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A Review of Bus Priority Systems in Brazil: from Bus Lanes to Busway Transit

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Abstract

Public transport in Brazil is almost completely based on bus services. In general, approximately 65% of motorized trips in large or medium sized cities use buses. The decision of investing in bus priority systems was stimulated by the federal government during the 80's and was based on two main factors: the lack of funds to implement rail transit systems and the need to improve the performance of bus systems, as a real alternative of medium capacity transit system. Therefore, the paper describes the operational planning, the design, the operational schemes and the performance of referential Brazilian busway systems. Examples of different arrangements of busway transit systems are analyzed, including the trunk-and-feeder operation, the use of biarticulated buses and different layouts of bus stops. The paper covers the most expressive experiences of busway implementation in Brazil in the cities of Belo Horizonte, Campinas, Curitiba, Goiânia, Porto Alegre, Recife and São Paulo. Aspects that deserve improvements are also highlighted, including the introduction of ITS devices, which will contribute to the increase of the performance of busways, approaching them to the operation of a metro.

Mobility in Brazilian Metropolitan Areas

Brazil is a large country with remarkable regional peculiarities, concerning cultural traces, climate, topography, personal incomes, economic development, urbanization, etc. Along the last 50 years, there was a dramatic change in terms of urban settlements. Up to the 50's, almost two thirds of the population lived in rural areas and nowadays more than 78% of the population are living in urban areas. Today, the Brazilian population amounts 160 million inhabitants. The population living in urban areas reaches some 123 million, of which 36 million live in the seven metropolitan areas selected for this study.

Considering the seven metropolitan areas within the scope of this paper, about two thirds of motorized trips in these areas are accounted for public transport, 56 percent by bus (and a very minor portion by trolleybus) and 6 percent by suburban railways and metros. About 32 percent of motorized trips are made by cars. The car ownership in Brazil already amounted to 19 cars/100 inhabitants in 1998 and is much higher in metropolitan areas, like São Paulo and Porto Alegre with approximately 48 cars/100 inhabitants or Curitiba with 42 cars/100 inhabitants.

Despite the increasing motorization of the Brazilian society, the urban bus is the main component of the public transport; it is used by the great majority of daily urban travels, in spite of the uncomfortable levels of service during peak times.

In urban areas, road transport accounts for about 90 % of people’s motorized travels and is also essential for the movement of goods. As traffic congestion increases, efficient use of available road space becomes the crucial issue in transport policies. Also the impact of road transport on the environment gives rise to considerable concern. Car traffic is the main cause of road congestion and road accidents. Buses and cars generate most of the air pollution and noise.

In many other countries, even in the developed countries, the modal split in urban areas shows exactly the opposite, private cars are responsible for the major part of urban transport. For that reason, there is a striving for the improvement of public transport to turn it more attractive to car users. Brazil is in an advantageous situation, compared to the one those countries are facing, since it has to keep and increase public transport ridership, not shifting the modal split from the car mode to the public transport mode.

Policies Towards Improving Brazilian Public Transport

The process called "municipalisation" of urban transport; fruit of the new Constitution and of the new Brazilian Traffic Code marked the 90's. That is to say that Federal and State Government transferred the management of public transport to the municipalities. During this period, many local governments created institutions dedicated to the management of public transport by bus and assumed road traffic enforcement, what was previously an attribution of state governments mainly in metropolitan areas. Besides, the Federal Government implemented a program to transfer all suburban passenger rail systems to local governments. This already happened in the cities of São Paulo and Rio de Janeiro and is under way in Belo Horizonte, Fortaleza, Recife and Salvador. Very recently the Federal Government created the SEDU (Secretaria Especial de Desenvolvimento Urbano - Urban Development Secretariat) dedicated to the formulation and coordination of urban policies, including urban transport, but up to the moment without practical and positive results.

There has been a clear tendency for policies that give privileges to public transport by bus. It is assumed by all levels of government that it is possible to improve bus transport capacity through different measures, such as a high level of travelways segregation, operation of trunk and feeder systems, better on-board or off-board automatic fare collection systems, improved layout and operation of bus stops, implementation of bus actuated traffic-signal systems and improvement of bus quality design, comfort and performance. Indeed, bus operation along properly designed segregated lanes offers a much better level of service than in mixed-traffic, on which passenger flows can reach more than 30.000 passengers/hour/direction. So, the question was, through infrastructure and operational measures, to convert bus systems into medium-capacity transit systems, capable of carrying flows varying from 12.000 to 30.000 passengers/hour/direction.

In terms of right-of-way, a mix of the following options is usually considered in bus projects:

(a) **Exclusive right-of-way** - total segregation through tunnels or elevated roads for the exclusive circulation of buses;

(b) **Segregated right-of-way** - this may result in the introduction of exclusive median lanes, such as those in Belo Horizonte, Campinas, Curitiba, Goiânia, Porto Alegre, Recife and São Paulo, where at-grade intersections prevail;

(c) **Reserved right-of-way** - part of the road is reserved for buses. The so-called conventional bus lanes may be delineated through road markings and studs;

(d) **No right-of-way** - the circulation of buses occur in mixed-traffic conditions, with transit vehicles competing for space with other vehicles.

It is important to emphasize that purpose of this paper is to describe the Brazilian experience with median bus lanes and median busways[1] , as they have been showing very similar results.

A basic busway, comprising one lane for buses in each direction is essentially a traffic engineering measure. However, performance of this basic busway can be enhanced substantially by adopting various "special operational measures" in order to form a "busway transit system" (Table 1).

[1] A Busway involves construction, where schemes may be partially physically segregated from other traffic, for example in the vicinity of bus stops (e.g. by means of island stops) or may be fully segregated from other traffic by kerbs or fences or even bus only streets.

