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The Future of Exclusive Busways: The Brazilian Experience

by

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ABSTRACT: This paper examines the operation of urban bus transport systems based upon exclusive bus roadways (busways) in three cities in Brazil. The historic, economic, political, regulatory and operating context for these services is discussed. The strengths and weaknesses of busway systems in Curitiba, Porto Allegre and Sao Paulo are compared, with particular reference to the operating capacity of the busways. The paper concludes with an assessment of the importance of operations techniques, infrastructure development, land use planning, political stability and regulation to the success or failure of these systems.

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Introduction

The 1988 - 1990 study of Bus Priority Systems for Less Developed Countries carried out by the U.K. Transport and Road Research Laboratory (TRRL) and Traffic & Transport Consultants Ltd cited a number of examples in Brazil of Busway Transit providing an effective solution for the need to develop an efficient means of public transportation in urban corridors where demand of between 10000 and 30000 passengers/hour/direction exists (Cornwell and Cracknell 1990). This paper assesses the current effectiveness of the systems in three of the cities cited in that paper. In order to do so, the paper includes a substantial discussion of the economic, political, regulatory and operating context in which these systems have developed.

Cornwell and Cracknell defined Busway Transit as:

> "... a system that includes a right-of-way for the exclusive use of buses, with at least one section of the busway physically separated from general traffic, and some or all of the following:
>
> (a) a collector/distributor system at one or more ends of the busway, most likely including bus priority measures in the CBD area;
> (b) bus stops (physical layout; management etc.);
> (c) fare collection methods (e.g. on or off-board collection);
> (d) bus fleet (vehicle capacity, door configuration, etc.);
> (e) operations (e.g. bus ordering, express services); and
> (f) marketing (passenger information; corporate image, etc)"
>
> *(Cornwell and Cracknell 1990, 192-193).*

This paper applies the generic term "busways" to transport systems of this type.

Such systems exist in at least five Brazilian cities. This paper discusses the history and operation of busways in three of these: Curitiba; Sao Paulo and Porto Allegre. These cities have been chosen as they illustrate a number of major themes in the operation of busways - the relationship between urban planning and the effectiveness of busways; the impact of different regulatory systems; and the capacity of bus based systems to respond to demographic, political and economic and regulatory change.

Curitiba has been chosen as it has a world reputation for effective urban planning and urban transport. Sao Paulo provides a stark contrast - unplanned, congested, and with a contrasting reputation for urban degradation and restricted mobility. Porto Allegre provides an example of

the relationship between regulation and the effective operation of busways, and of the capacity of a bus system to adapt to reduced regulation.

Costs and revenues quoted are in Australian dollars, based on a conversion of the Brazilian URV to United States dollars and then to Australian dollars at June 1994 exchange rates. The volatility of the Brazilian exchange rate ensures that these figures can only be used as an approximation of long term costs and revenues. Other statistics are generally based on 1993 or 1994 results. Discrepancies between the two reflect either rapid growth or statistical error.

Brazil : National History And Profile

History

Brazil is the largest country in the continent of South America, both in terms of physical size and population. The characteristics of the country range from the famous Amazonian rain forest of the central and western regions, to the deserts of the north east, to the rich coastal areas south of the equator.

European settlement followed the discovery of Brazil by Portugal in 1500. Brazil was a Portuguese colony until 1823; an independent empire until 1889; and a Federal republic to the present day. The population is concentrated on the coastal strip from the Equator to the southern border with Uruguay.

The economic strength of Brazil was traditionally based on mineral and agricultural exports. During the 1950s a substantial industrialisation process commenced, with strong encouragement by the Federal Government. This has resulted in strong, export oriented automotive, heavy industry, aerospace and military equipment industries. This process of industrialisation has been accompanied by a major population shift to the cities.

The defining event in postwar Brazilian politics was the military coup of 1964. This ushered in a period of centralisation. A civilian administration was installed by the military in 1985, and a democratically elected civilian President took power in 1989. Brazilian politics has been characterised by ongoing tension between the Federal and State Governments; endemic corruption; instable economic policies; and intense nationalism.

The current political structure is based upon shared power between a Federal Government based in Brasilia; twenty six State Governments and the Federal District of Brasilia; and municipal government. In major urban areas inter-municipal bodies exist for the purposes of co-ordination of urban development and functions. For the purposes of this paper, the term

"urban" will refer to the traditional urban area of each city controlled by municipal government; the term "metropolitan area" to the urban area and the surrounding suburbs that are under separate municipal jurisdictions; and "State" to the State government.

Population Trends

The population of Brazil has increased from 121.3m in 1980 to 150.4m in 1990, and it is anticipated to be 179.5m in 2000 (IBGE, 1990). Concurrently, there has been a major migration from rural to urban areas, with a shift in the urban population from 46% of the total in 1960, to 59% in 1970 and 75% in 1988. The annual urban growth rate nationwide was 4.5% between 1960 and 1980 and 3.6% between 1980 and 1988. Twenty four million people were involved in internal migration between 1970 and 1980. This has resulted in the formation of major urban areas - in 1970 there were five cities with a population greater than one million; by 1987 there were eleven such cities (EIU 1991).

This survey discusses urban transport developments in three cities -

- Sao Paulo, in the State of Sao Paulo;
- Curitiba, in the State of Parana; and
- Porto Allegre, in the State of Rio Grande do Sul.

The following table summarises demographic trends and the urban transport infrastructure in these three cities.

Table 1 Urban Demographic Trends - 1991

	Sao Paulo	Curitiba	Porto Allegre
Urban Population	9.48m	1.29m	1.26m
Metropolitan Area Population	15.20m	1.98m	2.94m
Metro Area	7951 km^2	8763 km^2	5806 km^2
Pop. Density	1912/km^2	567/km^2	507/km^2
Pop. Growth 1970 - 1980	3.67% pa	5.34% pa	2.43% pa
Pop. Growth 1980 - 1991	1.00% pa	2.11% pa	1.05% pa
Urban Buses	9779	1696	1930
Metro Lines	43.6 km	Nil	Nil
Urban Trains	192.0 km	Nil	27.0 km

Source : Almanaque Abril 1993.

The distinction between the "urban" and the "metropolitan area" populations reflects the growth of these cities to areas outside of their traditional boundaries. "Metro Lines" refer to underground, heavy rail services; "Urban Trains" refer to suburban services operating on existing rail lines.

Regulation Of Urban Transport

Public transport in all three cities is regulated by a combination of city (municipal), regional (metropolitan) and State bodies. In all cases the service levels and fares are controlled, but this control is diluted by substantial illegal bus operations (Sao Paulo); competing minibus systems (Porto Allegre); or by services provided within the urban area by operators from the surrounding metropolitan region that are outside of the control of the urban authorities (Curitiba and Porto Allegre).

Curitiba

Curitiba has the most comprehensive regulatory regime of the three cities. From 1965, bus transport has been given a pivotal role in the implementation of the city plan. The operation of bus services is controlled by a municipal body - URBS (Urbanizacao de Curitiba S.A.) - which controls not only buses but taxis, parking lots, public shopping areas, markets and bus

terminals. URBS acts as a planning body, a regulator and controller of the bus system - collecting all fares but contracting out the operation of the buses to private operators. The centrepiece of the Curitiba operation is the RIT (Rede Integrada de Transporte - Integrated Transport Network), which consists of a hierarchy of seven bus systems linked through "Integration Terminals". The operation of this system is dependent upon total integration of all the bus operations in the city. Fare revenues are pooled and paid to contractors on the basis of the service provided. Contractual payments are based on a complex formula that takes into account the full cost structure of the contractors. Vehicles are provided by the contractors. The only interruption to the control of this system is created by the lack of co-ordination with the transport systems in the surrounding cities (suburbs). To date, only one of these has permitted the extension of the RIT across the municipal boundary. This results in the operation of suburban buses within the urban area. However, they are restricted from conveying urban passengers. The principle disruption caused by this division is the inability of URBS to adequately plan for the metropolitan area, and to strengthen the bus corridors that operate to the urban boundary with the patronage available from these suburbs (URBS 1994).

Porto Allegre

Porto Allegre suffers from having the highest proportion of the metropolitan population resident outside of the urban boundary (57%, against 35% in Curitiba and 38% in Sao Paulo) (Almanaque Abril 1993). Furthermore, urban transport is provided by three modes - buses; minibuses and an urban rail line. The minibuses provide a competing service on high frequency scheduled routes charging a 70% premium on bus fares. The urban rail line was built by a Federal body (EBTU - Empresa Brasileira de Transportes Urbanos) during the period of the military dictatorship. It has failed to reach more than 31% of its projected ridership (110000 pax/day carried vs. a 350000 pax/day projection), and with the disbandment of EBTU in 1990 is now for sale (ATP 1994)

Regulation of the urban bus system was formerly heavily influenced by EBTU, which was responsible for developing and supervising bus corridors and providing an integrated network between various bus operators and the urban rail line. The demise of EBTU has removed this layer of regulation.

Urban operations are currently regulated by the municipal government in regards to routes operated and fares charged. Metropolitan operations are regulated by the State government in a similar fashion, but there is little co-ordination between the two in the areas where metropolitan buses enter the urban area. The effectiveness of restrictions on metropolitan buses operating within the urban area is open to doubt, but the prevalence of flat fare systems and the substantial premium on the fare of the longer distance metropolitan services effectively

limits their attraction to urban bus users, even though both groups of operators share in the use of the urban busways. Fares are set by the Municipality at a level that covers all operator costs as defined by an analysis of industry cost structures.

In contrast to Curitiba and Sao Paulo, there has been a significant reduction in the level of regulation of urban transport in Porto Allegre. The demise of EBTU has removed the integration formerly provided by EBTU, and this has led to a discontinuation of supervision on the busways; and of fare free transfers between operators at Integration Terminals. Furthermore, a relaxation on the limit on the size of minibuses (from 17 to 21 seats) has permitted the growth of competition from this sector. Effective fare pooling is now provided by the operators themselves through the industry association ATP (Transport Companies of Passengers Association of Porto Allegre), rather than by the municipality. Porto Allegre is the least regulated of the three cities.

Sao Paulo

The regulation of urban transport reflects the size and complexity of the city (15.2m residents in the metropolitan area, 5.72m of which are outside of the urban boundary). There are four major transport systems centred on the urban area - the urban bus system (CMTC - Companhia Municipal de Transportes Coletivos - a municipally owned company); a State underground railway and associated bus network (Metro and EMTU - Empresa Metropolitana de Transportes Urbanos de Sao Paulo S.A.); and two long distance rail networks that also provide urban services (FEPASA - Federal Railways and CBTU -State of Sao Paulo Railways). Of the nine million daily passengers on these systems, 67% travel by bus; 22% by Metro; and 11% by each of the railway systems (CMTC 1994). Overlaying these systems are a range of both Municipal and State planning bodies. There is no coherent transport organisation for the whole Metropolitan area, although Metro/EMTU has aspired to this role. Municipal planning is now predicated on the assumption that shortages of funds will limit the future role of Metro/EMTU, and that major transport infrastructure development in the city will be initiated and funded from private sources under the direction of CMTC.

The regulation of the urban bus system is controlled by CMTC, which was established in 1947 to acquire the tramway assets of the local power utility. By 1949 CMTC was also operating diesel and electric (trolley) buses. The intention of CMTC was to establish an operating monopoly in the urban area, and this came closest in fruition in 1954 when the company was operating 90% of the city's buses. However, CMTC was overwhelmed by the urban growth of the city during the late 1950s. Private buses re-appeared in 1957, and by 1977 CMTC was reduced to operating 14% of the urban buses. Increased investment increased this proportion to 30% by 1993. In 1994 a process of privatisation was implemented, whereby CMTC totally

divested itself of bus operations.

Throughout this period CMTC has functioned as the regulator of the urban bus system, controlling the operation of private buses within the urban area. These operations have moved in stages from a simple licensing to the current system known as "Municipalisation", whereby fare revenues are collected by CMTC and paid to contractors on the basis of a cost formula and passengers carried.

The transformation of CMTC from an operator and regulator to a regulator was primarily the result of the transport policies of Mayor Luiza Erundina de Sousa implemented in 1990/1991. Winning office on a left wing program that aimed to significantly increase the quality of bus transport in the city (where bus numbers had stagnated at 8500 for ten years, despite population growth), the program included the introduction of free fares ("Tarifa Zero"); the supply of large numbers of new buses (imported from Eastern Europe if necessary); and the "municipalisation" of fares (i.e. CMTC collecting revenues and paying operators on the basis of resources used). As an adjunct to this, private operators who lacked route licences were invited to provide additional buses on the city's routes.

Whilst the "Tarifa Zero" was rejected by the Municipality, the other aspects of the plan were implemented. This led firstly to a breakdown in regulation, with 3000 "pirate" buses operating on the city routes without route licences. Secondly, a rapid expansion in the size of the licensed fleet (from 8500 to over 10000) and an improvement in quality (from an average fleet age of 8.5 to 3.5yrs) co-incided with a period of no patronage growth, due to the economic recession. Fare income remained stable, but costs exploded as operators were reimbursed on the basis of resources provided.

In 1992 an attempt was made to control the "pirate" operators, with permits being issued for 600 buses. However, this has been only partially effective, with 1400 unlicensed buses remaining in service in 1994.

In 1993 a new administration was installed, and quickly concluded that this cost explosion would bankrupt the system within six months. Faced with the alternatives of a major fare increase (100% over the existing inflation rate) or privatisation, and noting the major cost advantage of the private operators (a cost per passenger of 67c vs $1.73 for CMTC), a rapid privatisation plan was implemented. This involved the disposal of three thousand buses (including 470 trolleybuses) to private operators and reducing CMTC employment from 27000 to 800 in twelve months (CMTC 1994).

