of-the-road, two-way busway that feeds into transfer points called "terminals," and also provides a limited number of traffic lanes (one or two in each direction) for nonthrough movements and for service access to frontage development. Approximately one block from each side of the central busway/service road, a one-way traffic road of three or four lanes has been developed for use by private vehicles. In the block width between the busway and the main traffic roads on either side, intensive, high-density land use development has been encouraged/permitted.

This land use form creates a concentrated, high demand for transport services along a narrow corridor that can be met efficiently by a track-based public transport service – the busway. Travel demand for the busway system is further generated as (1) the busways enter and cross the central business district (CBD) while traffic access is limited by traffic management methods (bus-only access, pedestrianization, parking controls, etc.), and (2) bus feeder services are integrated into the busway at through interchange terminals and stops. The busway system is operated largely by a fleet of some 114 bi-articulated vehicles, which are thought to be unique to Curitiba, in provision of day-to-day urban services. The buses are 24.52 meters [80.4 feet] in length, have five passenger doors and a capacity of some 270 passengers. Further details are given in subsequent sections.

The busway system along the five structural axes is only part of the Curitiba citywide bus mass transit system. The system, termed the Rede Integrada de Transporte (RIT – Integrated Transport Network), provides a hierarchy of types of bus service citywide, and all are operated under an integrated tariff system. Bus services are linked through integration terminals and at on-street stops where bus passengers may interchange between bus services without additional payment on the system. The buses operating the various RIT services are color-coded by function and include the following:

- "Troncal or express" (trunk line buses operating on the axes/busways – red/orange),
- "Ligeirinho" (express – grey/silver),
- "Interbarrios" (inter-district – green),
- "Alimentador" (feeders to/from terminals and stops serving trunk line or express buses – orange),
- "Convencional" (operating regular services on normal roads where other services are not justified - yellow),
- "Circular centro" (serving the CBD – white), and
- "Metropolitano" (serving out of city destinations – blue).

Figure 2 shows the system of bus services in Curitiba and the five structural axes. Figure 3 gives a schematic plan of the Curitiba busway system. The downtown area is the focal point of the bus system, although major destinations are served along each structural axis. The bus services form an integrated, bus-based, mass transit system for the city. The scale of the citywide operation is demonstrated by some key statistics:[vi]

- 340 bus lines,
- 1,550–1600 buses,
- 1,100 kms of bus route,
- 60 kms of segregated busway,
- 26 major and moderate size integration-interchange terminals, and
- Passenger demand of 1.9–2.1 million trips per day.

PLANNING AND IMPLEMENTATION BACKGROUND

The decision to rely on buses was perceived as a more flexible and affordable public transport solution than rail transit for a medium-sized developing city.[vii] Both the development of the city and the bus rapid transit system are the result of policies established over the last 30 years on land use, parkway, transit management and operations, and community participation.

LAND USE POLICIES [viii,ix]

Curitiba possesses a "Master Plan" and, vitally, an agency IPPUC, to monitor, implement, and update the plan. IPPUC is a largely independent institute and thus is less liable to political pressures and changes than a municipality-based department or division. The success of IPPUC (not of course in transport alone but in all urban development sectors) is legendary in Latin America, and the institute presents courses, based on its experience, to a wide range of central and local government agencies from other countries. The key features related to land use and transit in the plan are the following:

- Land use and transport are integrated; the "structural axes" concept of high-intensity development has created corridors with a travel demand that is well suited to be met by transit (high demand, short walk distances to the transit facility, etc.).
- Land within two blocks of the busway has been zoned for mixed commercial-residential uses. Beyond these two blocks, zoned residential densities taper with distance from the busways. (See Table 1.)
- Most importantly, the zoning prescribed by the structural axes has been realized by a combination of control and incentives. This combination includes various bonuses to develop as planned; incentives to transfer development rights; firm control over large-scale development (such as large shopping centers, which are limited to the structural axes); provision of incentives to developers to increase residential density close to the transit corridors; and development of transit terminals with a wide range of facilities – both public and private sector.
- The busway system has been instrumental in driving land use development and has been used to stimulate development along the structural axes.[x]

PARKING POLICIES

Parking policies have assisted in shaping travel demand, particularly to/from the central area. In the central area, roadside parking is limited in location and duration and is well enforced. Although off-street parking exists, it is reported to be expensive, and permission to supply parking has not matched potential demand arising from growth in vehicle ownership. Within the structural corridors, development (residential and commercial) must now provide off-street parking; it is paradoxical that the highest parking provision is, by virtue of the highest density of development, along the structural axes. However, two points are significant: (1) the design of the transitway eliminates any access or interference from parked private vehicles, and (2) the limited parking provision in the central area has assisted in maintaining a high mode share to transit (about 70%–75% of journey to work) despite the relatively high automobile ownership. In addition, the city's central area is partially closed to vehicular traffic. Bus/pedestrian streets further reinforce transit use.

GOVERNANCE, MANAGEMENT, AND OPERATIONS

In the RIT system, private bus companies operate under parameters established by the municipality in 1987. [xi] The operation of bus services is controlled by a municipal company, URBS (Urbanizacao de Curitiba SA), which also controls taxis, parking, bus terminals, and shopping areas and markets. URBS plans the system; defines routes, capacity and schedules; regulates and controls the bus system; and collects all fares. Bus operations are contracted to private sector operators. Fare revenues are pooled and paid to the contracted operators on the basis of the service provided. The levels of payment depend on a formula involving kilometers operated and the type of service and bus provided. From the URBS's payment, operators pay their full operating costs and capital replacement costs, depending on the age and type of bus operated. The payment to operators includes a profit, and in 1996, it was reported that profit was about 11.39% of fare revenue (fare levels are discussed in subsequent sections). [xii] About 16 bus companies provide the RIT services, and, it is understood that there is no tender process – contracts are rolled over through negotiation on their expiration. It is argued that efficiency is maintained by close supervision of service provision by URBS and by comparison between the companies.