Table 1: Special Operational Measures in Use in Brazil

Busway Transit = Busway Infrastructure + Special Operational Measures
Special Operational Measures Include: • trunk-and-feeder operations, including transfer terminals and bus priority measures in the city centers (e.g. bus lanes; spot improvements); • well-designed bus stops, suitably equipped and managed; • bus overtaking facilities at stops; • bus ordering (placing buses in the correct order at the beginning of the section); • high-capacity buses (e.g. articulated or biarticulated); • appropriate bus fleet characteristics (number of doors; door widths; low entry) • off-board ticketing or on-board electronic ticketing; • traffic signal techniques to give buses priority at intersections; • bus dwell time management (to eliminate excessive delays at very busy bus stops); • passenger information; and • guidance systems (e.g. O-Bahn).

Source: Adapted from TRL, 1993

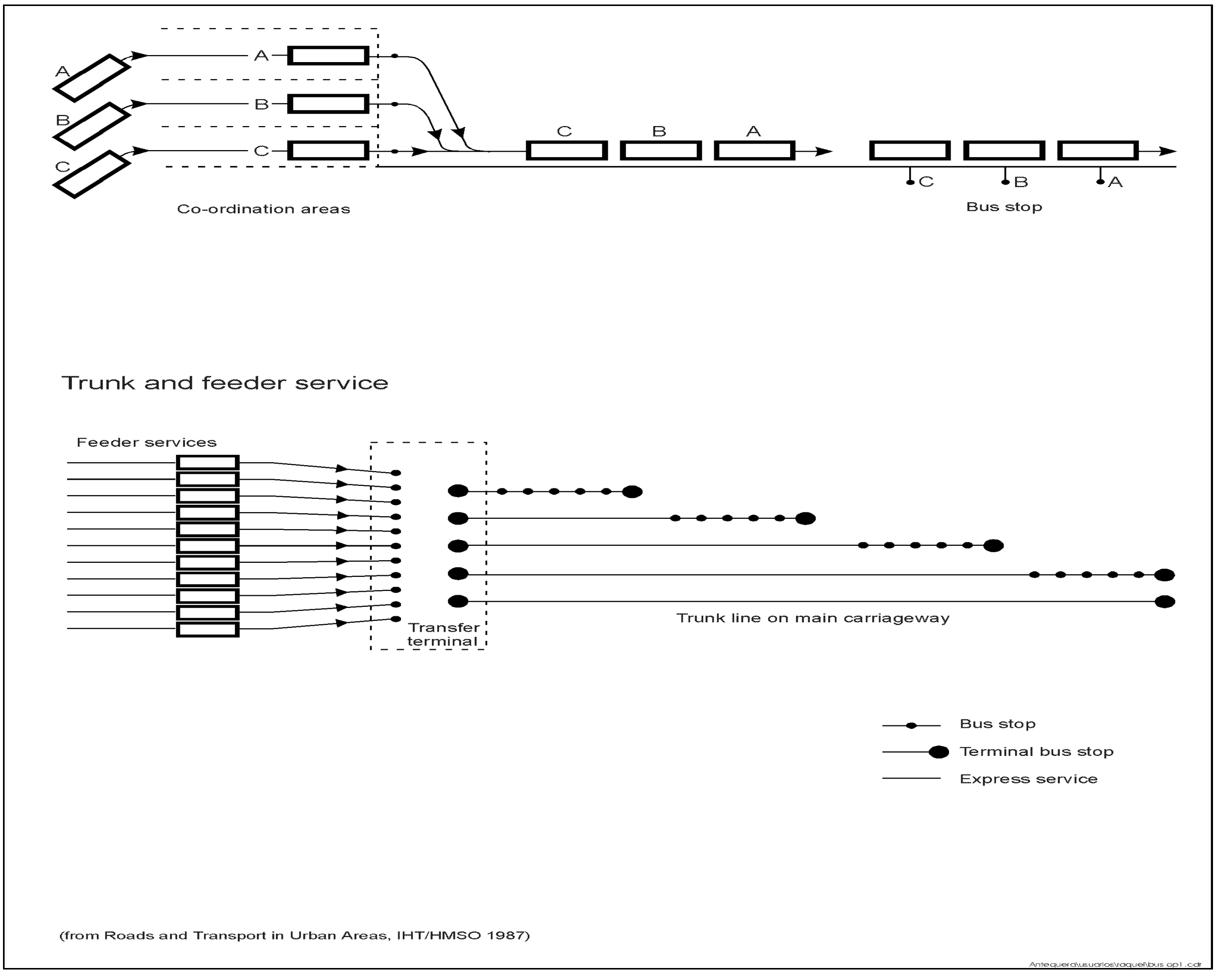
Where passenger demands are high, the provision of facilities to permit buses to overtake one another at bus stops can increase throughput and commercial speed considerably. This is because bus congestion is reduced and buses are no longer "trapped' behind one another in a single lane (as occurs with trams or light rail vehicles).

Trunk-and-feeder operations also offer good performance. In this system, feeder buses collect passengers and bring them to a transfer terminal, where they transfer to line-haul buses; some systems allow transfer without payment of an additional fare (e.g. Belo Horizonte, Curitiba).

Early work in Brazil led to the development of a high-capacity bus convoy scheme in São Paulo (COMONOR), in which buses were assembled at the beginning of a section in the order in which they would stop along the route (to form the on-street 'train'). Although not joined together, the group of buses started and stopped broadly in unison. COMONOR was initially successful but was found to be too difficult to sustain on a day-to-day basis. It evolved in Porto Alegre, for example, into bus ordering in which buses are allocated to one of three groups (A-B-C). The buses arrive in random order at the beginning of a section and are marshaled into the preferred sequence, though not into strict convoys (Figure 1). This method operates effectively and can improve commercial speeds at high levels of passenger demand.