CMTC now concentrates on the regulation of the urban bus network; the implementation of

new technology; and the development of a city-wide system of busways and integration terminals with private sector capital. Metro/EMTU continues to provide the underground rail service (45km on three lines carrying 2m pax/day) and an urban bus network that crosses the urban boundary, linking major suburban centres with Metro stations within the urban area.

Fare Systems, Funding And Operator Contracts

In each of the cities the principal means of funding is through the fare box, with only Sao Paulo providing municipal funds to support operating costs. Similarly, each city has a form of fare pooling, whereby revenues are aggregated and distributed on the basis of services provided. Fare systems are based on flat fares, which are in part implemented to ensure social equity for poorer residents who tend to live on the outskirts of these cities.

Fares are generally collected by conductors seated near the rear door. Passengers enter by the rear door to a holding bay; pay the conductor; and pass through to the main body of the bus. Passengers alight from the front door. Sao Paulo operates certain routes on the reverse principle, with passengers paying after entering the front door. Tokens are used for many forms of payment, as inflation rates of up to 40%/month have made coins inoperable as a form of currency.

Curitiba

Services provided within the urban area of Curitiba under the auspices of URBS charge a flat fare equivalent to AUD 0.53 (URBS 1994). Periodical fares are set to ensure that the "average worker" spends no more than 10% of income on transport (Herbst 1992). Flat fares are a deliberate policy to provide social equity for all residents of the city. Fares are set at a level to ensure that no subsidy is required to cover payments made to contractors.

A central feature of the RIT system is the provision of 16 sixteen transfer terminals, where "fare free" transfers are available between all services meeting at these points. These "free" transfers are an essential element of the integration of the city's transport system. The proportion of passengers making fare free transfers by type of service is set out in Table 2 .

Table 2 : Curitiba Bus Passengers By Service And Fare Type
Weekday Average Passenger Numbers - 1993

Service Type	Fares Paid to Conductor	Transfer Fares	Total Fares	Proportion of transfer pax
City Circular	5014	Nil	5014	0%
Conventional	343585	22264	365849	6.1%
Feeder	197649	168002	365651	45.9%
Intersuburb	94510	80470	174980	46.0%
Express	227138	131256	358394	36.6%
Speedybus	71201	138130	209331	66.0%
Bi Artic Exp	57976	37684	95660	39.4%
TOTAL	**997073**	**577806**	**1574879**	**36.7%**

Source: URBS 1993a.

The free transfer ticket is used by 36.7% of the average weekday patronage. Of the routes that are designed the serve the transfer terminals (all except the "City Circular" and "Conventional" services), 46.1% of the patronage is transferring. Furthermore, these transfers are occurring on the services which have shown the most patronage growth, and are targeted for further expansion ("Speedybus" and "Bi Artic Express"). A more detailed explanation of the service types is provided in Section 7 below.

Operator remuneration is provided through direct payments to the operators, calculated on the basis of the volume (km) and type of service (vehicle type) that is provided. Operators are responsible for the full operating and capital costs for their allocated routes. Contract payments are calculated from an analysis of each operator's cost structure, with a capital component based on the age and type profile of the fleet operated. Profit margins are set at 10% of turnover (Worcman 1993).

Porto Allegre

Urban services in Porto Allegre charge a flat fare of AUD 0.49 (ATP 1994). This fare is determined by the Municipality on the basis of an examination of the operators' cost structures and patronage numbers. The fare level covers all costs incurred by the system. Table 3 indicates the four fare types and their usage

Table 3 Fares Sold Per Month By Type - 1994

Type of Fare	Number Sold	Proportion

"Transport Ticket"	15000000	42.9%
Cash Fares	10000000	28.6%
Student Half Fares	5000000	14.3%
Free (elderly & others)	5000000	14.3%
TOTAL	**35000000**	**100.0%**

Source : ATP 1994.

Revenue is distributed by type of ticket. Operators retain revenues generated by cash and half fares, but receive no compensation for the revenue foregone for student and concession fares.

The "Transport Ticket" is a periodic multi-operator commuter ticket sold by ATP and valid for use on all urban services. Revenue from the "Transport Ticket" is controlled by ATP and distributed on the basis of kilometers operated. The fare receives limited Government support through an indirect employee subsidy -where the ticket is purchased by the employer, that portion of the fare over 6% of the monthly salary of the employee is tax deductible. Both the municipal operator and the private operators participate in this arrangement.

Transfer between buses is not facilitated. The "Transport Ticket" does enable this, but Integration Terminals established under the EBTU period no longer provide for "fare free" transfers. The elimination of "free transfers" has had no measurable impact on patronage.

Sao Paulo

The flat fare applicable in Sao Paulo is AUD 0.88. Through fares to the Metro are also available, as are periodical tickets. A major integration terminal at Santo Amaro provides "fare free" transfers to services in that area, but this is not a dominant feature of the overall transport network. All fare revenue is collected by CMTC and distributed to contractors by a formula that allocates a cost/passenger for the routes served. Thus routes with short distances and high average loadings are paid a lower rate/pax than long routes with lower average loadings. These fares contribute 88% of the costs of operating the bus system -the balance is provided as a subsidy by the Municipality through CMTC. Two percent of the funds distributed by CMTC are targeted towards operators that achieve quality and productivity benchmarks set by CMTC (CMTC 1994).

Ownership Structures

Bus operations are provided exclusively by private operators in Curitiba and Sao Paulo, with a small municipal operation in Porto Allegre.

Curitiba

There are ten private operators in Curitiba providing 1250 buses for URBS services. These operate under contracts that have evolved from original contracts established in 1955. Each contractor has routes in a geographic "slice" of the city. Contracts are "rolled over" on expiry with no tender process. Efficiency is maintained by tight supervision of each company's finances and by "benchmarking" between operators (URBS 1994).

Porto Allegre

Fifteen companies and one municipal operator provide urban services with 1360 buses (258 or 19% are owned by the municipality). In addition, there are 403 minibuses operated by 200 owners on competing, scheduled route services. A further 700 buses from the Metropolitan area also operate into the urban area. Route allocations are determined by the Municipality. However, it is currently proposed that route allocations be tendered in 1995. There is considerable confusion regarding the relationship between the Municipality and the private operators, that was unresolved in June 1994.

Sao Paulo

CMTC currently supervises operations by approx. 11000 buses in the urban area. All services are provided by private companies. These operate under a range of contract types, depending on the history of the operation:

(1) private operators that existed in 1993;
(2) private operators that tendered for services in 1994 but provided their own equipment;
(3) private operators that tendered for services in 1994 but lease equipment from CMTC;
(4) "pirate" operators that received temporary permits in 1992; and
(5) "pirate" operators that continue to operate without permission.

The goal of CMTC is to establish a standard 8 year contract let by tender. With new projects these contracts may involve the provision of substantial infrastructure in the form of dedicated bus roadways, in addition to the supply of buses and operating services.

Urban Planning

Brasilian cities have experienced major expansion during the past fifty years, resulting from both natural increase and internal migration. Cities have responded in two ways to this process

- those that have allowed planning processes to be overwhelmed by the growth, and are now engaged in trying to "insert" urban transport systems into an existing city structure; and those that have managed growth around transport corridors, such as Curitiba. The role of busways in the three cities examined is predicated by their position in the urban planning process. For this reason, it is not necessarily appropriate to compare systems in Curitiba with the Sao Paulo or Porto Allegre, unless the role of urban planning in Curitiba is accounted for.

Curitiba

Population growth in Curitiba has taken a small capital city of an agricultural state with a population of 140000 in 1940 through to a medium sized city of 500000 in 1965 to today's urban population of 1.29m and a metropolitan population of 1.98m (Herbst 1992).

The key decisions in the management of this growth were made in 1965, when a traditional urban master plan was jettisoned in favour of a scheme that would concentrate high-density growth along five slender corridors radiating from the city centre. This decision was rigidly enforced by the municipal government, and supported by land resumptions. High-rise developments were restricted to a four-block corridor on either side of these "transport axes". Much of the subsequent development (including 17000 low-income units) was then constructed by the Municipal Company for Housing (COHAB).

This development was strengthened by preserving the historic downtown area, through pedestrianisation of a central 17 block area, and encouraging the development of markets and 24-hour shopping precincts. With retailing based in the CBD, industrial employment was similarly channelled to the Curitiba Industrial City (CIC). This development, commenced in 1973 as a model industrial park, currently generates 20% of the jobs in the Metropolitan area. Public transport was facilitated by concentrating residential development on corridors that featured exclusive bus lanes, and concentrating employment in only two centres (CBD and CIC).

This development was overseen by the remarkable political stability of the Municipal government. Mayor Jaime Lerner, first appointed under the military dictatorship in 1971, held office until 1992, through successive changes in Federal governments and the introduction of democracy. The combination of a visionary mayor with an absolute commitment to the city's planning goals with 21 years of stable government provided a platform for orderly development that no other Brasilian city could match during this period of major political and economic change.

This combination of establishing clear planning goals prior to the major development of the city, with consistent management and political stability, has provided the platform upon which the Curitiba transport system has been developed.

Porto Allegre

The planning base for Porto Allegre provides a significant contrast to that of Curitiba. As an older city built around a harbour foreshore, planning was restricted by geography. Furthermore, the political structure of the city is fractured by the high proportion of the metropolitan population that is resident outside of the area served by the urban government (57% compared to 35% in Curitiba).

Further complexity was added by the strong role played by the Federal agency EBTU. The EBTU master plan - based upon the urban railway and the development of exclusive bus roadways - floundered with the disbandment of the Federal body in the decentralised political climate of 1990. The city allowed the co-ordinating aspects of this plan to flounder, and whilst the operators were successful in developing a co-ordinated fare regime, other aspects of the plan lapsed.

The current operating environment in Porto Allegre reflects these changes in political commitment to integrated transport in the city.

Sao Paulo

As one of the world's first Third World "mega-cities", Sao Paulo has long been a by-word for the negative impact of massive population growth in an ill-prepared urban environment. Although growth rates are lower than in the other two cities, the current annual increase of 1% will still add 1.25m residents (equivalent to the urban populations of either Curitiba or Porto Allegre) over the next five years.

As with Porto Allegre, political power has been divided, both between the urban Municipal government and the surrounding cities, and between the Municipal and the State governments. This has been compounded by the development of major transport infrastructures by each group, with CMTC pursuing exclusive bus roadways; the State government building the Metro underground rail lines; the "cross border" EMTU exclusive bus network and operating one of two metropolitan rail systems (CBTU); and the Federal government operating a second metropolitan rail system (FEPASA). Further planning breakdown resulted from the disparity between the goals of the Municipal bus operator

(CMTC) to provide the total system; and the reality of a constant requirement to rely on the private sector to meet the transport demand. Co-ordination between these organisations has been attempted by a series of planning bodies, none of which has produced a plan that has been capable of implementation. In particular, all of these plans suffered from the assumption that a full 147km Metro rail system would be constructed, when in fact only 45km is operational and further growth in proceeding at a glacial speed. This in turn reflects Federal priorities in the urban transport area and the position of the World Bank in funding such developments (SMT 1993b).

This disjointed transport planning framework reflects the general failure of urban planning in Sao Paulo during an extended period of massive population growth. As with Porto Allegre, the development of urban busways in Sao Paulo must be assessed in the context of both this population growth and planning failures.

Development & Operation Of Busways

The development of busways (exclusive bus roadways) in these three cities has been driven by five forces:

(1) the relentless growth of population, particularly on the extremities of these cities, that require an efficient transport system;
(2) the requirement for operational efficiency, as transport systems required rapid expansion during a period of on-going national political and financial chaos, with hyperinflation, currency crises and unmanageable deficits at local, State and Federal levels;
(3) the influence of the World Bank, which during the 1980s turned against "showcase" urban rail projects, on the basis of the benefit/cost ratios of such schemes;
(4) the strength of the local bus manufacturing industry, which has developed into the largest in the world; and
(5) the success of the Curitiba model, in terms of both efficiency and service delivery.

Each city has produced different variations on the busway theme, with Curitiba and Sao Paulo pushing bus technology and operating capacity to new limits. Porto Allegre, which at one stage operated the most intense busway in the world, has fallen behind the other two cities in innovation and operations, as the regulatory regime has altered and political support withdrawn.

From Busways to the System - The development of the RIT

Curitiba

The 1965 decision to concentrate urban development along radial corridors first impacted the Curitiba bus system with the introduction of the Express bus routes in 1974. Twenty buses operating with a distinctive red colour scheme were introduced on a 19.8km North-South exclusive bus lane, carrying 25000 pax/day. This route replaced eight existing conventional bus routes. The Express routes were fed by a 45km of feeder services. Further Express routes - all travelling in exclusive bus roads outside of the CBD - were introduced in 1976 and 1979, and continuing development led to the existing network of 56km of Express routes, served by 208 buses, carrying 454000 passengers daily. These services are fed by a further 300km of feeder services.

However, the development of these Express bus routes on exclusive bus lanes has only been one element in the RIT system. Just as the system cannot be assessed independently of the urban planning context in which it operates, neither can these busway services be considered independently of the supporting initiatives for non-busway services. In 1993, less than 50% of bus passengers in Curitiba were using the busway services, although in terms of passenger/km the proportion would have been higher.

The first of these initiatives was the 1979 introduction of the "Interbarrios" or cross-suburban services. These linked the Express route termini by means of cross-suburban routes. In 1993 there were seven of these connecting routes, carrying 11% of the daily patronage.

In 1980 RIT was established, with the implementation of the first Integration Terminals (manned, covered, barrier free transfer points between Feeder, Express and Intersuburban bus services); the "free transfer" between services at the terminals; and the flat "social fare". The sixteen terminals now in operation form the foundation of the system, facilitating transfers between the various elements of the RIT system.