COMMUNITY PARTICIPATION—CONSULTATION

It is reported that the innovations require the involvement of the public. However, there are reported examples of measures to motivate stakeholders in city life. For example, URBS responds to public concerns over the transit system, public consultation has taken place to promote the central area pedestrian usage schemes, and low-income riders are encouraged to collect waste from more inaccessible areas in exchange for bus travel tokens (leading to a cleaner environment and promotion of public transport). It appears that Curitiba follows an open approach to information, and all citizens can access data on every plot of land in the city.

THE BUSWAY SYSTEM

Curitiba's median busways have been progressively expanded over the last 30 years. The first 20 km [12.4 miles] were planned in 1972, built in 1973, and placed in service in 1974. In 2001, there were 40 km [37 miles] of busway along the five structural axes. Table 2 highlights the evolution of the public transport system.

A trunk and feeder bus system operates in which buses are routed through a series of terminals where passengers transfer between busway vehicles, feeder routes, and interdistrict links with no further payment of fares. Buses, which are operated by private companies under municipal supervision, use a common color-coding system.

Key features of the bus system include the following:

- Physically separated median bus lanes flanked by two local service streets;
- 26 mid-route and end-of-line terminals for transfer among bus takers;

- An integrated fare structure;
- “Tube” stations with off-vehicle fare collection and platform boarding of buses;
- “Direct” express service in the parallel one-way arterials; and
- Distinctly colored bi-articulated buses (see Figure 4) along the busway, each with five doors and designed for level (“high-platform”) boarding at tube stations.

Busway Track

The Curitiba busways are located along “structural axes” that comprise three roads, the central one of which is a busway and service-access road. Busways are continuous along five corridors or structural axes with a total length of 58 km.[xiii] The basic cross section of the busway and service roads is shown in Figure 5; the cross-section widths are shown in Table 3. Busway characteristics are the following:

- The track is used exclusively by trunk line buses.
- The track is separated from other service-access traffic by continuous physical islands or by island bus stop platforms.
- Busway crossings with other roads are generally at grade and signal controlled (it is believed bus traffic signal actuation exists).
- The track is located in the center of the bus and service-access road, and thus, the busway-road, unlike many attempted adaptations of the “Curitiba principle” in other cities, is not a major traffic-carrying route. Passenger access to/from stops does not involve crossing through dense, possibly fast moving traffic.
- The curb-to-curb envelope contains eight lanes; it is about 26 meters [85 feet] wide.
- Tube stations preempt the parking lanes adjacent to the busway.

Passenger Facilities

Passenger facilities along the busway structural axes/corridors are of three types:

- “Tube” stops, which equate to conventional bus stops and are located at spacing of about 450 to500 m along the 58 km of busways;
- Interchange-integration terminals at the out-of-city end of each of the five structural axes/corridors to permit trunk-feeder bus interchange; and
- Mid-route, smaller terminals at key points, about 2-km spacing, along each busway corridor to permit trunk-feeder bus interchange.

Tube Stops

The "tube" passenger stop platforms or stations are the trademark of the Curitiba system (Figure 6). They can serve three times as many passengers per hour as a conventional bus. "Tube" stops are used both on the trunk line busways and on the express buses (off the busway). Stop details are as follows:

- On busways, tube stops are located at about 500-m [0.3-mile] spacing.
- The tubes include raised platforms (low-floor buses are not in operation) and provide passenger weather protection; the stops are constructed from a plexiglass-type material with steel ribs.
- The tube stops are equipped with doors to enter/exit buses; these are coordinated with doors on the buses – five doors on the trunk line bi-articulated buses (and two on express buses).[xiv]
- Disabled and wheelchair access to the high-level stops is made through a small elevator at each stop (see Figures 7 and 8).
- Passenger boarding and alighting of buses is gap free and level; this is achieved by the use of fold-down steps from bus doors, which deploy automatically as bus doors are opened and position onto the threshold of the platform (see Figure 9); it is understood that bus-platform positioning door-to-door is done visually by the driver, and there is adequate tolerance to ensure safe operation of the system;
- The stops are designed to speed passenger handling, and fares are paid by passengers at the entry to the stop – similar to a metro. Each stop is equipped with turnstiles (numbers depend on size of stop) and are manned by a ticket collector–inspector (see later discussion on smart card technology). Typical dwell times at stops are less than 20 seconds.
- On busways, tube stops are on line with no special provision for bus-on-bus overtaking. Theoretically, the busway is wide enough to allow overtaking by buses entering the opposing bus stream, but this is not normal operational practice.
- Stops for both directions are generally located opposite each other and close to junctions. As stops are located on the central road of the trinary axes, access and traffic issues are less critical than on a busway introduced into an existing road.[xv] However, as with any stop, there is a need to balance safety, junction capacity, and busway capacity.

Integration and Mid-Route Terminals

Terminals are located both in the middle of route and at then end. They are similar in function but vary in scale and size. End-route integration terminals are used by many more feeder services and other buses than mid-route terminals.

Furthermore, the large end-route integration terminals are planned as "one-stop" facilities aimed at reducing travel demand on the busway system. Thus, land use development of the integration terminals may include a range of municipal services (such as offices for the payment of utility bills), sports facilities, and retail and commercial development (funded by the private sector).

The terminals are "closed" in that once a fare has been paid at the first point of entry to the system, interchange between urban buses requires no further payment. Fare payment to enter the terminal is similar to a metro system in that the stops for trunk line buses and the feeder buses that serve that line are usually located on either side of a platform to allow rapid interchange.