Line-haul capacity can be enhanced by the use of high-capacity buses, like the articulated or biarticulated bus, as in São Paulo and Curitiba. However, passenger transfer capacity at bus stops is often the constraint on system performance and door configurations and ticketing arrangements are often more important than bus capacity alone.

Figure 1 – Bus Convoy Operations



Bus priority systems in Brazil

Background

In Brazil, the implementation of bus priority systems started in mid 70's and the country has at present a long experience in catering for heavy passenger demand along urban and suburban corridors by high-capacity bus priority schemes. Indeed, Brazil has made some pioneering work in improving the performance of bus transport, as it is the case of Curitiba. Curitiba was the first Brazilian city to plan and implement bus priority facilities, using median busways, in 1974, followed by São Paulo in 1975, Goiânia in 1976 and Porto Alegre in 1977 (ANTP, 1980).

The main measures to create bus-priority schemes in Brazil include: (a) provision of separate travelways in the form of with-flow and contra-flow bus lanes or busways; (b) granting buses the priority at traffic signals; and (c) permitting buses an entry right or turns prohibited to other traffic. Many successful schemes result from a combination of these and other measures. Brazil has developed a unique experience in designing innovative high-flow bus-priority schemes. This experience is particularly suited to overcome congestion problems associated with numerous buses arriving almost simultaneously at critical bus stops where large numbers of passengers wait to board. Under such conditions the introduction, for example, of a single conventional bus lane may generate benefits also to non-bus traffic.

In fact, there were in Brazil in 1998 approximately 243 km of busways and 291 km of bus lanes, according to a survey conducted by ANTP (1998), and there will be at least more 84 km of busways until the end of this year.

Bus priority schemes: Brazilian practical examples

This section focuses on referential Brazilian practical experiences on the implementation and operation of successful bus priority schemes; that is to say, high flow bus corridors, in which median bus lanes or median busways were adopted. It is also mentioned the case of a guided busway system ("O-BANH" or Guided Light Transit - GLT) that is under implementation in the city of São Paulo.

(i) Belo Horizonte

Belo Horizonte is the capital of the state of Minas Gerais and has a population of 2,2 million inhabitants and about 675.000 vehicles. Public transport is managed by a public company, BHTRANS, and is operated by 47 private companies under concession contracts. The public transport system runs 2.978 buses, which carry an average 1,5 million passenger per day. The city has two bus transfer terminals, 6 km of median busways and 8 km of bus lanes.

Bus lanes and busways started to be implemented in 1981, as part of a transport master plan, which forecasted the implementation of 29 km of bus priority facilities. Along the time some stretches were deactivated because of modifications on traffic circulation schemes.

Nevertheless, the main important busway constructed at that time - **Avenida Cristiano Machado** - is still in operation and is being improved periodically. It is a purpose-built, median busway that links the city center with the northern suburbs. At the city center end of the busway, buses have exclusive use of the lower level of a double deck tunnel to link the busway with the city center. The busway has off-line bus stop bays to permit overtaking. The busway is separated from general traffic lanes by landscaped islands of varying width with fences to channel pedestrians to pedestrian crossings. At some points, there are pedestrian bridges. Besides, photographic radars enforce the 60 km/h speed limit compliance along the avenue. An automatic fare collection system (AFC) - contactless smartcard based, was recently contracted and will start operating late this year. Together with electronic ticketing, an automatic vehicle identification system (AVL) will be implemented, what will certainly improve the reliability of the bus services. All these measures (AFC and AVL) take part of the new public transport plan, named BHBUS, that includes the implementation of 10 bus transfer terminals, 3 bus-train transfer terminals and 20 km of busways and bus lanes, forming an integrated urban transport system in accordance with a trunk and feeder model, within a period of 5 years.

(ii) Campinas

Campinas is one of the most important industrial and university centers in Brazil, with a population of 937.000 inhabitants. Public transport is managed by a public company, EMDEC, and is operated by 6 private companies. The public transport system runs 800 buses, which carry on average 400.000 passengers per day.

The **Amoreiras** corridor is constituted by a 4,5 km median busway and a segment of 0,5 km of bus lanes in downtown area, linking the busway to the central bus terminal. Public transport in the city is integrated, following the trunk and feeder model, with six bus transfer terminals. The busway has off-line bus stop bays to permit overtaking. The busway is separated from general traffic lanes by concrete barriers and metal fences to channel pedestrians to pedestrian crossings. Traffic signals are coordinated, enabling green waves. An automatic fare collection system (AFC) is used, based on ISO magnetic stripe cards.

(iii) Curitiba

Curitiba is the best Brazilian example of integrated transport and urban planning. Curitiba is the capital of the state of Paraná and has a population of 1,5 million inhabitants and about 655.000 vehicles. Public transport is managed by a public company, URBS, and is operated by 10 private companies under concession contracts. The public transport system runs 1.677 buses, which carry on average 976.000 passengers per day.

The transport system planning began in the early 70's, as a direct initiative in accordance with the city's Master Plan that directed population and economic growth along linear "Structural Axis", as opposed to typical urban sprawl. These axis have a central busway, physically separated from two lateral service roads. Another two one-way roads, a block away form the busway, complete the axis, forming a three road "trinary" layout. The system has at present 25 bus transfer terminals and 65 km of median busways, divided into five express axis, **Eixo Sul, Eixo Norte, Eixo Leste, Eixo Oeste** and **Eixo Boqueirão**. The two first structural axis **Norte** and **Sul** were implemented in 1974.

The 65 km of busways are "fed" by 340 km of feeder routes that concentrate passenger demand on strategically placed interchange terminals. These terminals are linked in turn by 185 km of circular interdistrict routes. Acting in support of this network are 250 km of "Speedy Bus" routes (Ligeirinhos) that stop only at special "tube stations" set, on average, at every 3 km. For the same flat fare, the passenger can thus transfer from one bus to another at any of the terminals extending public transport access to 90% of the city. The tube stations provide a simple and creative means of speeding up operations. These glass and steel structures, 33 feet long and 9 feet in diameter, allow for loading and unloading at bus floor level. Fares are pre-paid - by token or to the attendant - and side elevators allow special access for the physically handicapped. Boarding times are thus reduced, approaching those of a subway (8 passengers/sec) and the short waiting times are in a sheltered and safe environment (VOLVO, 1998).