In 1991 a third principle form of corridor was added to the Express lines and the Interbarrios services - the "Linha Direta", or, as it is popularly referred to, the "Ligerinho", or "Speedybus". The Speedybus has proven to be the "engine" of much of the recent growth in patronage in Curitiba and, curiously in a city that has a world recognised series of busways, does not make use of any of these exclusive bus lanes. The Speedybus links the principle transfer points on the system (the Integration Terminals); a limited number of major stops; and the CBD area with a series of high speed bus routes. These avoid the busways, as the more frequent stops of the Express buses would impede operating speeds, and as a number of the

busways (particularly the North-South corridor) are heavily congested with buses. Unlike Sao Paulo, the Curitiba busways have no provision for buses to overtake. To further increase operating speeds, the Speedybus system is supported by purpose design bus stops ("Tubes"). These "Tubes" function as mini-stations on the bus route. Passengers pay a seated conductor on entering the tube, and board the bus across a step free ramp. This minimises the delay at stops. The Speedybus services operate at an average speed of 34km/hr (against 22km/hr for the Express buses), and have reduced daily travelling times for many passengers by over an hour. This improved service has led to rapid growth, with 28% of Speedybus passengers transferring from private cars. In June 1994 the Speedybus network was served by 156 buses that carry 300000 passengers/day (URBS 1994).

The success of the Speedybus illustrates three characteristics of the Curitiba system. Firstly, patronage growth in Curitiba has resulted in part from tailoring service provision to market needs (in this case reduced travel times), even when new services did not use all of the existing infrastructure (the bus lanes). Secondly, the growth of patronage and services on the busways has reached the point where they now suffer from congestion that is impeding further growth. Thirdly, the high mode split in favour of bus transport for commuters (75% of daily commuters travel by bus), has resulted in low traffic volumes that allow higher average speeds for buses on the general road system than on the exclusive bus lanes. Each of these characteristics supports the contention that the busways are only one factor contributing to the success of the RIT.

Congestion on the busways, created both by the volume of buses in use and the impact of intersections on through bus traffic, is the major current issue to be resolved in the development of the RIT. At one stage URBS saw the busways as an interim step to the development of a light rail (LRV) network. It was considered that only LRV could convey the predicted volumes at the speeds required. However, two developments have led to the abandonment of LRV plans - the relative costs of LRV, and technological advances in bus design and operating techniques that have significantly lifted the capacity and speed of busways, for little additional cost.

These advances were demonstrated through the upgrading of the Boqueirao Express route in 1992. This project consisted of combining the advances already implemented with the "Speedybus" - the tube stations - with biarticulated buses. The tube stations were installed at every stop along the Boqueiro to City route - 11km of exclusive busway. The buses were designed to maximise both loading speeds and capacity, with five doors designed to integrate with the tube station entrances, and a total capacity of 270 passengers. This project demonstrated that this combination could deliver a high quality, fast and high capacity service at a minimal capital cost to the Municipality. The Boqueirao route is currently operated by 33

biarticulated buses. There are 30 tube stations, spaced at approx. 500m intervals, and three Integrated Transfer Terminals on the route. At the current frequency, 10000 pax/hour are transported in the peak direction. URBS estimates that up to 22000 pax/hr could be efficiently transported at an equivalent speed to the current Express network (22km/hr) with this system.

The costs of the system to URBS have been minimal. Firstly, the use of large capacity bi-articulated buses reduces the overall bus and staffing requirement. The 33 biarticulated buses replaced 66 conventional vehicles, generating a 12.5% reduction in costs/passenger. (URBS, 1993). Thus the operating costs of the enhanced busway is less than the existing system, which itself meets all operating and capital costs without subsidy. Furthermore, the infrastructure cost for the Boqueirao was AUD2.7m for the entire route. The estimated cost of an LRV system was AUD21m/km, or nearly eight times greater (URBS, 1992). Given that the biarticulated busway is estimated to have the capacity to meet anticipated demand, Curitiba has abandoned all plans to move away from bus-based technology, and proudly promotes this system as their "Surface Subway".

The fundamental remaining difficulty for the RIT is the integration of the Curitiba urban bus network with the surrounding metropolitan area. Although one Speedybus route has been expanded across the city boundary, and plans exist for further extensions of each of the five trunk routes, political differences remain an effective barrier.

RIT Operations

The urban area of Curitiba has the second highest level of car ownership in Brazil, with 562000 motor vehicles, or more than one car per household (Worcman 1993 and URBS 1994). Within this environment, the urban bus network carries 997000 pax/day (1575000 if transfers are counted twice) (URBS, 1993a). 75% of the city's commuters and 50% of all of the residents use the bus on a daily basis (The Economist, 27/4/1993 and Worcman 1993). Table 4 outlines the current breakup of passengers between the various types of bus service.

Table 4 Service Characteristics - 1993

Type of Service	Number of Routes	Fleet Size	Daily Passengers	Percentage of Total	Average Speed
City Circular	2	11	5014	0.3%	N/A
Conventional	92	399	365849	23.2%	17 km/h
Feeder	115	328	365651	23.2%	N/A

Intersuburb	7	125	174980	11.1%	N/A
Express	19	179	358394	22.8%	22 km/h
Speedybus	10	135	209331	13.3%	34 km/h
Bi Artic Exp	2	29	95660	6.1%	22 km/h
TOTAL	**247**	**1206**	**1574879**	**100.0%**	

Sources :URBS 1993a and URBS 1994.

The RIT system does not carry the high passenger per hour volumes that are experienced on busways in Porto Allegre and Sao Paulo. This reflects the marketing emphasis of URBS, which ensures that the system offers an attractive service to passengers by avoiding "crush loadings", the ability of Curitiba's planners in maintaining capacity growth in the system at a rate in excess of demand growth; and the effect of service innovations that have reduced congestion on major corridors (such as the Speedybus). The most congested corridor in 1994 was the southern sector of the North - South route, carrying 11000 pax/hr in the direction of peak, with a theoretical capacity of 12650 pax/hr. Current loadings on the Boqueirao route approach 10000 pax/hr, with a theoretical potential of 22000 pax/hr. These existing capacities must be assessed in the context of the high average speeds currently achieved. The theoretical loading projections may be not be compatible with the current operational speeds.

The RIT system has clearly achieved many of the primary goals of an urban transport system - a high mode share in a city with significant car ownership; patronage growth matching population growth; and an effective network of services meeting market demands. Although "Curitibanos" are often criticised for overselling their city, the effectiveness of their bus system justifies the city's reputation as an example of effective land use and transport planning, and creative and efficient provision of transport services.

Porto Allegre

Exclusive bus roadways were a key plank in the policies implemented by the EBTU in Porto Allegre between the late 1970s and 1990. A total of 42km of these lanes were constructed in the medium lanes of fival arterial roads serving the CBD. The capacity of these busways was further enhanced by the institution of a "convoy" system, to ensure that buses used the roadway in a pre-ordered pattern, to reduce delays at intermediate stops. Central organisation was necessary as each of the lanes were used by a number of private and one municipal company (ATP 1994).

As an early example of the busway system, Porto Allegre attracted worldwide attention. In particular, two of the bus lanes (Farrapos and Assis Brazil) were noted as carrying very high loads in the peak hour (26100/hr Assis Brazil and 17500/hr Farrapos). Furthermore, this was achieved at reasonable average speeds (22.7 and 19.7 km/h respectively). These results were reported by Transport and Road Research Laboratory study in 1990 (Gardner and Fouracre 1990). The Porto Allegre results were the highest recorded in this international study in terms of peak hour loadings and the second highest in terms of average speeds. Results such as these have influenced bodies such as the World Bank to reduce support for rail based solutions in Third World cities.

Unfortunately, the Porto Allegre busways can no longer produce these results. In 1994 the Assis Brazil was still used by 20000 pax in the peak hour, but the 280 buses/hr that carried these passengers were moving at an average speed of only 12 km/hr. Operators represented by the ATP did not provide any explanation for this decline. It is possible that the earlier result was "oversold" by EBTU, as the study was conducted during the dying stages of that organisation's existence. Alternatively, the removal of the EBTU "organisational umbrella" over the operations of many companies may have led to a substantial decline in service quality. In particular, the convoy system has not been maintained, and the fare-free transfer interchanges no longer function in this manner. The current capacity of these routes is similar to that achieved in Sao Paulo, and may reflect the maximum speed that is possible when 4.7 buses per minute are operating on a single lane over 4.5km with stops every 560m.

The current performance of these busways in Porto Allegre gives credence to the policies of URBS in Curitiba, where enhanced performance is considered to be possible only with substantial upgrades to technology and operating methods. The major technological differences in Curitiba are the use of higher capacity buses (five-door 270 passenger double-articulated in Curitiba and one-door 110 passenger conventional rigid buses in Porto Allegre) and "tubes" at bus stops that reduce standing time with prepaid fares and "no step" entry. The principle operational difference in Curitiba is the operation of only one route on the corridor, with interchange by passengers required at either end and at set intermediate transfer stations on the route. This eliminates the requirement for passengers to choose their bus at the intermediate boarding points, which increases dwell times by buses at stops. The "convoy" system in Porto Allegre had attempted to resolve this obstacle, by enabling passengers to predict the order in which buses on different routes would arrive at each stop, and thus minimising the confusion created when a large number of buses arrive simultaneously. The breakdown of this system, and the slow boarding times at stops, undoubtedly make a major contribution to the slow speeds achieved on these busways.

These differences reflect the political environments of the two cities. Curitiba RIT system

developed during the 21 year "rule" of a charismatic mayor committed to designing a city that could prosper without dependence on private transport, and has bequeathed a powerful ethos to his successors. There is little uncertainty in regard to either future planning directions or political support in Curitiba. By contrast, the bus operator's in Porto Allegre are characterised by uncertainty (regarding contract term; biased administration of route allocation; competition from minibuses), and are focussed on ensuring continuing financial viability. Whilst this has led to the development of an innovative fare pooling arrangement, it has undermined the capacity of the city to offer residents a comprehensive transport system.

Sao Paulo

Four busways exist in Sao Paulo - three operated by the municipality (CMTC) and one "cross border" system by the State (EMTU). These two operators have both developed these busways as elements in a larger plan, although political instability, lack of resources and planning inconsistency have robbed these plans of long term coherence.

From the mid 1960s parallel bus and rail based plans were developed to provide Sao Paulo with an adequate urban transport system. From 1966 concrete steps were taken to construct the Metro - a planned 147km network of high speed underground rail lines. The initial 42km of this system was implemented by the early 1980s, but progress was then halted, and only a further 3km has been developed during the past ten years. Concurrently, a network of 33 trolley bus routes was planned, published as SISTRAN in 1975. These routes were to be characterised by dedicated bus lanes and Transfer Terminals. However progress was slow, and only one route was partially implemented by 1982. A further plan was published in 1983 (PAI) to develop four corridors, again based on trolley buses, terminals and bus lanes. Construction commenced on one corridor (Santo Amaro - Avenue 9 de Julho) in 1985. This was followed by a further plan (PMT) which aimed at 23 corridors and 28 Integration Terminals, linked to the Metro. By 1987 one of the two major terminals on the Santo Amaro route had been completed. A further plan was announced in 1989, again based around exclusive bus lanes. In 1990 transport planning was subsumed under the "Tarifa Zero" debate, although in 1991 the Vila Nova busway commenced partial operation. In 1993 a further plan was released - "Programa de Corredores e Terminais de Integracao". Unlike the previous plan, this assumes the Metro will not be constructed, and relies on private sector capital to construct and operate the busways (SMT 1993b).

Through this period of instability CMTC has constructed three busways, one of which ranks as amongst the busiest in the world. Table 5 outlines the operating characteristics of these routes:

Table 5 CMTC Busways In Sao Paulo - 1994

	Paes de Barros	Santo Amaro Avenue 9 de Julho	Vila Nova Cachoeinha
Year of Opening	1980	1987	1991
Type of Bus	Trolley	Trolley & Diesel	Diesel
Length	3.4 km	14.6 km (1)	11.0 km (2)
Terminals	1	1	2
Overtaking Lanes	No	Yes	No
Busway Rtes (3)	6	27	14
Number of Buses	61	372	159
Buses/Peak Hour	30	250 (4)	75
Pax Capacity/Hr	3000	25000	8250
Peak Hr Op Speed	N/A	AM: 21.0 km/h PM: 11.2 km/h	AM: 23.0 km/h PM: 16.0 km/h

Sources : SMT 1993a and SMT 1993b.

Notes:

(1) Of the 14.6km, only 11.0km is exclusive bus roadway.

(2) Of the 11.0km, only 5.5km is exclusive bus roadway.

(3) Includes both Trunk Routes (using the corridor) and associated Feeder Routes.

(4) In addition, up to 50 illegal buses use this corridor per hour.

The fourth system in Sao Paulo - EMTU corridors between Sao Mateus, Jabaquara (Metro) and the city of Sao Bernardo do Campo - operates a mixture of trolley- and diesel buses through four major terminals - one of which is linked to the Metro. Operating statistics were not available, although the outer suburban nature of the route and the observed low density of operation indicate that it operates in a different environment from the CBD based busways in Curitiba, Porto Allegre and Sao Paulo discussed above.

The Sao Paulo operation confirms the difficulties that conventional busways have in moving large numbers of passengers at reasonable speeds. In this respect, the Santo Amaro busway has similar characteristics to the Porto Allegre busways. Efforts have been made to improve performance on the Santo Amaro route - overtaking lanes are installed at all stops; four sets of trolley wires enable "express" and "all stops" services to be operated; and the terminal at Santo Amaro itself is comparable to those in Curitiba. However, the volume of traffic both on

the busway and at intersections, and the inability of CMTC to control illegal operation, has resulted in constantly decreasing operating speeds (PM speeds have dropped 33% in four years); Express buses operating no faster than All Stops buses; and buses on the busway travelling no faster than the surrounding traffic flow (average speeds for buses on the exclusive bus lanes are 16.0km/h, whilst average speeds on the normal road network are 17.6km/h) (SMT 1993b).