Flyovers, trees, shops, glass walls, and a pleasing architecture make terminals as lively and transparent as possible.

Vehicles

The busway system is operated by a fleet of dedicated -bi-articulated diesel buses (Figure 10). The bi-articulated buses were introduced in 1992, and there is a busway-dedicated fleet of about 115.

Characteristics of the bi-articulated buses are the following: [xvi]

- They are Manufactured byVolvo Brazil.
- They are 24.52 m [80.4 ft] long, 2.5 m [8.2 ft] wide, and 3.415 m [11.2 ft] high.
- There are five double-width doors on the conventional (right) side of the bus.
- The buses are bi- (or doubly) articulated with four axles.
- Motive power is conventional diesel.
- Passenger capacity is about 270 including standees. Buses are configured with only about 57 seats, because the aim of the trunk line buses is to move large volumes of passengers. Journey times on trunk line busways from outer terminals to the city center are relatively short (about 20 minutes).
- Buses are high floor, but because of the raised platform stops and fold-down ramp/door, passenger boarding and alighting is level and gap free;
- There is no on-vehicle fare collection or display of travel passes to bus drivers; all payments are made at terminals or as stop platforms are entered.
- Although it is necessary that buses stop accurately at "tube" stops to coordinate bus doors and stop doors, no automatic vehicle guidance is provided; this is achieved by the drivers without automatic aids. There is some tolerance laterally (because of the fold-down step) and longitudinally (because of the width of stop doors), but observation indicates that the arrangement works well.

Service and Operations

Curitiba's "bus rapid transit" system includes (1) trunk line buses operating on the busways as "express" services and "direct" services operating on the adjacent one-way arterial streets. Feeder buses serve the arterial trunk lines on the five structural axes/corridors, but they are not given priority over other traffic.

Express Service

The “express” services are segregated from other traffic. Shops are located every 500 meters [1,640 feet] and integrated terminals every 4 kilometers [2.5 miles]. They are reported to operate at a headway of 90 seconds during the peak periods.[xvii]

Direct Service

“Direct” express bus services run along the one-way roads on each side of the central roads that form the structural axes. These services feature fewer stops, and passengers pay before boarding the buses in special raised tubular stations. The service was initiated in 1991 with four routes that parallel the busways. By 1995, there were 12 lines that served more than 225,000 daily trips.[xviii]

SYSTEMS AND TRAFFIC CONTROL ELEMENTS

Systems and traffic control elements include (1) traffic controls and busway enforcements, (2) safety and security, and (3) fare collection.

Traffic Controls and Busway Enforcement

Key details are as follows:

- It is understood that traffic signal actuation exists and that buses are given signal priority where the segregated busways cross other roads.
- Key streets in the center of the city are pedestrianized and bus-only access is applied extensively to CBD cross streets.
- Unlike many cities, traffic enforcement along the busways is not an issue as (1) bus-traffic flows are fully physically segregated, (2) busways are in center of the road and parking is not an issue, (3) few left turns are permitted from the lateral service-access lanes across the busways, and thus, other traffic does not enter the busway to make turns, and (4) the service-access treatment of the lateral lanes outside the busways discourages their attempted use as through lanes for other vehicles.

Safety and Security

There are no reports of safety issues. In many cities that have sought to use centrally located busways, passenger access to/from stops can be a safety concern. In heavily trafficked roads, access to/from stops for central busways is usually controlled by signals either at the main junctions (such as the Nagoya, Japan, busway) or at mid block where special pedestrian signals are installed (see Sao Paulo case study). However, in Curitiba, although pedestrian access to stops on busways is safeguarded by signals at the road junctions, traffic flows on the lateral roads are less intense, as the roads are not used by through traffic.

Fare Collection

The “tube” stops and integration terminals are planned to avoid all fare collection on buses. Payment of fares at stops (which applies to the express services off the busway as well as the busway services) is at a manned turnstile at the stop entrance. Clearly, this has labor cost implications, and smart card fare payment systems are scheduled for imminent introduction. No data are available on fare avoidance, but the “tube” entry system and the integration terminals (which are manned by inspectors at the bus entry to prevent passengers attempting to enter without payment) appear to be secure systems.

MARKETING

Curitiba's RIT system is world renowned for its well-defined identity, its promotion, and for marketing the service to its users. Typical marketing measures include the following:

- Buses having a unique identity by route and function. User recognition of services and the image of those services are enhanced by color-coding of services/buses.
- Making the citizens of Curitiba aware and proud of the fact that their bus system is a world model. This has been achieved by ensuring that the bus services supplied are of high quality and that the mass media are aware of the views and reports from abroad.
- Creating a state-of-the-art image. This is almost unique among bus-based mass transit systems. The image has been created not only by the supply of an efficient service, but also by such innovations as bi-articulated buses and "tube" stops, and, in the near future, by smart card stored value ticket systems. The promotion of the bus service image in Curitiba is an object lesson to many cities worldwide where bus services have never been able to compete with (costly and inflexible but politically desirable) LRT/tram systems.

Clearly, there are additional quality measures, which given financing could be included to further promote the image of the RIT system (such as AVL coupled with real time displays of services at bus stops). However, the Curitiba philosophy appears to have concentrated on the provision of an affordable and efficient bus service, and it is these attributes that allow the promotion of a "state-of-the-art-image."

FINANCIAL INFORMATION AND FARES

Capital costs and current financial data are difficult to obtain because (1) the basic busway infrastructure was constructed in the 1970s and has been modified and updated (such as the addition of the tube stops or new interchange terminals) progressively over the last 30 years, (2) the integration of the busways into the trinary system of the axes makes capital costs almost impossible to isolate, and (3) the series of financial events in Brazil of inflation-devaluation make cost comparisons excessively difficult.