To avoid streetscape pollution and the cutting effect of a large number of buses running on a busway the decision was made to increase the size of the operating units and improve their design both in terms of emissions and visual impact. The first upgrade was made by using articulated buses. In March 1992 the city of Curitiba, decided to go ahead with a new project: operate a biarticulated vehicle on the Boqueirão busway. Each unit would be 25 meters in length and be capable of carrying up to 270 passengers. The project was developed and tested in a little over 6 months and the first route was inaugurated in December 1992, with 29 units transporting 115.000 passengers daily.

This first route proved to be so successful, both in terms of passenger acceptance and in economic savings, being 12% more economical than the previous articulated buses using conventional stops. For that reason, the City decided to shelve plans for an electric Light Rail Train (LRT) system on the main North-South route and use the biarticulated concept.

The main reason for this decision was cost: the 21 km LRT system would cost US$ 400 million to build and would take at least two years to be completed. The biarticulated project cost only US$40 million and was operating in 6 months - with far less civil works, route corrections and public investment. As private companies run the units, the largest part of the total investment (US$30 million) was financed by the private sector.

The new route also uses the tube stations and pre-paid loading at floor level; thus boarding times are also kept at subway values. Finally, operating speeds are kept high by the use of intelligent traffic signals along the route, which are timed for green wave progression of the units and, by means of loop detectors in the pavement, providing extra priority for the peak hour flows.

Even if there still exists a small difference in speed between a bus based mass transport system and a rail based one, this difference pales when the question of costs is raised. Compared with the internationally accepted value of US$ 100 million per km for the cost of a subway, a biarticulated mass transport route using existing road space costs US$ l,3 million per km - 80 times less than a subway. The cost of a speedy bus network - about US$ 0,2 million per km - is 500 times less (VOLVO, 1998).

(iv) Goiânia

Goiânia is the capital of the state of Goiás and has a population of 1,1 million inhabitants and about 537.000 vehicles. Public transport is managed by a public company, METROBUS, and is operated by 8 private companies. The public transport system runs 1.192 buses, which carry an average 604.000 passengers per day. The city has ten bus transfer terminals, 13 km of median busways and 27 km of bus lanes.

The **Avenida Anhanguera** busway was implemented in 1976 and remodeled in 1999. It is constituted of a 13,4 km median busway. It is separated from general traffic lanes by kerbed median with studs and metal fences. Along the busway there are 19 bus stations and 5 bus terminals. The bus stops are located in a central median. It is important to stress that in this operational model boardings and alightings occur at the bus floor level in raised platforms at the median stations and the busway is separated from mixed traffic by kerbs and fences. This operational model is similar to the one implemented in the city of São Paulo, in 1991, at the **Vila Nova Cachoeirinha** corridor.

(v) Porto Alegre

Porto Alegre is the capital of the southernmost state of Brazil, Rio Grande do Sul, and has a population of 1,3 million inhabitants and about 621.000 vehicles. Public transport is managed by a public company, EPTC, and is operated by 14 private companies and one public company. The public transport system runs 1.916 buses, which carry an average 1.300.000 passengers per day. Experiments with bus-priority schemes started in 1977. The city has 17 bus transfer terminals, 27 km of median busways and 1 km of bus lanes, along five radial routes.

Porto Alegre is the only place in Brazil that is adopting a bus ordering operational model, a technique evolved from the convoy system (COMONOR), previously implemented in São Paulo. It is in operation in the corridor **Avenida Assis Brasil** and **Avenida Farrapos** since 1980, along an extension of 9,1 km of a median busway. The corridors of **Protásio Alves** (5,5 km), **Bento Gonçalves** (6,8 km) and **João Pessoa** (1,4 km) have the same layout, but do not operate in convoys.

In the corridors **Cascatinha** (2,7 km) and **Oswaldo Aranha** (1,6 km), the buses run in a median busway with kerbed separators, where bus stops are located. The **Sertório** busway was implemented this year, operating on the left side close to the median with both side door buses and raised platforms. The corridors **Assis Brasil**, **Farrapos** and **Sertório** will, in the future, be the basis of a trunk and feeder operation.

(vi) Recife

Recife is the capital of the state of Pernambuco and has a population of 1,4 million inhabitants and about 309.000 vehicles. Public transport is managed by a public company, EMTU, and is operated by 10 private companies and one public company. The public transport system runs 1.344 buses, which carry an average 746.000 passengers per day. The city has five bus transfer terminals, 15,6 km of median busways and 3,4 km of bus lanes.

The corridor **Avenida Caxangá** (10,7 km) is the most important in the city, where beyond buses operate trolleybuses in a median busway. It is separated from general traffic lanes by studs and metal fences. In the corridor **Avenida Joaquim Nabuco** (3 km), the buses run in a median busway with kerbed separators, where bus stops are located. Both corridors attend trunk and feeder systems. The corridor **Avenida Sul** (2,9 km) is a median busway separated from general traffic by studs and road markings. Recife is the first place in Brazil that is testing a video camera enforcement system for bus lanes, specifically in a short bus lane at Avenida Herculano Bandeira (0,6 km). Recife was also pioneering in the use of an AVI system.

(vii) São Paulo

São Paulo is the most important financial and industrial center in Brazil. The city of São Paulo has 9,9 million inhabitants and 4,8 million vehicles. Bus public transport is managed by a public company, SPTRANS, and is operated by 53 private companies. The public transport system runs 12.000 buses, which carry an average 4,8 million passengers per day. The city has 35 bus transfer terminals, 28 km of median busways and 137 km of bus lanes.