The performance of the Vila Nova busway reflects an effort to introduce new operating methods that parallels the Curitiba experience. Bus stops on this route are fitted with platforms, that enhance boarding times. However, there is no equivalent to the "Tube" station that enables pre-payment of fares, and the vehicles used are conventional rigid urban two door buses modified for use on the route.

In contrast to both Curitiba and Porto Allegre, none of the CMTC busways is complete. The Paes de Barros corridor is but a small sector of the SISTRAN network planned in 1975. As such it links two major thoroughfares approx. 4km from the CBD terminus, but of itself links no other major transport terminal, and all services using the corridor also use the conventional street network. Similarly, both the Santo Amaro and Vila Nova corridors are punctuated by sections on non-exclusivity, which seriously compromise the operation. Furthermore, all three corridors have poor road surfaces, with only Santo Amaro having concrete standing areas at bus stops.

For these reasons, each of these corridors performs poorly. They have been crippled by inconsistent planning; partial construction; inadequate maintenance and poor supervision. Although the volumes carried are high, the service quality is poor.

From an operational viewpoint, the contrast between these cities confirms that for busways to play a role equivalent to rail based systems, it is necessary for the system to be supported by:

(1) effective long term planning, to ensure network integrity;
(2) maximum use of innovative operational techniques and enhanced equipment;
(3) enforcement of exclusivity and co-operation between operators.

It is clear that the more the busway approaches a railway in terms of basic infrastructure (stations, terminals, exclusive right-of-way and high capacity) the more effectively it performs. It is also clear that there can be no real comparison between either capital or operating costs between the two modes, as busways can be constructed at a minimal cost and, given adequate patronage, operated by the private sector without subsidy. Whilst rail based systems can match the busway in operational characteristics, they cannot replicate this economic efficiency.

Brazilian Busways In The Future - Current Proposals

Although population growth rates in these three cities are declining, all three are anticipating the need to upgrade the existing public transport system. Plans in both Curitiba and Sao Paulo aim to build extensive new busways, incorporating Integration Terminals; stopping platforms; high capacity vehicles; and improved ticketing technology. Plans in both cities rely on private sector financing to meet capital costs, and both assume that the resulting systems will not only deliver an improved public transport product, but also earn a financial surplus. Plans in Porto Allegre concentrate on re-orienting the bus route network to a less centralised pattern, and do not include new busway proposals.

Curitiba

The major challenge facing URBS in Curitiba is adapting the North-South busways to the current volume of traffic. Services on the route are by conventional rigid and articulated buses, with no platforms at stops. This route is served by 7 Express and 4 Speedybus routes, which are fed by 4 Intersuburban and 53 feeder routes. The Express and Speedybus routes in the northern sector are currently used by 85000 passengers/day, and 60000 daily passengers use the Feeder routes to the three Integration Terminals. In the southern sector, 160000 daily passengers use the Express routes, with 130000 passengers using Feeder buses to four terminals. The maximum hourly patronage for the bus lane is 11000 pax/hr/direction. An additional 62000 daily passengers use "Speedybus" services that parallel the exclusive bus lanes on this route (URBS 1993a). These volumes are considered to be the maximum that this operating system can efficiently handle. Two capacity restraints exist -the first on the bus lane, where capacity for growth is restricted; and the second for the general traffic on the cross roads at intersections, where the constant flow of buses impedes traffic flow. A solution to these restraints must therefore involve both increasing the capacity of the bus lane and reducing the number of buses in use.

The proposal to relieve this congestion is to modify 19km of the busway on the model of the Boqueirao route, with the introduction of bi-articulated buses; the construction of "tubes" at all stops; and the extension of the exclusive lane through the CBD area to serve three new terminals. This will require the purchase of 67 new buses, at a cost of AUD41m; the construction of 56 "tubes" (AUD3.4m); the modification of 6 existing terminals (AUD1.2m) and the construction of three new terminals (AUD1.9m). Of this total cost of AUD47.5m, the private contractors will contribute 86% (AUD41m for the vehicles) and the Municipal government the balance. This infrastructure cost will be AUD 0.342m/km. The cost/passenger

of operating the system is anticipated to be 6.8% below that of a the existing system. The number of vehicles operated per peak hour will reduce from 91 to 44, and the average speed will marginally increase from 18.1 to 18.6 km/h. The AUD47.5m cost of the proposal compares to an estimated AUD400m for an equivalent LRV line (URBS 1993a and URBS 1994). As the financial commitment required by the Municipality is small, and as the political support for the RIT is strong, there is no anticipation that the project will face undue delays. Furthermore, all of the technology and operating systems are currently operating on the Boqueirao route.

That URBS considers it necessary to substantially upgrade this route with passenger numbers of 11000 pax/hr/direction suggests that such volumes are the level at which conventional busway systems reach their capacity limit.

Porto Allegre

As already discussed, the fragmentation of the political structures in Porto Allegre, and the vacuum left by the collapse of EBTU, has left the city without a coherent plan to upgrade and further develop the busway system. Furthermore, commercial growth in the city is now concentrated in six subregional centres, that are not directly served by the CBD oriented busways. Current studies indicate that these developments have redirected 30% of the demand away from the radial routes, but the current route structure only supplies 10% of capacity to cross-regional services. This restriction in part reflects the desire of the Municipal regulators to reserve these growth routes for the Municipal company. These restrictions are preventing the system from developing in a manner that meets the new demands created by decentralisation. No current proposals exist to extend the busway system, or even to re-organise the operations to return service levels to those achieved under the supervision of EBTU.

Sao Paulo

As always in Brazil, it is in Sao Paulo that the most ambitious plans exist. However, the foundations for the 1993 "Programa de Corredores e Terminais de Integracao" - PCTI - (SMT 1993b) are a realistic assessment of the probable failure of the State funded Metro to expand, and a reliance on private capital to meet the construction costs of the new busways and terminals. These may enable the proposal to reach fruition despite the political fragmentation of the city and the ongoing financial disorder at every level of government in Brazil.

The PCTI has been developed on the following assumptions:

(1) The CMTC bus system will remain the backbone of the city's transport network, transporting 70% of daily passengers;
(2) The 1992 expansion plans for the Metro (from 43 to 83km) are unlikely to be implemented due to budgetary constraints;
(3) the private sector, having absorbed the operation of the 3000 strong CMTC bus fleet in 1994, will have the capacity to develop a series of major bus corridors on a BOOT (Build, Own, Operate, Transfer) basis, without a requirement for CMTC funds;
(4) the subsequent operation on the corridors will generate a financial surplus for CMTC, and
(5) CMTC will continue to control the planning and operational aspects of the system.

The objective of the PCTI is the construction of 188km of busways on 16 new corridors with operations commencing by 1996. The operating model is similar to that of Curitiba, with specialised vehicles providing trunk line service to which passengers transfer in terminals from co-ordinated feeder routes. Two articulated buses operating in convoy will be used in lieu of bi-articulated buses. Bus stops will incorporate a platform, as with the current Vila Nova service. The current turnstile-based ticketing system will be replaced by a magnetic system. Stops will be placed at 500m intervals. The new terminals will be sited to maximise co-ordination with the Metro and EMTU systems. 1100 new articulated buses will replace 2400 currently in use on these routes. An average speed of 25km/h is anticipated, an increase from 18km/h currently achieved on these routes. This will save passengers an average of 45 minutes per day. Vehicles will transport an average of 1800 pax/day, compared to the current average of 700 pax/day (SMT 1993b).

Financial projections have indicated that the full costs of the system can be amortised over eight years. Construction costs for the busways are estimated at AUD170m, or AUD 0.9m/km. It is assumed that the cost per passenger of the system will be 22% below that of the conventional system, or 71c/pax. The full construction and vehicle costs are to be met by private contractors, who will bid for an eight year contract to build and operate the busway.

There are many parallels between the proposals for Curitiba and Sao Paulo. Both are premised on an operating system based upon transfer terminals, feeder buses and trunk express routes. Both assume that all bus stops will include platforms, principally to improve boarding times. As a result of this, both assume that a dedicated fleet of vehicles will be used. Both see the capital and operating costs being fully covered from the farebox. In each city, improved financial performance will result from higher vehicle utilisation levels, through higher speeds. The essential contrast between the proposals is that Curitiba will be adding at the margin to an existing system, whereas Sao Paulo will largely be implementing a comprehensive busway

system for the first time. Some doubt must also exist that the Sao Paulo network will be constructed as planned, given the history of major infrastructure projects in the city.

Conclusion

The experience of these operators in Curitiba, Porto Allegre and Sao Paulo supports the contention that, under appropriate regulation, organisation and capital investment, bus based transit systems are capable of transporting large volumes of passengers at reasonable speeds for minimal capital and operational costs. Appendix One illustrates this capacity by a comparison of the volumes achieved by busways in these cities with a number of heavy rail corridors in the Sydney metropolitan region.

However, it is equally clear that busways only function as efficient high volume transport corridors where the operations are adapted from traditional bus practice and where substantial infrastructure investments are made in bus stops, terminals and vehicle types. Certain advantages of busways over rail based systems (such as the avoidance of transfers at terminals; the use of standard equipment) may correlate negatively with the capacity the busway can achieve. Certainly the most successful high-volume busways in Brazil require both passenger transfer and specialised equipment. On the other hand, where busway systems are based merely on providing road space for operators to utilise (as in Porto Allegre), this results in low operating speeds and productivity.

Although previous research has suggested that busways on the Porto Allegre model could efficiently transport 39000 passengers/hour (Cornwell and Cracknell 1990), operating experience in Brazil does not confirm this figure. The current maximum volume carried on an efficient busway (i.e. with an average speed greater than 20km/h) is 11000 pax/h in Curitiba, and where volumes exceed this, the average bus speed drops towards that of the surrounding traffic flow. It remains to be seen whether the Curitiba "surface subway" and the proposed systems in Sao Paulo will be capable of both moving 22000 pax/hr volume and maintaining average speeds in excess of 25 km/h, as predicted.

Nevertheless, the existing busways can provide an equivalent capacity to an LRV system, at a fraction of the capital costs. As Cornwell and Cracknell concluded:

> "The capacity of a well designed and efficiently managed busway can be equivalent to that of an LRT, on a comparable basis (for example, degree of segregation; stop spacing)" (Cornwell and Cracknell 1990, 195)

and that

> "... it should be noted that despite the current wave of LRT proposals, and the considerable resources which have been invested in various LRTs (Manila, Hong Kong, Rio de Janeiro etc.), the consultants know of no LRT in a less-developed country which outperforms the busways surveyed in terms of productivity (passenger volumes x speeds)" (Cornwell and Cracknell 1990, 200).

In interpreting comparisons between LRV and busway systems, it is important to note the contrast between 'theoretical" capacity and capacity achieved.

The Brasilian experience also supports the key interrelationships that exist between successful busway operation and long term planning, land use, appropriate regulation and political stability. Where busways have been implemented in isolation from coherent planning and land use strategies, the results have been either partial, inefficient systems (as in Sao Paulo) or overcrowded systems, that cannot adequately meet demand (Porto Allegre and Sao Paulo). The outstanding feature of Curitiba is that an integrated system of bus service types has developed in response to a clear and structured urban plan. This combination of a planning driven "bus-friendly" urban form and a marketing driven, innovative bus operation has provided Curitiba with an excellent transport systems. The busways are no more than an important element in this process. Furthermore, the contrast between Curitiba and Sao Paulo is not so much in the preparation of plans, but in their consistent implementation over a thirty year time frame. Political stability has enabled the planning and innovation in Curitiba to deliver results. Similarly, the effective of busways is also dependent on an integrated regulatory regime. The decline in the effectiveness of the Porto Allegre busways results from the removal of the "umbrella" regulation of EBTU. Although the multiple operators have effectively developed an system wide fare system, they have not been able to maintain the efficiencies of the busways. Similarly, a major restraint on the Santo Amaro busway in Sao Paulo is the presence of "pirate" bus operators, who overload the capacity. An efficient busway requires a firm and coherent system of regulation.

The busway systems in Curitiba, Porto Allegre and Sao Paulo provide an illustration of the strengths and weaknesses of this transport mode. Although these systems have operating weaknesses, and although many aspects of their operation are not transferable to other national contexts, they nevertheless provide working examples of the capacity of the bus to provide cheap and efficient solutions to major urban transport problems.

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Appendix - International Comparisons

Volume Of Passengers Using Transport Corridors In The Peak Direction Of Travel During The Peak Hour

CITY	MODE	LINE	PAX/HOUR
Curitiba	**Busway**	**Pinheirinho**	11000
Porto Allegre	Busway	Assis Brasil	20000
Sao Paulo	Busway	Santo Amaro	25000
Sydney	Heavy Rail	Carlingford	400
Sydney	Heavy Rail	Bankstown	5700
Sydney	Heavy Rail	Bondi Junction	6200
Sydney	Heavy Rail	Chatswood	11900
Sydney	**Heavy Rail**	**Parramatta**	**14800**
Sydney	**Heavy Rail**	**Strathfield**	**28000**
Sydney	**Bus Lane**	**Military Road**	**6700**

Sources: URBS 1994; CMTC 1994; ATP 1994; Cityrail 1994 and discussions with State Transit (1994).

The Future of Exclusive Busways: The Brazilian Experience

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Abstract

This paper examines the operation of urban bus transport systems based upon exclusive bus roadways (busways) in three cities in Brazil. The historic, economic, political, regulatory and operating context for these services is discussed. The strengths and weaknesses of busway systems in Curitiba, Porto Allegre and Sao Paulo are compared, with particular reference to the operating capacity of the busways. The paper concludes with an assessment of the importance of operations techniques, infrastructure development, land use planning, political stability and regulation to the success or failure of these systems.