However, in general terms, the following observations emerge:

- The complete RIT system, with its range of buses and integrated flat passenger fare, is reported to operate without subsidy;
- The remuneration to bus operators is adequate to cover vehicle replacement costs (buses in Curitiba are said to be among the most modern in Brazil) and to allow operators to make a profit; and
- In 1994, it was reported that (last major busway construction) that busway costs were $1.5 million (U.S. dollars) per km (including tube stops and excluding buses). [xix]

It is reported that fares are periodically reviewed by URBS and are set to cover all costs including operation/maintenance and administration and capital replacement, as well as to ensure that the "average worker" (Brazil has a system of identifying "minimum salaries") pays no more than 10% of income on transport.[xx] The system operates on a flat fare basis, which, as well as providing simplicity in operation (particularly in view of the integrated, interchange nature of RIT), is regarded as equitable for poorer community members who tend to live furthest from the city center and the places of employment. The flat fare is variously reported, but the latest data refer to about $0.60 (U.S. dollars). This is one of the lowest fares in South America, considering that a typical rider averages 2.4 transfers per day.

RESULTS

RIDERSHIP/USAGE

Reports of the passenger volumes on the complete citywide system vary from about 1.9 million passengers trip per day (including transfers as two trips) to 2.1 million per day. [xxi, xxii] Reported daily busway ridership volumes are approximately 188,000 passengers in the north-south corridor, 80,000 in the Boqueirao corridor, 52,000 in the east corridor, and 19,000 in the west corridor.[xxiii]

The most heavily loaded corridor carries about 11,000 passengers per hour per direction, which is consistent with a headway of 90 seconds and a bi-articulated bus capacity of 270 passengers per bus. It appears likely that bi-articulated buses could operate at closer headways, and, in this case, the constraint to capacity would become the dwell time at bus stops. However, Curitiba has all the factors that go to make up rapid passenger handling (wide bus doors; level access; five doors per bus that are designated for separate, simultaneous boarding and alighting; no fare payment or display of passes to drivers; etc.). It is reported that large-use stops can handle passenger movements from bi-articulated buses in about 15 to 20 seconds. Thus, higher capacities than 11,000 appear possible, and some agencies place the capacity as high as 27,000 passengers per hour per direction. Further research is necessary to determine current performance of bi-articulated buses, but, at minimum, it seems likely that a headway of some 60 seconds is operational, and with buses with a load factor of 85%, this would represent about 14,000 passengers per hour per direction.

RIDERSHIP TRENDS

There is no doubt that RIT ridership in Curitiba has increased since the initial stages of the scheme 30 or so years ago and continues to increase. In 1971, ridership was 0.58 million trips per day; in 2000 overall, ridership had increased to 1.9 million per day. This represents an increase of about 4.5% per year. However, interpretation of such figures in a developing city requires care; in the same period, population grew (more demand for public transport), and automobile ownership grew (less demand for public transport) – both at levels not likely to be experienced in a developed city. The key point is that RIT has maintained, if not increased, commuter mode share to transit at 70% to 75%, and there are no indications that this proportion is decreasing.

In 1974, the first BRT service operated along two arterial busways and carried 54,000 passengers per day. By 1982, the bus service along five structural axes carried 400,000 passengers per day. After improvements in fare collection and distribution, vehicles, and route extensions, the busway system carried more than 1,000,000 passengers per day.

BUS SPEEDS–TRAVEL TIMES

Buses on busways operate at a commercial speed (including stops) of about 19 to 20 kph [12 mph]. As buses are fully segregated from other traffic, speeds appear to be controlled by bus stop spacing at about 500 m and junction spacing. The advantages of longer stop spacing coupled with the facilities (both physical layout of stops and the method of fare collection) can be seen in the direct/"ligeirinho" (express) services that operate at a commercial speed of about 30 kph [19 mph] along the parallel one-way arterial streets.

The direct line services save an average of 15 minutes travel time for each segment of a work trip. (e.g., home to work in the morning, work to home for lunch midday, home to work in the early afternoon, and from work to home in the evening).

ENVIRONMENTAL BENEFITS

The popularity of Curitiba's BRT system has attracted motorists, despite a high rate of automobile ownership relative to the rest of Brazil. A 1991 travel survey reported that about 28% of ("direct bus") users previously traveled by automobile. BRT service resulted in 27 million fewer automobile trips each year and about 27 million fewer liters of fuel annually. Curitiba uses about 30% less fuel per capita because of its heavy transit usage, and its ambient air pollution is one of the lowest in Brazil.[xxiv]

ASSESSMENT

Curitiba's busway system has proven successful in many respects and is cited as the model for BRT development in other cities. It is effectively coordinated with land development, it is heavily patronized, and it operates quickly and reliably. Express and feeder services are effectively integrated with free transfers between them. Bi-articulated, multi-door buses with level boarding coupled with off-vehicle fare collection significantly reduce passenger service times. Red-colored buses and transparent tube stations provide a clear distinct image.

The vehicles, routes, terminals, and surrounding land uses are key elements of an integrated transport system. They are perceived as more important than any specific hardware. The busway system, which functions as a rubber-tired, rival LRT system, was developed at a cost of about $1.5 million per km [$2.4 million per mile]. These costs are orders of magnitude less than any street-based LRT, and the busway system does not require any subsidy as it is financed from the farebox revenues.

Curitiba has been successful in integrating land use and transport to ensure an efficient and self-sustaining transport system. Its mixture of incentives and controls applied to land use planning are precisely what transport planners worldwide have sought to achieve – but often with less success. Collectively, Curitiba has achieved a transit-oriented land use pattern and continued ridership growth.