São Paulo was the pioneering city in Brazil in the implementation of bus priority facilities, which were implemented in an accelerated manner in the years of 1977 and 1978, as a consequence of a fuel saving program (ANTP, 1980). At the beginning of 1979, there were 62,5 km of bus lanes in 24 locations. The concept of bus operation in ordered convoys, depicted in Figure 1, was first implemented along **Av. 9 de Julho**, in order to organize the flow of at 300 buses per peak-hour along a with-flow, kerb-side bus lane. In an effort to overcome saturation problems, new solutions have been implemented along the **Santo Amaro-9 de Julho** corridor, as the implementation of a third lane along the busway stops enabling overtaking and a trunk and feeder operational scheme. A worldwide busway survey study conducted by TRRL (Gardner et al, 1991) ranked this corridor as probably the best among all. Nevertheless, some further measures are still required in order to improve its efficiency. The **Paes de Barros** corridor has the same layout and functionality of the **Santo Amaro-9 de Julho** corridor, although carrying lower demands.

In 1991, a new type of busway was implemented - the **Vila Nova Cachoeirinha** corridor - which main innovation was the use of buses with doors on both sides and the operation of loading and alighting occurring at raised platforms, at the level of bus floors (one meter of height) (Gimenez and Oliveira, 1998; CET, 1992). This enables the bus to run both on the busway and also on common roads. Along common roads, outside the busway, the bus operates with the right side doors. Within the busway using the left side doors, the buses run along dedicated bus lanes close to the median, in the same direction of mixed traffic but segregated from them by heavy studs. Passenger platforms are located on the central median. The estimated capacity of this type of busway is 120 buses/hour, considering that overtaking operations are not possible. Consequently, as each platform allows the stop of two articulated buses per direction, this leads to a supply of some 20.000 places/hour/direction, what constitutes a median capacity transit system. This scheme is being repeated and adapted in a number of cities, due to their advantages when compared to ordinary right side bus lanes. Among their advantages, one could mention (Gimenez and Oliveira, 1998):

- Lower costs and shorter terms for implementation (central medians are preserved);
- Higher commercial speeds than in ordinary busways or bus lanes, since boarding and alighting occur more rapidly at raised platforms at the same level of the bus floor;
- Less environmental and landscape impact (trees are kept at the central median and there is little interference in urban developments;
- Safer pedestrian crossings (pedestrians cross only one traffic flow each time and in the same direction and can rely on the median as a refuge);
- More accessibility to disabled users, considering that the access to platforms are made through ramps;
- Maximization of bus flexibility, since buses can operate on the right or on the left side of the road.

The Itapecirica corridor, implemented in June 2000, follows the same operational scheme of the **Vila Nova Cachoeirinha** corridor, using only high capacity vehicles - articulated and biarticulated buses - and adopting some improvements like: users' information signs, safety fences, facilities for disabled users and signalized pedestrian crossings.

The **São Mateus - Jabaquara** corridor serves an industrial area of the metropolitan region of São Paulo and is under the jurisdiction of EMTU, a public company of the São Paulo State Government (Machado, 1998). The corridor is managed and operated by a private concessionaire company, covering an extension of 33 km median busway, running common and articulated buses and trolleybuses, which attend 9 bus terminals. The corridor has an electronic fare collection systems - Edmonson card based. The concession contract forecasts the substitution of the Edmonson system by a Smartcard technology and also the substitution of all diesel buses by trolleybuses.

São Paulo city and state authorities have proposed separate programs on the implementation of bus corridors and terminals (trunk and feeder system) covering 226 km/39 terminals and 153 km/24 terminals each one. The estimated cost of both programs is US$ 1.079,1 millions (US$ 700 millions and US$ 379,1 millions, respectively) (Rebelo and Benvenuto, 1994). By using the existing infrastructure, these new schemes will integrate the intercity bus lines, the suburban rail and metro systems, and the local bus routes. The effort will require combined actions of the São Paulo State Government, metropolitan authorities and the private sector. The latter will be responsible for supplying the vehicles, infrastructure and terminals, in a BOT-like operation. At the moment both programs are paralyzed due to funding and legislation problems.

Busway operational features and performance

This section is based on a survey conducted among the selected cities during the months of August and September 2000. It covers a total of 19 busways. The results presented herein have some limitations due to different levels of institutional development, operational control procedures and data collection methods. The questionnaires sent to transport authorities covered the topics that are presented in the **Tables 2** to **4**, except for traffic accident data, because of either they were not available or showed some inconsistency. Therefore, they are not presented in this paper, although busway traffic accidents constitute a major problem in Brazil, mainly those involving pedestrians.

(i) Physical and operational characteristics

Table 2 shows the main characteristics of the nineteen surveyed busways. It shows a tendency on the implementation and consolidation of trunk and feeder systems in Brazil and the remainder case of operation in bus convoys in Porto Alegre. Table 3 (Appendix 1) shows the main busway characteristics affecting speed and capacity. Average bus commercial speeds ranged from 13,0 to 40 km/h. The highest average bus speeds - 40 km/h - were recorded on the Anhanguera busway, where boarding and alighting operations happen at raised platforms. It should be noted that the average bus commercial speeds along the selected busways were 20,7 km/h at the AM peak and 20,4 km/h at the PM peak. Slightly higher average speeds were found in segregated median bus lanes, operating with raised platforms and using high capacity buses. Considering the number of signalized junctions or pedestrian crossings along the corridors, it seems to be mandatory the introduction of bus actuated signals to keep bus right of way. **Figure 2** (Appendix 2) shows typical layouts of referential Brazilian busways, emphasizing the position of bus stops.