Introduction

The 1988 - 1990 study of Bus Priority Systems for Less Developed Countries carried out by the U.K. Transport and Road Research Laboratory (TRRL) and Traffic & Transport Consultants Ltd cited a number of examples in Brazil of Busway Transit providing an effective solution for the need to develop an efficient means of public transportation in urban corridors where demand of between 10000 and 30000 passengers/hour/direction exists (Cornwell and Cracknell 1990). This paper assesses the current effectiveness of the systems in three of the cities cited

in that paper. In order to do so, the paper includes a substantial discussion of the economic, political, regulatory and operating context in which these systems have developed.

Cornwell and Cracknell defined Busway Transit as:

> "... a system that includes a right-of-way for the exclusive use of buses, with at least one section of the busway physically separated from general traffic, and some or all of the following:
>
> (a) a collector/distributor system at one or more ends of the busway, most likely including bus priority measures in the CBD area;
> (b) bus stops (physical layout; management etc.);
> (c) fare collection methods (e.g. on or off-board collection);
> (d) bus fleet (vehicle capacity, door configuration, etc.);
> (e) operations (e.g. bus ordering, express services); and
> (f) marketing (passenger information; corporate image, etc)"
> *(Cornwell and Cracknell 1990, 192-193).*

This paper applies the generic term "busways" to transport systems of this type.

Such systems exist in at least five Brazilian cities. This paper discusses the history and operation of busways in three of these: Curitiba; Sao Paulo and Porto Allegre. These cities have been chosen as they illustrate a number of major themes in the operation of busways - the relationship between urban planning and the effectiveness of busways; the impact of different regulatory systems; and the capacity of bus based systems to respond to demographic, political and economic and regulatory change.

Curitiba has been chosen as it has a world reputation for effective urban planning

and urban transport. Sao Paulo provides a stark contrast - unplanned, congested, and with a contrasting reputation for urban degradation and restricted mobility. Porto Allegre provides an example of the relationship between regulation and the effective operation of busways, and of the capacity of a bus system to adapt to reduced regulation.

Costs and revenues quoted are in Australian dollars, based on a conversion of the Brazilian URV to United States dollars and then to Australian dollars at June 1994 exchange rates. The volatility of the Brazilian exchange rate ensures that these figures can only be used as an approximation of long term costs and revenues. Other statistics are generally based on 1993 or 1994 results. Discrepancies between the two reflect either rapid growth or statistical error.

Brazil : National History And Profile

History

Brazil is the largest country in the continent of South America, both in terms of physical size and population. The characteristics of the country range from the famous Amazonian rain forest of the central and western regions, to the deserts of the north east, to the rich coastal areas south of the equator.

European settlement followed the discovery of Brazil by Portugal in 1500. Brazil was a Portuguese colony until 1823; an independent empire until 1889; and a Federal republic to the present day. The population is concentrated on the coastal strip from the Equator to the southern border with Uruguay.

The economic strength of Brazil was traditionally based on mineral and

agricultural exports. During the 1950s a substantial industrialisation process commenced, with strong encouragement by the Federal Government. This has resulted in strong, export oriented automotive, heavy industry, aerospace and military equipment industries. This process of industrialisation has been accompanied by a major population shift to the cities.

The defining event in postwar Brazilian politics was the military coup of 1964. This ushered in a period of centralisation. A civilian administration was installed by the military in 1985, and a democratically elected civilian President took power in 1989. Brazilian politics has been characterised by ongoing tension between the Federal and State Governments; endemic corruption; instable economic policies; and intense nationalism.

The current political structure is based upon shared power between a Federal Government based in Brasilia; twenty six State Governments and the Federal District of Brasilia; and municipal government. In major urban areas inter-municipal bodies exist for the purposes of co-ordination of urban development and functions. For the purposes of this paper, the term "urban" will refer to the traditional urban area of each city controlled by municipal government; the term "metropolitan area" to the urban area and the surrounding suburbs that are under separate municipal jurisdictions; and "State" to the State government.

Population Trends

The population of Brazil has increased from 121.3m in 1980 to 150.4m in 1990, and it is anticipated to be 179.5m in 2000 (IBGE, 1990). Concurrently, there has been a major migration from rural to urban areas, with a shift in the urban population from 46% of the total in 1960, to 59% in 1970 and 75% in 1988. The annual urban growth rate nationwide was 4.5% between 1960 and 1980 and 3.6% between 1980 and 1988. Twenty four million people were involved in internal

migration between 1970 and 1980. This has resulted in the formation of major urban areas - in 1970 there were five cities with a population greater than one million; by 1987 there were eleven such cities (EIU 1991).

This survey discusses urban transport developments in three cities -

- Sao Paulo, in the State of Sao Paulo;
- Curitiba, in the State of Parana; and
- Porto Allegre, in the State of Rio Grande do Sul.

The following table summarises demographic trends and the urban transport infrastructure in these three cities.

Table 1 inserted here

The distinction between the "urban" and the "metropolitan area" populations reflects the growth of these cities to areas outside of their traditional boundaries. "Metro Lines" refer to underground, heavy rail services; "Urban Trains" refer to suburban services operating on existing rail lines.

Regulation Of Urban Transport

Public transport in all three cities is regulated by a combination of city (municipal), regional (metropolitan) and State bodies. In all cases the service levels and fares are controlled, but this control is diluted by substantial illegal bus operations (Sao Paulo); competing minibus systems (Porto Allegre); or by services provided within the urban area by operators from the surrounding metropolitan region that are outside of the control of the urban authorities (Curitiba and Porto Allegre).

Curitiba

Curitiba has the most comprehensive regulatory regime of the three cities. From 1965, bus transport has been given a pivotal role in the implementation of the city

plan. The operation of bus services is controlled by a municipal body - URBS (Urbanizacao de Curitiba S.A.) - which controls not only buses but taxis, parking lots, public shopping areas, markets and bus terminals. URBS acts as a planning body, a regulator and controller of the bus system -collecting all fares but contracting out the operation of the buses to private operators. The centrepiece of the Curitiba operation is the RIT (Rede Integrada de Transporte - Integrated Transport Network), which consists of a hierarchy of seven bus systems linked through "Integration Terminals". The operation of this system is dependent upon total integration of all the bus operations in the city. Fare revenues are pooled and paid to contractors on the basis of the service provided. Contractual payments are based on a complex formula that takes into account the full cost structure of the contractors. Vehicles are provided by the contractors. The only interruption to the control of this system is created by the lack of co-ordination with the transport systems in the surrounding cities (suburbs). To date, only one of these has permitted the extension of the RIT across the municipal boundary. This results in the operation of suburban buses within the urban area. However, they are restricted from conveying urban passengers. The principle disruption caused by this division is the inability of URBS to adequately plan for the metropolitan area, and to strengthen the bus corridors that operate to the urban boundary with the patronage available from these suburbs (URBS 1994).

Porto Allegre

Porto Allegre suffers from having the highest proportion of the metropolitan population resident outside of the urban boundary (57%, against 35% in Curitiba and 38% in Sao Paulo) (Almanaque Abril 1993). Furthermore, urban transport is provided by three modes - buses; minibuses and an urban rail line. The minibuses provide a competing service on high frequency scheduled routes charging a 70% premium on bus fares. The urban rail line was built by a Federal body (EBTU - Empresa Brasileira de Transportes Urbanos) during the period of the military dictatorship. It has failed to reach more than 31% of its projected ridership

(110000 pax/day carried vs. a 350000 pax/day projection), and with the disbandment of EBTU in 1990 is now for sale (ATP 1994)

Regulation of the urban bus system was formerly heavily influenced by EBTU, which was responsible for developing and supervising bus corridors and providing an integrated network between various bus operators and the urban rail line. The demise of EBTU has removed this layer of regulation.

Urban operations are currently regulated by the municipal government in regards to routes operated and fares charged. Metropolitan operations are regulated by the State government in a similar fashion, but there is little co-ordination between the two in the areas where metropolitan buses enter the urban area. The effectiveness of restrictions on metropolitan buses operating within the urban area is open to doubt, but the prevalence of flat fare systems and the substantial premium on the fare of the longer distance metropolitan services effectively limits their attraction to urban bus users, even though both groups of operators share in the use of the urban busways. Fares are set by the Municipality at a level that covers all operator costs as defined by an analysis of industry cost structures.

In contrast to Curitiba and Sao Paulo, there has been a significant reduction in the level of regulation of urban transport in Porto Allegre. The demise of EBTU has removed the integration formerly provided by EBTU, and this has led to a discontinuation of supervision on the busways; and of fare free transfers between operators at Integration Terminals. Furthermore, a relaxation on the limit on the size of minibuses (from 17 to 21 seats) has permitted the growth of competition from this sector. Effective fare pooling is now provided by the operators themselves through the industry association ATP (Transport Companies of Passengers Association of Porto Allegre), rather than by the municipality. Porto Allegre is the least regulated of the three cities.

Sao Paulo

The regulation of urban transport reflects the size and complexity of the city (15.2m residents in the metropolitan area, 5.72m of which are outside of the urban boundary). There are four major transport systems centred on the urban area - the urban bus system (CMTC - Companhia Municipal de Transportes Coletivos - a municipally owned company); a State underground railway and associated bus network (Metro and EMTU - Empresa Metropolitana de Transportes Urbanos de Sao Paulo S.A.); and two long distance rail networks that also provide urban services (FEPASA - Federal Railways and CBTU -State of Sao Paulo Railways). Of the nine million daily passengers on these systems, 67% travel by bus; 22% by Metro; and 11% by each of the railway systems (CMTC 1994). Overlaying these systems are a range of both Municipal and State planning bodies. There is no coherent transport organisation for the whole Metropolitan area, although Metro/EMTU has aspired to this role. Municipal planning is now predicated on the assumption that shortages of funds will limit the future role of Metro/EMTU, and that major transport infrastructure development in the city will be initiated and funded from private sources under the direction of CMTC.

The regulation of the urban bus system is controlled by CMTC, which was established in 1947 to acquire the tramway assets of the local power utility. By 1949 CMTC was also operating diesel and electric (trolley) buses. The intention of CMTC was to establish an operating monopoly in the urban area, and this came closest in fruition in 1954 when the company was operating 90% of the city's buses. However, CMTC was overwhelmed by the urban growth of the city during the late 1950s. Private buses re-appeared in 1957, and by 1977 CMTC was reduced to operating 14% of the urban buses. Increased investment increased this proportion to 30% by 1993. In 1994 a process of privatisation was implemented, whereby CMTC totally divested itself of bus operations.

Throughout this period CMTC has functioned as the regulator of the urban bus

system, controlling the operation of private buses within the urban area. These operations have moved in stages from a simple licensing to the current system known as "Municipalisation", whereby fare revenues are collected by CMTC and paid to contractors on the basis of a cost formula and passengers carried.

The transformation of CMTC from an operator and regulator to a regulator was primarily the result of the transport policies of Mayor Luiza Erundina de Sousa implemented in 1990/1991. Winning office on a left wing program that aimed to significantly increase the quality of bus transport in the city (where bus numbers had stagnated at 8500 for ten years, despite population growth), the program included the introduction of free fares ("Tarifa Zero"); the supply of large numbers of new buses (imported from Eastern Europe if necessary); and the "municipalisation" of fares (i.e. CMTC collecting revenues and paying operators on the basis of resources used). As an adjunct to this, private operators who lacked route licences were invited to provide additional buses on the city's routes.

Whilst the "Tarifa Zero" was rejected by the Municipality, the other aspects of the plan were implemented. This led firstly to a breakdown in regulation, with 3000 "pirate" buses operating on the city routes without route licences. Secondly, a rapid expansion in the size of the licensed fleet (from 8500 to over 10000) and an improvement in quality (from an average fleet age of 8.5 to 3.5yrs) co-incided with a period of no patronage growth, due to the economic recession. Fare income remained stable, but costs exploded as operators were reimbursed on the basis of resources provided.

In 1992 an attempt was made to control the "pirate" operators, with permits being issued for 600 buses. However, this has been only partially effective, with 1400 unlicensed buses remaining in service in 1994.
In 1993 a new administration was installed, and quickly concluded that this cost explosion would bankrupt the system within six months. Faced with the

alternatives of a major fare increase (100% over the existing inflation rate) or privatisation, and noting the major cost advantage of the private operators (a cost per passenger of 67c vs $1.73 for CMTC), a rapid privatisation plan was implemented. This involved the disposal of three thousand buses (including 470 trolleybuses) to private operators and reducing CMTC employment from 27000 to 800 in twelve months (CMTC 1994).

CMTC now concentrates on the regulation of the urban bus network; the implementation of new technology; and the development of a city-wide system of busways and integration terminals with private sector capital. Metro/EMTU continues to provide the underground rail service (45km on three lines carrying 2m pax/day) and an urban bus network that crosses the urban boundary, linking major suburban centres with Metro stations within the urban area.

Fare Systems, Funding And Operator Contracts

In each of the cities the principal means of funding is through the fare box, with only Sao Paulo providing municipal funds to support operating costs. Similarly, each city has a form of fare pooling, whereby revenues are aggregated and distributed on the basis of services provided. Fare systems are based on flat fares, which are in part implemented to ensure social equity for poorer residents who tend to live on the outskirts of these cities.

Fares are generally collected by conductors seated near the rear door. Passengers enter by the rear door to a holding bay; pay the conductor; and pass through to the main body of the bus. Passengers alight from the front door. Sao Paulo operates certain routes on the reverse principle, with passengers paying after entering the front door. Tokens are used for many forms of payment, as inflation rates of up to 40%/month have made coins inoperable as a form of currency.

Curitiba

Services provided within the urban area of Curitiba under the auspices of URBS charge a flat fare equivalent to AUD 0.53 (URBS 1994). Periodical fares are set to ensure that the "average worker" spends no more than 10% of income on transport (Herbst 1992). Flat fares are a deliberate policy to provide social equity for all residents of the city. Fares are set at a level to ensure that no subsidy is required to cover payments made to contractors.