Curitiba's busway system was a key tool in directing the growth of the city; this contrasts with experiences in other Brazilian cities where busways were a response to immediate problems of traffic congestion.

IMPORTANT LESSONS RELEVANT TO U.S. CONDITIONS

Some lessons from Curitiba are applicable to the United States and other developed country conditions. Of course, there are differences in city structure, economic prosperity and income levels, automobile ownership, public perspective and image of public transport, and other factors, which make it essential that local conditions be evaluated. Indeed, one of the great merits of busway transit is that it can be planned, designed, and operated in a flexible manner and thus can be geared to local conditions. However, there are some policies and principles that may be applicable.

The characteristics of the Curitiba busway system are precisely those necessary for *any* fully successful transit scheme – rail or bus. Prerequisites of any system that is to be well used and financially viable should include protection of the transit right-of-way from traffic congestion, good and preferential access to areas of high demand (such as city centers), and planning around land use that provides a potentially high passenger demand.

Transit First Policy

The need to give public transport priority in large cities and to integrate public transport with community development wherever possible are the most important lessons.

Conclusion: These are important lessons, although they may be difficult to achieve in the United States (and Canadian urban areas).

Busways as a Mass Transit System

The Curitiba experience shows that with good planning and organization busways can carry high volumes of passengers at reasonable commercial speeds – equivalent to those of LRT or tram technology under the same operating environment. Before the bi-articulated buses were introduced in Curitiba, busways were operated by conventional articulated buses and carried some 9,000 passengers per hour per direction at a commercial speed of 21 kph [13 mph]. [xxv] With bi-articulated buses, passenger throughputs are recorded at 11,000 passengers per hour per direction, and possible capacity is estimated to be at least 14,000 passengers per hour per direction and could be more.[xxvi] Such volumes are well in excess of the public transport demand in most corridors in the United States or other developed cities.

Conclusion: Even if corridor travel demand is high, busway capacity is not usually an issue, especially in a U.S. context.

Busway Passenger Handling

The operational success of the Curitiba busways depends on the ability of the system to handle passenger boarding and alighting efficiently, with little delay. Great effort has been made to accelerate passenger handling: buses are equipped with wide doors, buses on busways have five doors, passenger boarding/alighting is level and gap free as a result of the integrated design of the "tube" stops and buses, and the pre-payment of fares to enter the stop area ensure that no delays are encountered from fare collection on buses.

These arrangements enable the busways to operate at reasonable speeds despite the very high passenger loading. In the United States, or other developed areas, it is not likely that many corridors will have passenger volumes equal to those in Curitiba, and the pressure for maximum stop efficiency will be less; nevertheless, efficient passenger handling maximizes the use of buses and reduces operating costs.

Conclusion: Curitiba shows that with good organization and appropriate design, passenger handling delays can be minimized and can assist in achieving a very high level of operational performance; efficient passenger handling and fare payment systems are possible with busways/buses and are a vital part of a modern system.

Busway Design

Many busways in Brazil are located in the center of the road with the great advantage that they are freed from the effects of frontage property servicing/loading and, by virtue of the central location, are less liable to violation by other traffic. Centrally located busways do of course present other issues, including (1) ensuring safe access to/from bus stop platforms for passengers and (2) providing facilities for left turn traffic across the busway (the same issues apply to rail-based, street-running LRT).

In the case of the center-of-the-road busways in Curitiba, these two issues – passenger access and left turns – are less significant because the busways are located on the central road of "trinary" structural axes, and the adjacent traffic lanes do not have a primary traffic function. This provides a traffic environment that is less intense than conventional center-of-the-road busways in major traffic roads (see Sao Paulo case study); thus safe passenger access is relatively straightforward to arrange. Furthermore, because the center road of the trinary axes is not a major traffic route, traffic turning across the busway is not a major issue.

There is great merit in center-of-the-road busways, but Curitiba is not the model for an "instant scheme design" in other cities. Replication of the Curitiba "trinary" axes concept is unlikely in the short term in most cities. Indeed, in some cities, not recognizing the close relationship between the busways and the structure of the road system has led to unsuccessful attempts to replicate Curitiba busways. Clearly, design solutions exist (as has been demonstrated in other Latin America cities and with LRT in Europe) to overcome the issues in service, access, passenger handling, and so forth that arise when a bus lane is installed in the center of an existing road. Some examples follow:

- Adequate facilities can be provided for safe passenger access to/from stops by signals at junctions (e.g., Nagoya), or by pedestrian mid-block signals (e.g., Sao Paulo), or by grade separation (e.g. Tel Aviv);
- Secure protection can be provided from traffic while passengers are waiting on the stop platform by providing adequate platform width and protective barriers; and
- Left turns for traffic can be accommodated by signalized left or "U" turn lanes, or with special phases, or by indirect round-the-block routings.

Conclusion: The Curitiba center-of-the-road busway design (as part of the "trinary" system) is unlikely to be exactly replicable except in transit corridors that are either new or subject to massive redevelopment; however, alternative design actions exist to overcome center-of-the-road issues. The main constraint is finding roadways that are wide enough and also suitably located. Curitiba's 85-foot wide rights-of-way are not common in U.S. cities.[xxvii]

Bus Operations

The bus system in Curitiba, with its functional mix of buses and bus services, interchange-integration terminals, and integrated fares is unsurpassed worldwide. At the core of the busway system is the trunk-and-feeder principle. Curitiba uses the trunk-and-feeder system to overcome mainly the capacity issue, and, by the use of very large buses on the trunk lines, is able to use buses efficiently and maintain bus flows at a level that optimizes the busway operation. Key to the success of the trunk-and-feeder system, however, is good integration (both in terms of service and fares) between the trunk-and-feeder lines, and Curitiba has achieved this integration.