(ii) Bus flows

Table 4 shows the maximum hourly bus flows observed along each busway, excluding any buses using general traffic lanes outside the busway. The highest recorded one-way bus flows were along Santo Amaro/9 de Julho corridor, with 431buses/hour inbound (towards the city center) during the morning peak and 359 buses/hour outbound during the evening peak. The flows were achieved in a single lane busway, with bus overtaking and no other special operational measures, but with high levels of high capacity buses, what tends to reduce bus queues at stops. Among the nineteen corridors, five showed bus flow levels higher than 300 buses/hour.

Table 2 – Physical and operational characteristics of surveyed busways

City	Location	Length (km)	Special features
Belo Horizonte	Cristiano Machado	5,9	Trunk and feeder (partially)
Campinas	Amoreiras	4,5	Trunk and feeder, 22% articulated buses
Curitiba	Eixo Sul	10,9	Trunk and feeder, 100% biarticulated buses
	Eixo Norte	9,9	Trunk and feeder, 100% biarticulated buses
	Eixo Leste	12,0	Trunk and feeder, 100% biarticulated buses
	Eixo Oeste	8,4	Trunk and feeder, 100% biarticulated buses
	Boqueirão	11,1	Trunk and feeder, 100% biarticulated buses
Goiânia	Anhanguera	13,4	Trunk and feeder, 100% articulated buses, left side oper.
Porto Alegre	Farrapos	4,2	Bus ordering, 2% articulated buses
	Assis Brasil	4,9	Bus ordering, 2% articulated buses
	Sertório	5,6	Left side operation (trunk and feeder planned)
	Bento Gonçalves	6,8	7% articulated buses
	Protásio Alves	5,5	7% articulated buses
Recife	Caxangá	10,7	Trunk and feeder
São Paulo	S. Amaro/9 de Julho	14,2	Trunk and feeder, 44% artic./biarticulated buses
	Paes de Barros	4,0	Trunk and feeder
	Vila Nova Cachoeirnha	12,0	Trunk and feeder, 31% articulated buses, left side oper.
	Itapecirica	7,9	Trunk and feeder, 59% artic./biarticulated buses, left side operation
	S. Mateus/Jabaquara	33,0	Trunk and feeder, 17% articulate buses

Source: BHTRANS, EMDEC, URBS, METROBUS, EPTC, EMTU/RECIFE, SPTrans and EMTU/SP

(iii) Available passenger places flows

The observed numbers of available passenger places during the morning peak periods based on nominal bus capacities achieved some 50.000/ hour for the AM peak direction in Santo Amaro/9 de Julho busway and some 42.000/hour for the PM peak direction. Maximum recorded available passenger places at bus crush capacities, which represents the absolute maximum number of passengers which could theoretically be carried during the morning and evening peak periods, were 63.369/hour and 52.839/hour in one direction respectively along Santo Amaro/9 de Julho.

(iv) Bus load factors

It is important to mention that passenger flows data were the most difficult to obtain, since it seemed that transit authorities are not used to monitoring passenger demand as a whole, along the corridors. So the numbers should be considered with some caution. Table 4 summarizes bus load factors at the maximum recorded load points for each scheme. Average bus load factors reached 0,84 or higher (1,42 in Anhanguera corridor) and only five corridors showed values greater than 1,0.

Table 4 – Maximum observed peak hour bus flows, available passenger places and passenger flows at peak load points on busways Corridor

City	Location	Period	Bus flows (b/h/d)	Bus avaiable passenger places (Passenger/hour in one direction) SEATED	NOMINAL	CRUSH	Actual passenger flows (p/h/d)	Average bus load factor (a)
Belo Horizonte	Cristiano Machado	AM	314	12560	27946	34540	21100	0,76
		PM	289	11560	25721	31790	12595	0,49
Campinas	Amoreiras	AM	116	4374	10732	13401	9200	0,85
		PM	116	4374	10732	13401	9200	0,85
Curitiba (b)	Eixo Sul	AM	56	3976	11816	15120	10640	0,90
		PM	50	3550	10550	13500	9500	0,90
	Eixo Norte	AM	20	1420	4220	5400	3800	0,90
		PM	18	1278	3798	4860	3420	0,90
	Eixo Leste	AM	24	1704	5064	6480	4560	0,90
		PM	21	1491	4431	5670	3990	0,90
	Eixo Oeste	AM	12	852	2532	3240	2280	0,90
		PM	10	710	2110	2700	1900	0,90
	Boqueirão	AM	36	2556	7596	9720	6840	0,90
		PM	32	2272	6752	8640	6080	0,90
Goiânia	Anhanguera	AM	62	2294	8060	10478	11500	1,42
		PM	53	1961	6890	8957	9500	1,38
Porto Alegre	Farrapos	AM	320	11699	24987	30483	25600	1,02
		PM	300	10966	23390	28528	21100	0,90
	Assis Brasil	AM	350	12795	27293	33289	28000	1,03
		PM	290	10602	22626	27599	20300	0,90
	Sertório	AM	21	840	1869	2310	2029	1,08
		PM	20	800	1780	2200	1415	0,79
	Bento Gonçalves	AM	129	4686	9459	12612	8500	0,89
		PM	122	4433	9757	11956	7650	0,78
	Protásio Alves	AM	162	5932	13118	16096	11800	0,89
		PM	153	5603	12374	15180	10600	0,86
Recife	Caxangá	AM	359	13328	28339	34588	29800	1,05
		PM	319	11840	25171	30720	23840	0,95
São Paulo	S. Amaro/9 de Julho	AM	431	18434	50043	63369	34911	0,70
		PM	359	15355	41722	52839	32976	0,79
	Paes de Barros	AM	42	1616	35014	4316	3000	0,85
		PM	31	1192	2591	3182	2000	0,77
	Vila Nova Cachoeirnha	AM	55	2149	5592	7053	4000	0,71
		PM	41	1601	4182	5277	3000	0,72
	Itapecirica	AM	133	6001	17263	22018	10000	0,58
		PM	116	5249	15097	19255	9000	0,60
	S.Mateus/Jabaquara	AM	210	8292	20166	25224	12583	0,62
		PM	210	8292	20166	25224	11407	0,57