A central feature of the RIT system is the provision of 16 sixteen transfer terminals, where "fare free" transfers are available between all services meeting at these points. These "free" transfers are an essential element of the integration of the city's transport system. The proportion of passengers making fare free transfers by type of service is set out in Table 2 .

Table 2 inserted here

The free transfer ticket is used by 36.7% of the average weekday patronage. Of the routes that are designed the serve the transfer terminals (all except the "City Circular" and "Conventional" services), 46.1% of the patronage is transferring. Furthermore, these transfers are occurring on the services which have shown the most patronage growth, and are targeted for further expansion ("Speedybus" and "Bi Artic Express"). A more detailed explanation of the service types is provided in Section 7 below.

Operator remuneration is provided through direct payments to the operators, calculated on the basis of the volume (km) and type of service (vehicle type) that is provided. Operators are responsible for the full operating and capital costs for their allocated routes. Contract payments are calculated from an analysis of each operator's cost structure, with a capital component based on the age and type

profile of the fleet operated. Profit margins are set at 10% of turnover (Worcman 1993).

Porto Allegre

Urban services in Porto Allegre charge a flat fare of AUD 0.49 (ATP 1994). This fare is determined by the Municipality on the basis of an examination of the operators' cost structures and patronage numbers. The fare level covers all costs incurred by the system. Table 3 indicates the four fare types and their usage

Tabel 3 inserted here

Revenue is distributed by type of ticket. Operators retain revenues generated by cash and half fares, but receive no compensation for the revenue foregone for student and concession fares.

The "Transport Ticket" is a periodic multi-operator commuter ticket sold by ATP and valid for use on all urban services. Revenue from the "Transport Ticket" is controlled by ATP and distributed on the basis of kilometers operated. The fare receives limited Government support through an indirect employee subsidy -where the ticket is purchased by the employer, that portion of the fare over 6% of the monthly salary of the employee is tax deductible. Both the municipal operator and the private operators participate in this arrangement.

Transfer between buses is not facilitated. The "Transport Ticket" does enable this, but Integration Terminals established under the EBTU period no longer provide for "fare free" transfers. The elimination of "free transfers" has had no measurable impact on patronage.

Sao Paulo

The flat fare applicable in Sao Paulo is AUD 0.88. Through fares to the Metro are

also available, as are periodical tickets. A major integration terminal at Santo Amaro provides "fare free" transfers to services in that area, but this is not a dominant feature of the overall transport network. All fare revenue is collected by CMTC and distributed to contractors by a formula that allocates a cost/passenger for the routes served. Thus routes with short distances and high average loadings are paid a lower rate/pax than long routes with lower average loadings. These fares contribute 88% of the costs of operating the bus system -the balance is provided as a subsidy by the Municipality through CMTC. Two percent of the funds distributed by CMTC are targeted towards operators that achieve quality and productivity benchmarks set by CMTC (CMTC 1994).

Ownership Structures

Bus operations are provided exclusively by private operators in Curitiba and Sao Paulo, with a small municipal operation in Porto Allegre.

Curitiba

There are ten private operators in Curitiba providing 1250 buses for URBS services. These operate under contracts that have evolved from original contracts established in 1955. Each contractor has routes in a geographic "slice" of the city. Contracts are "rolled over" on expiry with no tender process. Efficiency is maintained by tight supervision of each company's finances and by "benchmarking" between operators (URBS 1994).

Porto Allegre

Fifteen companies and one municipal operator provide urban services with 1360 buses (258 or 19% are owned by the municipality). In addition, there are 403 minibuses operated by 200 owners on competing, scheduled route services. A further 700 buses from the Metropolitan area also operate into the urban area. Route allocations are determined by the Municipality. However, it is currently proposed that route allocations be tendered in 1995. There is considerable

confusion regarding the relationship between the Municipality and the private operators, that was unresolved in June 1994.

Sao Paulo

CMTC currently supervises operations by approx. 11000 buses in the urban area. All services are provided by private companies. These operate under a range of contract types, depending on the history of the operation:

(1) private operators that existed in 1993;
(2) private operators that tendered for services in 1994 but provided their own equipment;
(3) private operators that tendered for services in 1994 but lease equipment from CMTC;
(4) "pirate" operators that received temporary permits in 1992; and
(5) "pirate" operators that continue to operate without permission.

The goal of CMTC is to establish a standard 8 year contract let by tender. With new projects these contracts may involve the provision of substantial infrastructure in the form of dedicated bus roadways, in addition to the supply of buses and operating services.

Urban Planning

Brasilian cities have experienced major expansion during the past fifty years, resulting from both natural increase and internal migration. Cities have responded in two ways to this process - those that have allowed planning processes to be overwhelmed by the growth, and are now engaged in trying to "insert" urban transport systems into an existing city structure; and those that have managed growth around transport corridors, such as Curitiba. The role of busways in the three cities examined is predicated by their position in the urban planning process.

For this reason, it is not necessarily appropriate to compare systems in Curitiba with the Sao Paulo or Porto Allegre, unless the role of urban planning in Curitiba is accounted for.

Curitiba

Population growth in Curitiba has taken a small capital city of an agricultural state with a population of 140000 in 1940 through to a medium sized city of 500000 in 1965 to today's urban population of 1.29m and a metropolitan population of 1.98m (Herbst 1992).

The key decisions in the management of this growth were made in 1965, when a traditional urban master plan was jettisoned in favour of a scheme that would concentrate high-density growth along five slender corridors radiating from the city centre. This decision was rigidly enforced by the municipal government, and supported by land resumptions. High-rise developments were restricted to a four-block corridor on either side of these "transport axes". Much of the subsequent development (including 17000 low-income units) was then constructed by the Municipal Company for Housing (COHAB).

This development was strengthened by preserving the historic downtown area, through pedestrianisation of a central 17 block area, and encouraging the development of markets and 24-hour shopping precincts. With retailing based in the CBD, industrial employment was similarly channelled to the Curitiba Industrial City (CIC). This development, commenced in 1973 as a model industrial park, currently generates 20% of the jobs in the Metropolitan area. Public transport was facilitated by concentrating residential development on corridors that featured exclusive bus lanes, and concentrating employment in only two centres (CBD and CIC).

This development was overseen by the remarkable political stability of the

Municipal government. Mayor Jaime Lerner, first appointed under the military dictatorship in 1971, held office until 1992, through successive changes in Federal governments and the introduction of democracy. The combination of a visionary mayor with an absolute commitment to the city's planning goals with 21 years of stable government provided a platform for orderly development that no other Brasilian city could match during this period of major political and economic change.

This combination of establishing clear planning goals prior to the major development of the city, with consistent management and political stability, has provided the platform upon which the Curitiba transport system has been developed.

Porto Allegre

The planning base for Porto Allegre provides a significant contrast to that of Curitiba. As an older city built around a harbour foreshore, planning was restricted by geography. Furthermore, the political structure of the city is fractured by the high proportion of the metropolitan population that is resident outside of the area served by the urban government (57% compared to 35% in Curitiba).

Further complexity was added by the strong role played by the Federal agency EBTU. The EBTU master plan - based upon the urban railway and the development of exclusive bus roadways - floundered with the disbandment of the Federal body in the decentralised political climate of 1990. The city allowed the co-ordinating aspects of this plan to flounder, and whilst the operators were successful in developing a co-ordinated fare regime, other aspects of the plan lapsed.

The current operating environment in Porto Allegre reflects these changes in political commitment to integrated transport in the city.

Sao Paulo

As one of the world's first Third World "mega-cities", Sao Paulo has long been a by-word for the negative impact of massive population growth in an ill-prepared urban environment. Although growth rates are lower than in the other two cities, the current annual increase of 1% will still add 1.25m residents (equivalent to the urban populations of either Curitiba or Porto Allegre) over the next five years.

As with Porto Allegre, political power has been divided, both between the urban Municipal government and the surrounding cities, and between the Municipal and the State governments. This has been compounded by the development of major transport infrastructures by each group, with CMTC pursuing exclusive bus roadways; the State government building the Metro underground rail lines; the "cross border" EMTU exclusive bus network and operating one of two metropolitan rail systems (CBTU); and the Federal government operating a second metropolitan rail system (FEPASA). Further planning breakdown resulted from the disparity between the goals of the Municipal bus operator (CMTC) to provide the total system; and the reality of a constant requirement to rely on the private sector to meet the transport demand. Co-ordination between these organisations has been attempted by a series of planning bodies, none of which has produced a plan that has been capable of implementation. In particular, all of these plans suffered from the assumption that a full 147km Metro rail system would be constructed, when in fact only 45km is operational and further growth in proceeding at a glacial speed. This in turn reflects Federal priorities in the urban transport area and the position of the World Bank in funding such developments (SMT 1993b).

This disjointed transport planning framework reflects the general failure of urban planning in Sao Paulo during an extended period of massive population growth. As with Porto Allegre, the development of urban busways in Sao Paulo must be assessed in the context of both this population growth and planning failures.

Development & Operation Of Busways

The development of busways (exclusive bus roadways) in these three cities has been driven by five forces:

(1) the relentless growth of population, particularly on the extremities of these cities, that require an efficient transport system;

(2) the requirement for operational efficiency, as transport systems required rapid expansion during a period of on-going national political and financial chaos, with hyperinflation, currency crises and unmanageable deficits at local, State and Federal levels;

(3) the influence of the World Bank, which during the 1980s turned against "showcase" urban rail projects, on the basis of the benefit/cost ratios of such schemes;

(4) the strength of the local bus manufacturing industry, which has developed into the largest in the world; and

(5) the success of the Curitiba model, in terms of both efficiency and service delivery.

Each city has produced different variations on the busway theme, with Curitiba and Sao Paulo pushing bus technology and operating capacity to new limits. Porto Allegre, which at one stage operated the most intense busway in the world, has fallen behind the other two cities in innovation and operations, as the regulatory regime has altered and political support withdrawn.

Curitiba

From Busways to the System - The development of the RIT

The 1965 decision to concentrate urban development along radial corridors first impacted the Curitiba bus system with the introduction of the Express bus routes in 1974. Twenty buses operating with a distinctive red colour scheme were

introduced on a 19.8km North-South exclusive bus lane, carrying 25000 pax/day. This route replaced eight existing conventional bus routes. The Express routes were fed by a 45km of feeder services. Further Express routes - all travelling in exclusive bus roads outside of the CBD - were introduced in 1976 and 1979, and continuing development led to the existing network of 56km of Express routes, served by 208 buses, carrying 454000 passengers daily. These services are fed by a further 300km of feeder services.

However, the development of these Express bus routes on exclusive bus lanes has only been one element in the RIT system. Just as the system cannot be assessed independently of the urban planning context in which it operates, neither can these busway services be considered independently of the supporting initiatives for non-busway services. In 1993, less than 50% of bus passengers in Curitiba were using the busway services, although in terms of passenger/km the proportion would have been higher.

The first of these initiatives was the 1979 introduction of the "Interbarrios" or cross-suburban services. These linked the Express route termini by means of cross-suburban routes. In 1993 there were seven of these connecting routes, carrying 11% of the daily patronage.

In 1980 RIT was established, with the implementation of the first Integration Terminals (manned, covered, barrier free transfer points between Feeder, Express and Intersuburban bus services); the "free transfer" between services at the terminals; and the flat "social fare". The sixteen terminals now in operation form the foundation of the system, facilitating transfers between the various elements of the RIT system.

In 1991 a third principle form of corridor was added to the Express lines and the Interbarrios services - the "Linha Direta", or, as it is popularly referred to, the

"Ligerinho", or "Speedybus". The Speedybus has proven to be the "engine" of much of the recent growth in patronage in Curitiba and, curiously in a city that has a world recognised series of busways, does not make use of any of these exclusive bus lanes. The Speedybus links the principle transfer points on the system (the Integration Terminals); a limited number of major stops; and the CBD area with a series of high speed bus routes. These avoid the busways, as the more frequent stops of the Express buses would impede operating speeds, and as a number of the busways (particularly the North-South corridor) are heavily congested with buses. Unlike Sao Paulo, the Curitiba busways have no provision for buses to overtake. To further increase operating speeds, the Speedybus system is supported by purpose design bus stops ("Tubes"). These "Tubes" function as mini-stations on the bus route. Passengers pay a seated conductor on entering the tube, and board the bus across a step free ramp. This minimises the delay at stops. The Speedybus services operate at an average speed of 34km/hr (against 22km/hr for the Express buses), and have reduced daily travelling times for many passengers by over an hour. This improved service has led to rapid growth, with 28% of Speedybus passengers transferring from private cars. In June 1994 the Speedybus network was served by 156 buses that carry 300000 passengers/day (URBS 1994).

The success of the Speedybus illustrates three characteristics of the Curitiba system. Firstly, patronage growth in Curitiba has resulted in part from tailoring service provision to market needs (in this case reduced travel times), even when new services did not use all of the existing infrastructure (the bus lanes). Secondly, the growth of patronage and services on the busways has reached the point where they now suffer from congestion that is impeding further growth. Thirdly, the high mode split in favour of bus transport for commuters (75% of daily commuters travel by bus), has resulted in low traffic volumes that allow higher average speeds for buses on the general road system than on the exclusive bus lanes. Each of these characteristics supports the contention that the busways are

only one factor contributing to the success of the RIT.

Congestion on the busways, created both by the volume of buses in use and the impact of intersections on through bus traffic, is the major current issue to be resolved in the development of the RIT. At one stage URBS saw the busways as an interim step to the development of a light rail (LRV) network. It was considered that only LRV could convey the predicted volumes at the speeds required. However, two developments have led to the abandonment of LRV plans - the relative costs of LRV, and technological advances in bus design and operating techniques that have significantly lifted the capacity and speed of busways, for little additional cost.