Busways, unlike LRT, allow local buses to collect passengers in a neighborhood, join a busway at any point, and proceed to the central area or other large attractor served by the system. Unlike LRT, such a busway system does not require passengers to interchange between a feeder mode and the trunk line mode.

However, there can be a problem if demand is very high, and there is a danger that busways may be over-loaded. There can also be a problem if bus volumes are high, but vehicles are not fully occupied. Such uneconomical use of vehicles requires that other bus routing arrangements be made. In such cases, trunk-and-feeder services with good passenger interchange are essential.

Conclusion: While the Curitiba trunk-and-feeder system is not a prerequisite for successful busway operation, the system can offer potential in the corridors of developed cities where demand is high.

Land Use and Transport Coordination

Curitiba is one of the few cities worldwide that has successfully implemented a policy of integrated land use and transportation supply over a long period (Singapore is perhaps the only other major city example). It has been stated that

> Curitiba chose to integrate land use and transportation at a very opportune time in its development, just prior to a very significant population surge. Mass transit has become more than just a transportation system; it is an instrument to control and guide city growth. . . . It is unlikely that many U.S. cities can expect such significant growth. In addition, many U.S. cities are at a mature point in development, and significant redevelopment is unlikely.[xxviii]

Although this is clearly the case, Curitiba has been able to sustain land use development by a mixture of controls and incentives and has used the transport system both to sustain and to encourage development (e.g., around terminals).

Conclusion: Integrated land use and transport is the aim of any well-managed city, but in stable cities, such as in the United States, that linkage is difficult to achieve. However, a long-term view must be taken. Transport supportive activities should be encouraged in busway transit corridors, and, where new development is scheduled, integrated development of busway transit and land use can bring great benefits.

Supply of Bus Services

In the developing world, it is a commonly held view that public sector bus services are inefficient, unresponsive to public demands, subject to political interference over fares, unable to generate adequate revenues for investment-replacement of buses, and require heavy subsidy. To seek to overcome these issues in developing cities (and to some extent in the developed world, notably the United Kingdom), there has been a trend towards privatization and deregulation of bus services. However, Curitiba has demonstrated that a well-run, regulated system is possible. Although the Curitiba system is operated by private sector bus companies, the system is highly regulated (in all respects including fares, service levels, quality of service, profits etc.), and service levels delivered to users are high. Bus mode share has been maintained despite increasing automobile ownership.[xxix]

Conclusion: Although the organization of bus services in a city depends on specific circumstances, the Curitiba system has shown that a combination of public-private initiatives can deliver a high-quality and efficient bus service and demonstrates the case for a regulated service to any city.

Organization

There are few citywide busway-based mass transit systems worldwide. One of the deficiencies of busway transit is that it has no unified promoter, and responsibilities are fragmented. LRT is usually developed by a single agency and sometimes supplied as a "package" by a single supplier (or some form of supply-operator consortium under a single contract). In the case of busway transit, numerous agencies are likely to be involved, including the transport planning agency, the traffic management agency, the highway agency, bus vehicle suppliers, bus operating companies, traffic police and so on. There is no unified structure for the delivery of busway transit. Curitiba has combined the functions necessary for the successful planning and delivery of the busway system under two agencies – IPPUC for planning and URBS for delivery. Not only are the two agencies professionally at a high level, but their semi-independent status from the city administrative structure appears to have ensured policy continuity.

Conclusion: Planning, design, procurement, and operation of busway transit should be treated in an integrated manner similar to an LRT system; the IPPUC/URBS arrangement in Curitiba is one example of how this may be achieved and possibly replicated.

Image

Many decision makers, politicians, and the general public do not view busway transit as a "state-of-the-art" mode. Arguments such as cost-effectiveness, potential for citywide route coverage at a fraction of the cost of LRT, and potential for incremental implementation, and so on, do not counteract the "image" deficiency of buses. The Curitiba system has a good image within the city and is much admired worldwide.

Conclusion: With additional resources, the quality of systems in U.S. cities could be increased through such measures as the following:

- Clean fuel buses;
- Low-floor, quiet buses;
- Real-time passenger information at stops and terminals;
- Smart card fare systems (being implemented in Curitiba);

- Security and safety (CCTV cameras at stops etc.);
- Improved amenities at stations; and
- Urban design and marketing enhancements.

APPLICABILITY TO U.S. CITIES

Many features of the Curitiba system have applicability in U.S. cities. These include the segregated median busways, multi-door buses, fare prepayment at major boarding points, distinctive vehicles, and attractive passenger interchange facilities. Several features, however, are not directly transferable. Bus rapid transit in the United States needs substantially higher speeds than those provided in Curitiba; travel distances are longer, and there is more competition from expressways. Also, buses usually need to provide service beyond the limits of the busway, and this is not practical where vehicles are designed for elevated loading. A more promising approach is the increased use of low-floor buses on BRT routes.

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[xiii] "Autobus in Site Propre," RATP, Paris 1977., The dimensions may vary by corridor but those shown are typical. The dimensions and the "same side of junction" location of stop platforms (Fig 2) are discussed in subsequent sections.

[xiv] Express buses do not use the dedicated busways but use similar "tube" stops in other locations; in the case of the express buses, the doors are on the left ("wrong side") of the vehicles to enable easier sharing of a single stop on a median.

[xv] A wide range of stop locations and configurations is possible including (i) one stop for each direction on the approach side junctions (Nagoya), (ii) mid block stops for each direction opposite each other (Belo Horizonte), (iii) mid block stops staggered/not directly opposite each other and with no bus overtaking (Porto Alegre), (iv) mid block stops staggered/not directly opposite with bus-on-bus overtaking (Sao Paulo), and so on. The current case study does not explore the advantages and disadvantages for each stop type.