Source: BHTRANS, EMDEC, URBS, METROBUS, EPTC, EMTU/RECIFE, SPTrans and EMTU/SP
Note (a) Load factor = passenger flow/nominal available passenger places
(b) Actual passenger flows (p/h/d) were estimated. URBS provided data on a daily basis

The maximum recorded line-haul passenger throughput varied from 2.029 passengers/ hour/direction (p/h/d) in Sertório corridor, to 34.911 p/h/d on Santo Amaro/9 de Julho corridor, during the AM peak when alighting predominated (Table 4). The corresponding maximum recorded passenger flows during the evening peak periods varied from 1.415/hour in Sertório to 32.976/hour in Santo Amaro/9 de Julho, where overtaking lanes at bus stops facilitate high throughputs. Passenger throughputs exceeded 25.000 p/h/d on four of the nineteen busways surveyed.

Conclusions

Many lessons can be drawn form the Brazilian experience on busways. They cover many different aspects, from institutional development and integration, design characteristics, operational schemes up to costs and benefits. Among them, the following have to be emphasized:

a) The creation or existence of an agency oriented towards defining a national public transport policy is determinant to other national policies dedicated to energy saving, pollution and traffic accident control and also for local authorities, enabling them to reach international funds or only providing technical expertise to local staff. At this moment, Brazil lacks an agency like that.

b) Advantageous fare policies from the users' viewpoint, subsidizing low income segments of the population, like the Brazilian "vale transporte", helps to improve public transport ridership.

c) Busway schemes have to be faced as a system, not limited to the roadway itself . An integrated approach, joining bus priority, park-and-ride, trunk-and-feeder operation, properly designed buses, ITS devices (travel information, automatic fare collection, actuated signals, automatic vehicle location, bus centralized operational control and dispatching), associated to private traffic restrictions can attract car users too.

d) The cost of busways is undoubtedly much lower than rail-based systems and do not compromise other social investments, since concessions schemes seemed to be attractive to private investors and operators.

e) The majority of peak-hour flows along main corridors of median or large urban areas can be suited by bus transit systems.

f) The interference of private vehicles on the busway can be minimized by the adoption of physical segregation, including central or side islands and heavy studs. They are also important for protecting pedestrians who cross the road. All pedestrian crossings shall be cautiously designed, considering aspects of visibility (illumination, road markings), provision of signals and electronic enforcement of speed and red light violations.

g) During morning peak hours, boarding passengers are dispersed among several bus stops located among the suburban roads, outside the busways. These passengers tend to alight at bus stops located inside the busway, close to the city center. During the afternoon peak hours, the situation is reversed, i.e., passengers tend to board at bus stops close to the city center (usually located inside the busway) and alight at bus stops near to the end of a bus route. As the passenger-transfer capacity of bus stops and the time spent by buses at bus stops largely determine the capacity of a busway as a whole, and as the boarding of buses takes more time than alighting, afternoon peak-hour traffic bound to the suburbs is critical for busway operation (Gardner et al, 1991).

h) Finally, the implementation of busway schemes needs a social pact, since different interests and segments of the society are involved and affected by the scheme. So, society participation and consultation along the process can be essential for the success of the scheme.

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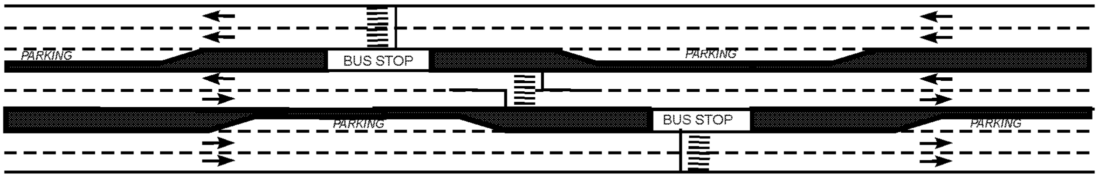
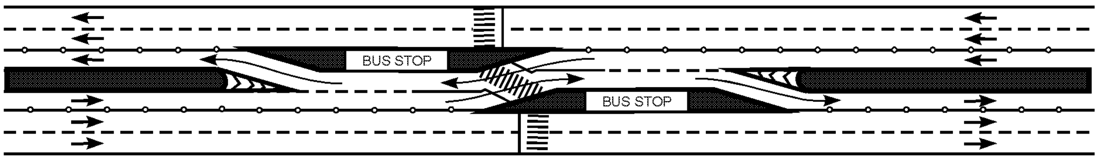
Appendix