These advances were demonstrated through the upgrading of the Boqueirao Express route in 1992. This project consisted of combining the advances already implemented with the "Speedybus" - the tube stations - with biarticulated buses. The tube stations were installed at every stop along the Boqueiro to City route - 11km of exclusive busway. The buses were designed to maximise both loading speeds and capacity, with five doors designed to integrate with the tube station entrances, and a total capacity of 270 passengers. This project demonstrated that this combination could deliver a high quality, fast and high capacity service at a minimal capital cost to the Municipality. The Boqueirao route is currently operated by 33 biarticulated buses. There are 30 tube stations, spaced at approx. 500m intervals, and three Integrated Transfer Terminals on the route. At the current frequency, 10000 pax/hour are transported in the peak direction. URBS estimates that up to 22000 pax/hr could be efficiently transported at an equivalent speed to the current Express network (22km/hr) with this system.

The costs of the system to URBS have been minimal. Firstly, the use of large capacity bi-articulated buses reduces the overall bus and staffing requirement. The 33 biarticulated buses replaced 66 conventional vehicles, generating a 12.5%

reduction in costs/passenger. (URBS, 1993). Thus the operating costs of the enhanced busway is less than the existing system, which itself meets all operating and capital costs without subsidy. Furthermore, the infrastructure cost for the Boqueirao was AUD2.7m for the entire route. The estimated cost of an LRV system was AUD21m/km, or nearly eight times greater (URBS, 1992). Given that the biarticulated busway is estimated to have the capacity to meet anticipated demand, Curitiba has abandoned all plans to move away from bus-based technology, and proudly promotes this system as their "Surface Subway".

The fundamental remaining difficulty for the RIT is the integration of the Curitiba urban bus network with the surrounding metropolitan area. Although one Speedybus route has been expanded across the city boundary, and plans exist for further extensions of each of the five trunk routes, political differences remain an effective barrier.

RIT Operations

The urban area of Curitiba has the second highest level of car ownership in Brazil, with 562000 motor vehicles, or more than one car per household (Worcman 1993 and URBS 1994). Within this environment, the urban bus network carries 997000 pax/day (1575000 if transfers are counted twice) (URBS, 1993a). 75% of the city's commuters and 50% of all of the residents use the bus on a daily basis (The Economist, 27/4/1993 and Worcman 1993). Table 4 outlines the current breakup of passengers between the various types of bus service.

Table 4 inserted here

The RIT system does not carry the high passenger per hour volumes that are experienced on busways in Porto Allegre and Sao Paulo. This reflects the marketing emphasis of URBS, which ensures that the system offers an attractive service to passengers by avoiding "crush loadings", the ability of Curitiba's

planners in maintaining capacity growth in the system at a rate in excess of demand growth; and the effect of service innovations that have reduced congestion on major corridors (such as the Speedybus). The most congested corridor in 1994 was the southern sector of the North - South route, carrying 11000 pax/hr in the direction of peak, with a theoretical capacity of 12650 pax/hr. Current loadings on the Boqueirao route approach 10000 pax/hr, with a theoretical potential of 22000 pax/hr. These existing capacities must be assessed in the context of the high average speeds currently achieved. The theoretical loading projections may be not be compatible with the current operational speeds.

The RIT system has clearly achieved many of the primary goals of an urban transport system - a high mode share in a city with significant car ownership; patronage growth matching population growth; and an effective network of services meeting market demands. Although "Curitibanos" are often criticised for overselling their city, the effectiveness of their bus system justifies the city's reputation as an example of effective land use and transport planning, and creative and efficient provision of transport services.

Porto Allegre

Exclusive bus roadways were a key plank in the policies implemented by the EBTU in Porto Allegre between the late 1970s and 1990. A total of 42km of these lanes were constructed in the medium lanes of fival arterial roads serving the CBD. The capacity of these busways was further enhanced by the institution of a "convoy" system, to ensure that buses used the roadway in a pre-ordered pattern, to reduce delays at intermediate stops. Central organisation was necessary as each of the lanes were used by a number of private and one municipal company (ATP 1994).

As an early example of the busway system, Porto Allegre attracted worldwide attention. In particular, two of the bus lanes (Farrapos and Assis Brazil) were

noted as carrying very high loads in the peak hour (26100/hr Assis Brazil and 17500/hr Farrapos). Furthermore, this was achieved at reasonable average speeds (22.7 and 19.7 km/h respectively). These results were reported by Transport and Road Research Laboratory study in 1990 (Gardner and Fouracre 1990). The Porto Allegre results were the highest recorded in this international study in terms of peak hour loadings and the second highest in terms of average speeds. Results such as these have influenced bodies such as the World Bank to reduce support for rail based solutions in Third World cities.

Unfortunately, the Porto Allegre busways can no longer produce these results. In 1994 the Assis Brazil was still used by 20000 pax in the peak hour, but the 280 buses/hr that carried these passengers were moving at an average speed of only 12 km/hr. Operators represented by the ATP did not provide any explanation for this decline. It is possible that the earlier result was "oversold" by EBTU, as the study was conducted during the dying stages of that organisation's existence. Alternatively, the removal of the EBTU "organisational umbrella" over the operations of many companies may have led to a substantial decline in service quality. In particular, the convoy system has not been maintained, and the fare-free transfer interchanges no longer function in this manner. The current capacity of these routes is similar to that achieved in Sao Paulo, and may reflect the maximum speed that is possible when 4.7 buses per minute are operating on a single lane over 4.5km with stops every 560m.

The current performance of these busways in Porto Allegre gives credence to the policies of URBS in Curitiba, where enhanced performance is considered to be possible only with substantial upgrades to technology and operating methods. The major technological differences in Curitiba are the use of higher capacity buses (five-door 270 passenger double-articulated in Curitiba and one-door 110 passenger conventional rigid buses in Porto Allegre) and "tubes" at bus stops that reduce standing time with prepaid fares and "no step" entry. The principle

operational difference in Curitiba is the operation of only one route on the corridor, with interchange by passengers required at either end and at set intermediate transfer stations on the route. This eliminates the requirement for passengers to choose their bus at the intermediate boarding points, which increases dwell times by buses at stops. The "convoy" system in Porto Allegre had attempted to resolve this obstacle, by enabling passengers to predict the order in which buses on different routes would arrive at each stop, and thus minimising the confusion created when a large number of buses arrive simultaneously. The breakdown of this system, and the slow boarding times at stops, undoubtedly make a major contribution to the slow speeds achieved on these busways.

These differences reflect the political environments of the two cities. Curitiba RIT system developed during the 21 year "rule" of a charismatic mayor committed to designing a city that could prosper without dependence on private transport, and has bequeathed a powerful ethos to his successors. There is little uncertainty in regard to either future planning directions or political support in Curitiba. By contrast, the bus operator's in Porto Allegre are characterised by uncertainty (regarding contract term; biased administration of route allocation; competition from minibuses), and are focussed on ensuring continuing financial viability. Whilst this has led to the development of an innovative fare pooling arrangement, it has undermined the capacity of the city to offer residents a comprehensive transport system.

Sao Paulo

Four busways exist in Sao Paulo - three operated by the municipality (CMTC) and one "cross border" system by the State (EMTU). These two operators have both developed these busways as elements in a larger plan, although political instability, lack of resources and planning inconsistency have robbed these plans of long term coherence.

From the mid 1960s parallel bus and rail based plans were developed to provide Sao Paulo with an adequate urban transport system. From 1966 concrete steps were taken to construct the Metro - a planned 147km network of high speed underground rail lines. The initial 42km of this system was implemented by the early 1980s, but progress was then halted, and only a further 3km has been developed during the past ten years. Concurrently, a network of 33 trolley bus routes was planned, published as SISTRAN in 1975. These routes were to be characterised by dedicated bus lanes and Transfer Terminals. However progress was slow, and only one route was partially implemented by 1982. A further plan was published in 1983 (PAI) to develop four corridors, again based on trolley buses, terminals and bus lanes. Construction commenced on one corridor (Santo Amaro - Avenue 9 de Julho) in 1985. This was followed by a further plan (PMT) which aimed at 23 corridors and 28 Integration Terminals, linked to the Metro. By 1987 one of the two major terminals on the Santo Amaro route had been completed. A further plan was announced in 1989, again based around exclusive bus lanes. In 1990 transport planning was subsumed under the "Tarifa Zero" debate, although in 1991 the Vila Nova busway commenced partial operation. In 1993 a further plan was released - "Programa de Corredores e Terminais de Integracao". Unlike the previous plan, this assumes the Metro will not be constructed, and relies on private sector capital to construct and operate the busways (SMT 1993b).

Through this period of instability CMTC has constructed three busways, one of which ranks as amongst the busiest in the world. Table 5 outlines the operating characteristics of these routes:

Table 5 inserted here

The fourth system in Sao Paulo - EMTU corridors between Sao Mateus, Jabaquara (Metro) and the city of Sao Bernardo do Campo - operates a mixture of

trolley- and diesel buses through four major terminals - one of which is linked to the Metro. Operating statistics were not available, although the outer suburban nature of the route and the observed low density of operation indicate that it operates in a different environment from the CBD based busways in Curitiba, Porto Allegre and Sao Paulo discussed above.

The Sao Paulo operation confirms the difficulties that conventional busways have in moving large numbers of passengers at reasonable speeds. In this respect, the Santo Amaro busway has similar characteristics to the Porto Allegre busways. Efforts have been made to improve performance on the Santo Amaro route - overtaking lanes are installed at all stops; four sets of trolley wires enable "express" and "all stops" services to be operated; and the terminal at Santo Amaro itself is comparable to those in Curitiba. However, the volume of traffic both on the busway and at intersections, and the inability of CMTC to control illegal operation, has resulted in constantly decreasing operating speeds (PM speeds have dropped 33% in four years); Express buses operating no faster than All Stops buses; and buses on the busway travelling no faster than the surrounding traffic flow (average speeds for buses on the exclusive bus lanes are 16.0km/h, whilst average speeds on the normal road network are 17.6km/h) (SMT 1993b).

The performance of the Vila Nova busway reflects an effort to introduce new operating methods that parallels the Curitiba experience. Bus stops on this route are fitted with platforms, that enhance boarding times. However, there is no equivalent to the "Tube" station that enables pre-payment of fares, and the vehicles used are conventional rigid urban two door buses modified for use on the route.

In contrast to both Curitiba and Porto Allegre, none of the CMTC busways is complete. The Paes de Barros corridor is but a small sector of the SISTRAN network planned in 1975. As such it links two major thoroughfares approx. 4km

from the CBD terminus, but of itself links no other major transport terminal, and all services using the corridor also use the conventional street network. Similarly, both the Santo Amaro and Vila Nova corridors are punctuated by sections on non-exclusivity, which seriously compromise the operation. Furthermore, all three corridors have poor road surfaces, with only Santo Amaro having concrete standing areas at bus stops.

For these reasons, each of these corridors performs poorly. They have been crippled by inconsistent planning; partial construction; inadequate maintenance and poor supervision. Although the volumes carried are high, the service quality is poor.

From an operational viewpoint, the contrast between these cities confirms that for busways to play a role equivalent to rail based systems, it is necessary for the system to be supported by:

(1) effective long term planning, to ensure network integrity;
(2) maximum use of innovative operational techniques and enhanced equipment;
(3) enforcement of exclusivity and co-opera tion between operators.

It is clear that the more the busway approaches a railway in terms of basic infrastructure (stations, terminals, exclusive right-of-way and high capacity) the more effectively it performs. It is also clear that there can be no real comparison between either capital or operating costs between the two modes, as busways can be constructed at a minimal cost and, given adequate patronage, operated by the private sector without subsidy. Whilst rail based systems can match the busway in operational characteristics, they cannot replicate this economic efficiency.

Brazilian Busways In The Future - Current Proposals

Although population growth rates in these three cities are declining, all three are anticipating the need to upgrade the existing public transport system. Plans in both Curitiba and Sao Paulo aim to build extensive new busways, incorporating Integration Terminals; stopping platforms; high capacity vehicles; and improved ticketing technology. Plans in both cities rely on private sector financing to meet capital costs, and both assume that the resulting systems will not only deliver an improved public transport product, but also earn a financial surplus. Plans in Porto Allegre concentrate on re-orienting the bus route network to a less centralised pattern, and do not include new busway proposals.

Curitiba

The major challenge facing URBS in Curitiba is adapting the North-South busways to the current volume of traffic. Services on the route are by conventional rigid and articulated buses, with no platforms at stops. This route is served by 7 Express and 4 Speedybus routes, which are fed by 4 Intersuburban and 53 feeder routes. The Express and Speedybus routes in the northern sector are currently used by 85000 passengers/day, and 60000 daily passengers use the Feeder routes to the three Integration Terminals. In the southern sector, 160000 daily passengers use the Express routes, with 130000 passengers using Feeder buses to four terminals. The maximum hourly patronage for the bus lane is 11000 pax/hr/direction. An additional 62000 daily passengers use "Speedybus" services that parallel the exclusive bus lanes on this route (URBS 1993a). These volumes are considered to be the maximum that this operating system can efficiently handle. Two capacity restraints exist -the first on the bus lane, where capacity for growth is restricted; and the second for the general traffic on the cross roads at intersections, where the constant flow of buses impedes traffic flow. A solution to these restraints must therefore involve both increasing the capacity of the bus lane and reducing the number of buses in use.