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[xxvi] Some agencies suggest a capacity of 27,000 passengers per hour per direction with bi-articulated buses; such a capacity implies that buses are 100% full and have a headway of about 35 secs; both factors are possible but realization depends on passenger handling characteristics.

[xxvii] The detailed requirements for road width will depend upon the requirements for left turn lanes, suitable platform widths, through travel lanes, and frontage loading/servicing. Generally, a minimum curb-to-curb width of about 20 to 25 meters is required.

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[xxix] Of course, this is partly due to other constraints such as parking controls but the bus service does provide an acceptable service to car owners.

Table 1: Residential Densities in Curitiba’s Structural Axes and Adjoining Neighborhoods, 1992

		Residential Population		Dwelling Units	
Zone	**Population**	**Per Hectare**	**Per Acre**	**Per Hectare**	**Per Acre**
Mixed High-Rise Residential	130,700	294	119.0	93	37.6
Medium-to-High-Density Residential (ZR 4)	217,300	164	66.4	40	16.2
Medium-Density Residential (ZR 3)	240,800	76	30.8	22	8.5
Low-Density Residential (ZR 2)	416,506	63	25.5	17	6.9

Source: Instituto de Pesquisa e Planejamento Urbano de Curitiba (IPPUC), Advanced Planning Section, data files.

Table 2: Highlights in the Evolution of Curitiba’s Public Transport System

Year	Highlights
1974	Implementation of the first two express bus lanes along the northern and southern structural axes.
1978	Three new express busways added along structural axes.
1978	Introduction of a new computerized area traffic control system.
1979	Introduction of the social fare: a standard fare paid by all bus users that benefits those who live on the city periphery (predominantly low-income groups) as shorter journeys subsidize longer ones.
1979	Introduction of interdistrict bus lines to complement the existing public transport system.
1982	Opening of a new connection between the city center and the industrial city and improvement of the interdistrict routes.
1991	Introduction of the Rapid Transit System (Direct Lines) using boarding tubes.
1992	Introduction of bi-articulated buses.

Source: Rabinovitch S., and Leitmann J., “Environmental Innovation and Management in Curitiba, Brazil”, Working Paper No. 1 UNDP/UNCHS, (Habitat) World Bank, June 1993.

Table 3: Curitiba – Typical Cross Section for Busway Road

At Bus Stop Platforms		Mid Block	
Access traffic lanes	1 to 2 lanes (say 4.0-6.0m)	Access traffic lanes	1 to 2 lanes (say 4.0-6.0m)
Bus stop platform	Approx 3.5m	Parking-loading	Approx 2.0m
Busway (2 way)	1 lane each way (say 7.0m)	Separator bus-traffic	Approx 1.5m
Bus stop platform	Approx 3.5m	Busway (2 way)	1 lane each way (say 7.0m)
Access traffic lanes	1 to 2 lanes (say 4.0-6.0m)	Separator bus-traffic	Approx 1.5m
Total	Approx 22-26m	Parking-loading	Approx 2.0m
		Access traffic lanes	1 to 2 lanes (say 4.0-6.0m)
		Total	Approx 22-26m

Source: "Autobus in Site Propre", RATP, Paris 1977; the dimensions may vary by corridor but those shown are typical.