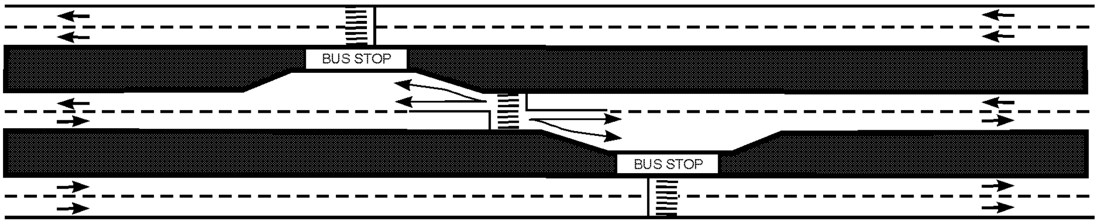
Figura 2
Bus Stop Configurations



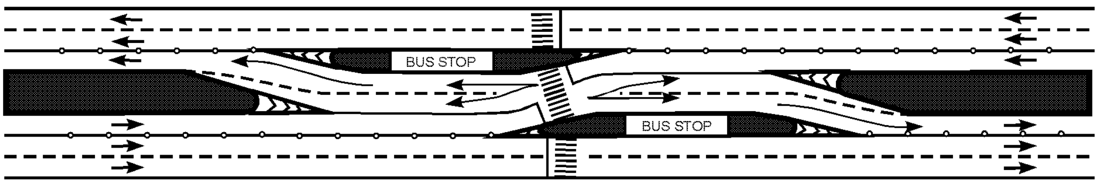
On-line bus stop: Curitiba



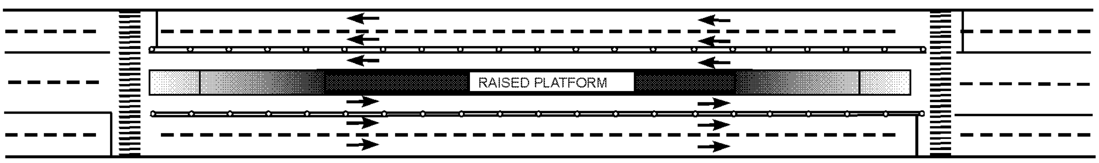
On-line bus stop: Porto Alegre



Off-line bus stop: Belo Horizonte



Off-line bus stop: São Paulo



On-line bus stop: Goiânia

(Adapted from Gardner et al., 1991)

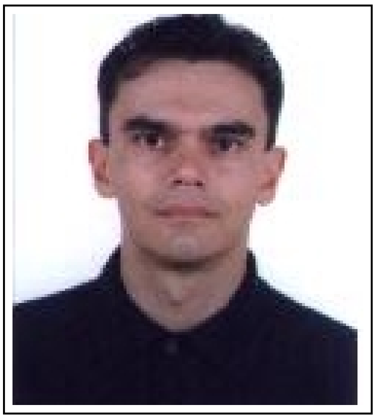
TABLE 3 - Busway Characteristics Affecting Speed and Capacity

City	Location	Bus Commercial Speeds (km/h)		Average Stop Spacing (m)	Average Junction Spacing (m)	Number of Signalized Junctions	Average Signalized Junction Spacing (m)	Priority Conditions (a)	Bus Stops Conditions			Fare Collection System		
		AM	PM						Overtaking	Bus bay	Raised platform	In	Out	Type
Belo Horizonte	Cristiano Machado	22	24	400	655	22	268	KB-GW	Yes	Yes	No	Yes	Yes	Cash
Campinas	Amoreiras	18	18	490	320	14	321	KB-GW	Some	Some	No	Yes	Yes	Iso mag. Card
Curitiba	Eixo Sul	19,5	19	550	140	30	364	KB-MBL-BAS	No	No	Tube station	No	Yes	Cash/token
	Eixo Norte	19,5	19	550	145	34	292	KB-MBL-BAS	No	No	Tube station	No	Yes	Cash/token
	Eixo Leste	19,5	19	550	144	25	482	KB-MBL-BAS	No	No	Tube station	No	Yes	Cash/token
	Eixo Oeste	19,5	19	550	164	14	604	KB-MBL-BAS	No	No	Tube station	No	Yes	Cash/token
	Boqueirão	19,5	19	550	180	36	309	KB-MBL-BAS	No	No	Tube station	No	Yes	Cash/token
Goiânia	Anhanguera	40	40	562	212	52	258	KB	No	No	Yes	Yes	No	Smartcard Edmonson
Porto Alegre	Farrapos	22	18	700	230	18	233	MBL-GW	No	No	No	Yes	No	Cash
	Assis Brasil	19	17	600	85	57	86	MBL-GW	No	No	No	Yes	No	Cash
	Sertório	21,7	20,8	1200	200	29	193	MBL	No	No	Yes	Yes	No	Cash
	Bento Gonçalves	19,7	19,1	485	220	31	219	MBL	No	No	No	Yes	No	Cash
	Protásio Alves	19,3	18,3	500	135	41	134	MBL	No	No	No	Yes	No	Cash
Recife	Caxangá	19	21	563	535	20	535	MBL	Some	No	No	Yes	No	Cash/smart
São Paulo	S. Amaro/9 de Julho	13	13	500	380	37	384	MBL	Yes	No	No	Yes	Yes	Cash Edmonson
	Paes de Barros	18	18	500	330	13	308	KB	No	No	No	Yes	Yes	Cash Edmonson
	Vila Nova Cachoeirnha	21	21	500	340	35	343	KB	No	No	Yes	Yes	Yes	Cash Edmonson
	Itapecirica	22	22	550	460	18	439	KB	No	No	Yes	Yes	Yes	Cash Edmonson
	S. Mateus/Jabaquara	22	22	500	242	136	243	KB-MBL	No	Some	No	Yes	Yes	Edmonson

Note: (a) KB - Kerbed Segregated Median Busway, MBL - Stud Segregated Median Bus Lane, BAS - Bus Actuated Signal, GW - Green Wave Signal Timings

Source: BHTRANS, EMDEC, URBS, METROBUS, EPTC, EMTU/RECIFE, SPTrans and EMTU/SP

About the author



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Alexandre graduated from universities in Brazil in civil engineering and transport planning/ engineering. His career of 16 years has been varied. Since 1992 he has worked with the BHTRANS (Belo Horizonte Transport and Traffic Agency) since 1992 in a number of positions including Road Planning Manager, Central Area Traffic Planning Manager, Development and Information Manager and Transport and Traffic Analyst. His main present area of responsibility is in analytical work on bus and traffic system performance to support BHTRANS' operations including busway operations. Previously he worked at the Municipality of Contagem as Chief of the Public Transport and Traffic Planning Division. Alexandre has worked as a consultant on Project Engineering, Economics and Engineering and has also lectured in Traffic Engineering, Public Transportation, Traffic Legislation and Traffic Safety.