The proposal to relieve this congestion is to modify 19km of the busway on the

model of the Boqueirao route, with the introduction of bi-articulated buses; the construction of "tubes" at all stops; and the extension of the exclusive lane through the CBD area to serve three new terminals. This will require the purchase of 67 new buses, at a cost of AUD41m; the construction of 56 "tubes" (AUD3.4m); the modification of 6 existing terminals (AUD1.2m) and the construction of three new terminals (AUD1.9m). Of this total cost of AUD47.5m, the private contractors will contribute 86% (AUD41m for the vehicles) and the Municipal government the balance. This infrastructure cost will be AUD 0.342m/km. The cost/passenger of operating the system is anticipated to be 6.8% below that of a the existing system. The number of vehicles operated per peak hour will reduce from 91 to 44, and the average speed will marginally increase from 18.1 to 18.6 km/h. The AUD47.5m cost of the proposal compares to an estimated AUD400m for an equivalent LRV line (URBS 1993a and URBS 1994). As the financial commitment required by the Municipality is small, and as the political support for the RIT is strong, there is no anticipation that the project will face undue delays. Furthermore, all of the technology and operating systems are currently operating on the Boqueirao route.

That URBS considers it necessary to substantially upgrade this route with passenger numbers of 11000 pax/hr/direction suggests that such volumes are the level at which conventional busway systems reach their capacity limit.

Porto Allegre

As already discussed, the fragmentation of the political structures in Porto Allegre, and the vacuum left by the collapse of EBTU, has left the city without a coherent plan to upgrade and further develop the busway system. Furthermore, commercial growth in the city is now concentrated in six subregional centres, that are not directly served by the CBD oriented busways. Current studies indicate that these developments have redirected 30% of the demand away from the radial routes, but the current route structure only supplies 10% of capacity to cross-regional services. This restriction in part reflects the desire of the Municipal regulators to

reserve these growth routes for the Municipal company. These restrictions are preventing the system from developing in a manner that meets the new demands created by decentralisation. No current proposals exist to extend the busway system, or even to re-organise the operations to return service levels to those achieved under the supervision of EBTU.

Sao Paulo

As always in Brazil, it is in Sao Paulo that the most ambitious plans exist. However, the foundations for the 1993 "Programa de Corredores e Terminais de Integracao" - PCTI - (SMT 1993b) are a realistic assessment of the probable failure of the State funded Metro to expand, and a reliance on private capital to meet the construction costs of the new busways and terminals. These may enable the proposal to reach fruition despite the political fragmentation of the city and the ongoing financial disorder at every level of government in Brazil.

The PCTI has been developed on the following assumptions:

(1) The CMTC bus system will remain the backbone of the city's transport network, transporting 70% of daily passengers;
(2) The 1992 expansion plans for the Metro (from 43 to 83km) are unlikely to be implemented due to budgetary constraints;
(3) the private sector, having absorbed the operation of the 3000 strong CMTC bus fleet in 1994, will have the capacity to develop a series of major bus corridors on a BOOT (Build, Own, Operate, Transfer) basis, without a requirement for CMTC funds;
(4) the subsequent operation on the corridors will generate a financial surplus for CMTC, and
(5) CMTC will continue to control the planning and operational aspects of the system.

The objective of the PCTI is the construction of 188km of busways on 16 new

corridors with operations commencing by 1996. The operating model is similar to that of Curitiba, with specialised vehicles providing trunk line service to which passengers transfer in terminals from co-ordinated feeder routes. Two articulated buses operating in convoy will be used in lieu of bi-articulated buses. Bus stops will incorporate a platform, as with the current Vila Nova service. The current turnstile-based ticketing system will be replaced by a magnetic system. Stops will be placed at 500m intervals. The new terminals will be sited to maximise co-ordination with the Metro and EMTU systems. 1100 new articulated buses will replace 2400 currently in use on these routes. An average speed of 25km/h is anticipated, an increase from 18km/h currently achieved on these routes. This will save passengers an average of 45 minutes per day. Vehicles will transport an average of 1800 pax/day, compared to the current average of 700 pax/day (SMT 1993b).

Financial projections have indicated that the full costs of the system can be amortised over eight years. Construction costs for the busways are estimated at AUD170m, or AUD 0.9m/km. It is assumed that the cost per passenger of the system will be 22% below that of the conventional system, or 71c/pax. The full construction and vehicle costs are to be met by private contractors, who will bid for an eight year contract to build and operate the busway.

There are many parallels between the proposals for Curitiba and Sao Paulo. Both are premised on an operating system based upon transfer terminals, feeder buses and trunk express routes. Both assume that all bus stops will include platforms, principally to improve boarding times. As a result of this, both assume that a dedicated fleet of vehicles will be used. Both see the capital and operating costs being fully covered from the farebox. In each city, improved financial performance will result from higher vehicle utilisation levels, through higher speeds. The essential contrast between the proposals is that Curitiba will be adding at the margin to an existing system, whereas Sao Paulo will largely be implementing a

comprehensive busway system for the first time. Some doubt must also exist that the Sao Paulo network will be constructed as planned, given the history of major infrastructure projects in the city.

Conclusion

The experience of these operators in Curitiba, Porto Allegre and Sao Paulo supports the contention that, under appropriate regulation, organisation and capital investment, bus based transit systems are capable of transporting large volumes of passengers at reasonable speeds for minimal capital and operational costs. Appendix One illustrates this capacity by a comparison of the volumes achieved by busways in these cities with a number of heavy rail corridors in the Sydney metropolitan region.

However, it is equally clear that busways only function as efficient high volume transport corridors where the operations are adapted from traditional bus practice and where substantial infrastructure investments are made in bus stops, terminals and vehicle types. Certain advantages of busways over rail based systems (such as the avoidance of transfers at terminals; the use of standard equipment) may correlate negatively with the capacity the busway can achieve. Certainly the most successful high-volume busways in Brazil require both passenger transfer and specialised equipment. On the other hand, where busway systems are based merely on providing road space for operators to utilise (as in Porto Allegre), this results in low operating speeds and productivity.

Although previous research has suggested that busways on the Porto Allegre model could efficiently transport 39000 passengers/hour (Cornwell and Cracknell 1990), operating experience in Brazil does not confirm this figure. The current maximum volume carried on an efficient busway (i.e. with an average speed

greater than 20km/h) is 11000 pax/h in Curitiba, and where volumes exceed this, the average bus speed drops towards that of the surrounding traffic flow. It remains to be seen whether the Curitiba "surface subway" and the proposed systems in Sao Paulo will be capable of both moving 22000 pax/hr volume and maintaining average speeds in excess of 25 km/h, as predicted.

Nevertheless, the existing busways can provide an equivalent capacity to an LRV system, at a fraction of the capital costs. As Cornwell and Cracknell concluded:

> "The capacity of a well designed and efficiently managed busway can be equivalent to that of an LRT, on a comparable basis (for example, degree of segregation; stop spacing)" (Cornwell and Cracknell 1990, 195)

and that

> "... it should be noted that despite the current wave of LRT proposals, and the considerable resources which have been invested in various LRTs (Manila, Hong Kong, Rio de Janeiro etc.), the consultants know of no LRT in a less-developed country which outperforms the busways surveyed in terms of productivity (passenger volumes x speeds)" (Cornwell and Cracknell 1990, 200).

In interpreting comparisons between LRV and busway systems, it is important to note the contrast between 'theoretical" capacity and capacity achieved.

The Brasilian experience also supports the key interrelationships that exist between successful busway operation and long term planning, land use, appropriate regulation and political stability. Where busways have been implemented in isolation from coherent planning and land use strategies, the

results have been either partial, inefficient systems (as in Sao Paulo) or overcrowded systems, that cannot adequately meet demand (Porto Allegre and Sao Paulo). The outstanding feature of Curitiba is that an integrated system of bus service types has developed in response to a clear and structured urban plan. This combination of a planning driven "bus-friendly" urban form and a marketing driven, innovative bus operation has provided Curitiba with an excellent transport systems. The busways are no more than an important element in this process. Furthermore, the contrast between Curitiba and Sao Paulo is not so much in the preparation of plans, but in their consistent implementation over a thirty year time frame. Political stability has enabled the planning and innovation in Curitiba to deliver results. Similarly, the effective of busways is also dependent on an integrated regulatory regime. The decline in the effectiveness of the Porto Allegre busways results from the removal of the "umbrella" regulation of EBTU. Although the multiple operators have effectively developed an system wide fare system, they have not been able to maintain the efficiencies of the busways. Similarly, a major restraint on the Santo Amaro busway in Sao Paulo is the presence of "pirate" bus operators, who overload the capacity. An efficient busway requires a firm and coherent system of regulation.

The busway systems in Curitiba, Porto Allegre and Sao Paulo provide an illustration of the strengths and weaknesses of this transport mode. Although these systems have operating weaknesses, and although many aspects of their operation are not transferable to other national contexts, they nevertheless provide working examples of the capacity of the bus to provide cheap and efficient solutions to major urban transport problems.

Appendix - International Comparisons

Volume Of Passengers Using Transport Corridors In The Peak Direction Of Travel During The Peak Hour

CITY	MODE	LINE	PAX/HOUR
Curitiba	**Busway**	**Pinheirinho**	11000
Porto Allegre	Busway	Assis Brasil	20000
Sao Paulo	Busway	Santo Amaro	25000
Sydney	Heavy Rail	Carlingford	400
Sydney	Heavy Rail	Bankstown	5700
Sydney	Heavy Rail	Bondi Junction	6200
Sydney	Heavy Rail	Chatswood	11900
Sydney	**Heavy Rail**	**Parramatta**	**14800**
Sydney	**Heavy Rail**	**Strathfield**	**28000**
Sydney	**Bus Lane**	**Military Road**	**6700**

Sources: URBS 1994; CMTC 1994; ATP 1994; Cityrail 1994 and discussions with State Transit (1994).

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Table 1 Urban Demographic Trends - 1991

	Sao Paulo	Curitiba	Porto Allegre
Urban Population	9.48m	1.29m	1.26m
Metropolitan Area Population	15.20m	1.98m	2.94m
Metro Area	7951 km^2	8763 km^2	5806 km^2
Pop. Density	1912/km^2	567/km^2	507/km^2
Pop. Growth 1970 - 1980	3.67% pa	5.34% pa	2.43% pa
Pop. Growth 1980 - 1991	1.00% pa	2.11% pa	1.05% pa
Urban Buses	9779	1696	1930
Metro Lines	43.6 km	Nil	Nil
Urban Trains	192.0 km	Nil	27.0 km

Source : Almanaque Abril 1993.

Table 2 : Curitiba Bus Passengers By Service And Fare Type
Weekday Average Passenger Numbers - 1993

Service Type	Fares Paid to Conductor	Transfer Fares	Total Fares	Proportion of transfer pax
City Circular	5014	Nil	5014	0%
Conventional	343585	22264	365849	6.1%
Feeder	197649	168002	365651	45.9%
Intersuburb	94510	80470	174980	46.0%
Express	227138	131256	358394	36.6%
Speedybus	71201	138130	209331	66.0%
Bi Artic Exp	57976	37684	95660	39.4%
TOTAL	**997073**	**577806**	**1574879**	**36.7%**

Source: URBS 1993a.

Table 3 Fares Sold Per Month By Type - 1994

Type of Fare	Number Sold	Proportion
"Transport Ticket"	15000000	42.9%
Cash Fares	10000000	28.6%
Student Half Fares	5000000	14.3%
Free (elderly & others)	5000000	14.3%
TOTAL	**35000000**	**100.0%**

Source : ATP 1994.

Table 4 Service Characteristics - 1993

Type of Service	Number of Routes	Fleet Size	Daily Passengers	Percentage of Total	Average Speed
City Circular	2	11	5014	0.3%	N/A
Conventional	92	399	365849	23.2%	17 km/h
Feeder	115	328	365651	23.2%	N/A
Intersuburb	7	125	174980	11.1%	N/A
Express	19	179	358394	22.8%	22 km/h
Speedybus	10	135	209331	13.3%	34 km/h
Bi Artic Exp	2	29	95660	6.1%	22 km/h
TOTAL	**247**	**1206**	**1574879**	**100.0%**	

Sources :URBS 1993a and URBS 1994.

Table 5 CMTC Busways In Sao Paulo - 1994

	Paes de Barros	Santo Amaro Avenue 9 de Julho	Vila Nova Cachoeinha
Year of Opening	1980	1987	1991
Type of Bus	Trolley	Trolley & Diesel	Diesel
Length	3.4 km	14.6 km (1)	11.0 km (2)
Terminals	1	1	2
Overtaking Lanes	No	Yes	No
Busway Rtes (3)	6	27	14
Number of Buses	61	372	159
Buses/Peak Hour	30	250 (4)	75
Pax Capacity/Hr	3000	25000	8250
Peak Hr Op Speed	N/A	AM: 21.0 km/h PM: 11.2 km/h	AM: 23.0 km/h PM: 16.0 km/h

Sources : SMT 1993a and SMT 1993b.

Notes:

(1) Of the 14.6km, only 11.0km is exclusive bus roadway.

(2) Of the 11.0km, only 5.5km is exclusive bus roadway.

(3) Includes both Trunk Routes (using the corridor) and associated Feeder Routes.

(4) In addition, up to 50 illegal buses use this corridor per hour.

About the Authors

Neil Smith is Managing Director of Swan Transit (Western Australia) and a Visiting Fellow at the Institute of Transport Studies, The University of Sydney. This paper was written when Neil Smith was in residence at ITS and during a period of active inquiry into the viability of busways systems as an alternative to light rail in Australia. Neil's interests are in urban bus transport and the role of markets in opening up entrepreneurial opportunities. Professor David A. Hensher is Professor of Management and Director of ITS, The University of Sydney. He is a Fellow of the Academy of Social Sciences of Australia, Executive Chair and founder of the International Conference Series on Competition and Ownership of Land Passenger Transport, President of the International Association of Traveller Behaviour Research, and a Vice-Chair of the International Scientific Committee of the World Conference of Transport Research Society. David's research interests are broad and include discrete choice modeling, competition and ownership of land passenger transport, performance measurement and infrastructure financing.

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