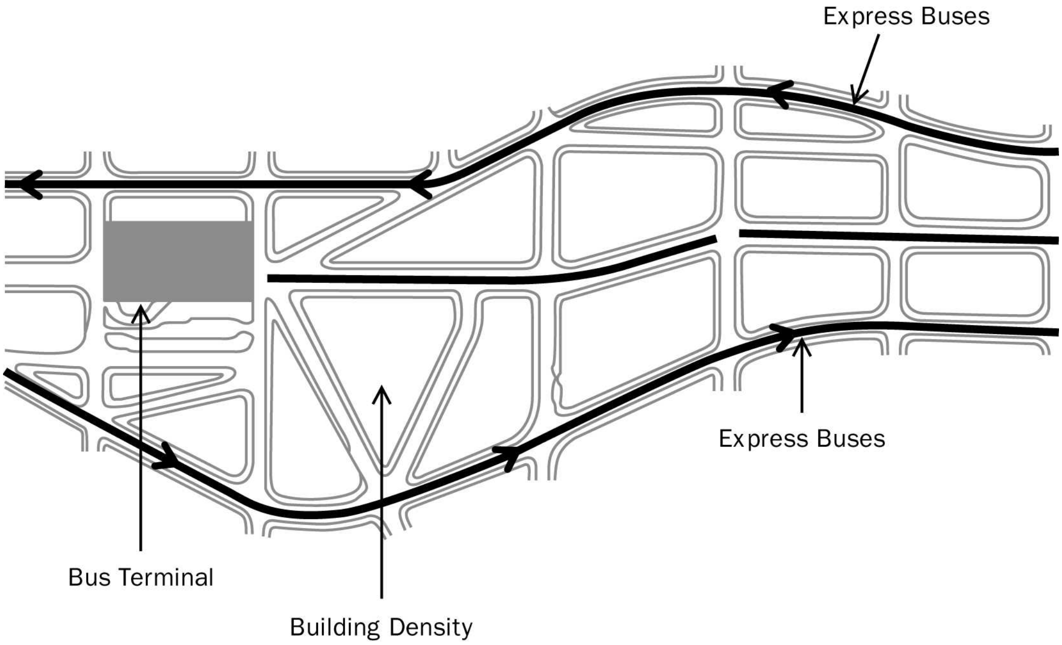

Figure 1: Trinary Road Concept

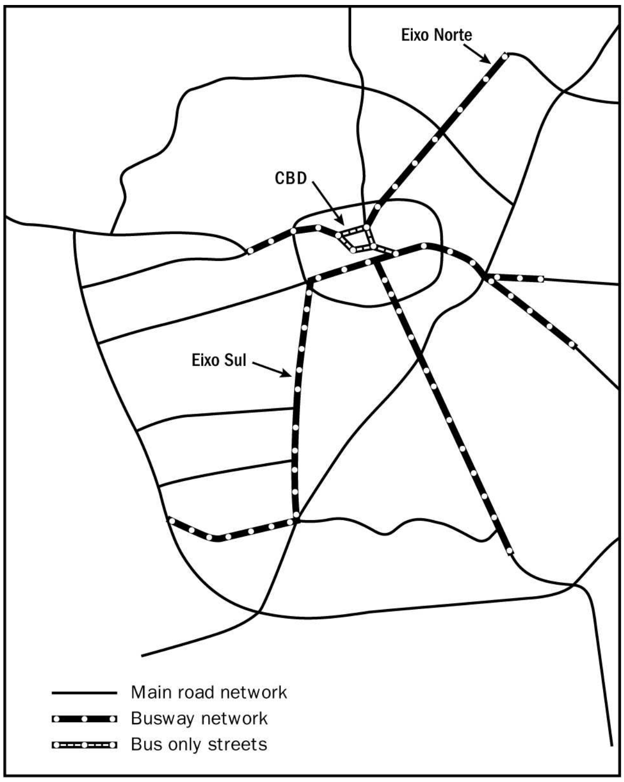

Figure 2: System of Bus Services

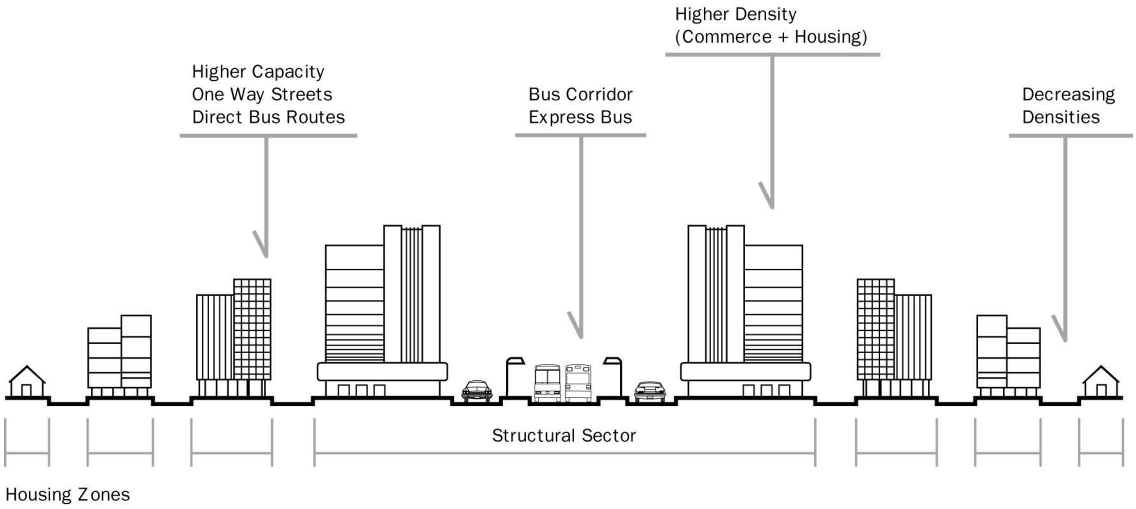

Figure 3: Schematic Arrangement of Structural Axes (From IPPUC, Rabinovitch and Hoehn, 1993 and *Creating a Linear City with a Surface Metro*, R. Cervero, UC Berkeley, 1995)

Figure 4: Bi-articulated Buses

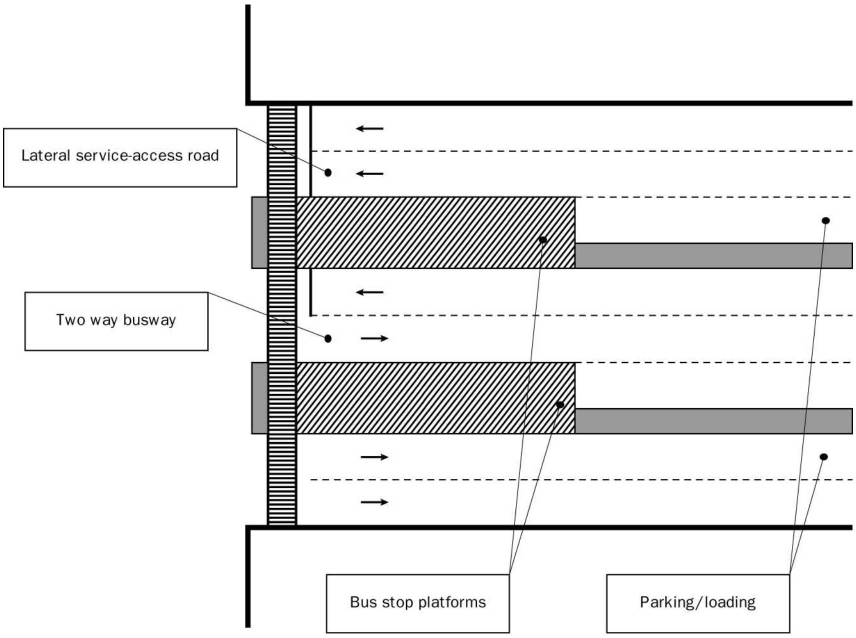

Figure 5: Cross Section of Busway and Service Roads

Figure 6: Tube Station Loading

Figure 7: Tube Elevator for Special Needs Users, View #1

Figure 8: Tube Elevator for Special Needs Users, View #2

Figure 9: Level Boarding of Buses

Figure 10: Bi-articulated Bus