BRT in metropolitan regions: two examples in Brazil

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Abstract

Many Brazilian cities are currently implementing BRT (bus rapid transit) systems due to their lower cost and shorter construction time when compared to rail systems. The lobbies of bus operators and manufacturers are also an important issue.

Two projects are under way in the state of São Paulo, connecting two or more cities within metropolitan regions. The Northwest BRT Corridor is 25.0 km long and connects four cities, catering to a total population of 920,000 inhabitants in the Campinas Metropolitan Region. The Guarulhos Corridor is 4.0 km long and connects São Paulo's eastern sector to Guarulhos, both of which are part of the São Paulo Metropolitan Region, and caters to 2.6 million inhabitants.

This paper describes the process of planning and designing BRT systems in Brazil and presents the traditional path of such projects: feasibility analysis (transportation demand studies, urban insertion and sustainability evaluation and analysis) followed by architecture and engineering design (bus stops and terminals, bus corridor and street network infrastructure).
Keywords: BRT systems, metropolitan regions, mobility, planning, design.

1 Introduction

Although there are no specific technical standards for BRT systems in Brazil, recent projects have observed the following: segregated/exclusive bus lanes along the left lane in existing avenues; closed bus stops located on avenues central medians; provision of full accessibility on all facilities; on-level embarkment/ disembarkment; bus stops and multimodal terminals designed under sustainability criteria; segregated bicycle ways along the corridor (when possible); extra lane at bus stops for overtaking (when possible); bus priority at intersections; real time

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operation information at bus stops and multimodal terminals. Operational details include: trunk lines at the corridor integrated with feeder lines at multimodal terminals; pre-paid tariff; free transfers between buses; forecasted average daily demand: 16,000 pax; designed average bus speed: 25 kph.

Due to space availability and expropriation costs, not all of these parameters were followed. This led to certain compromises, all of which are explained in the next section.

2 The Northwest Corridor

This Northwest Corridor segment is 30.0 km long and connects four fast growing industrial cities (Sumaré, Nova Odessa, Americana, Santa Barbara d'Oeste) with total population of 920,000. This corridor is part of a São Paulo State plan to improve mobility among important urban centers within Metropolitan Regions.

2.1 Feasibility analysis

2.1.1 Transport demand studies

Demand studies are based on the Campinas Metropolitan Region Origin/ Destination Survey [1]. The survey was the input for the construction of a 4-step TRANUS transportation model (trip generation, trip distribution, modal split and trip allocation).

The trip generation model assumed that trips would increase according to population growth in 2014, 2018 and 2025. Thus, a total trip matrix was obtained for the same years. Modal split assumed no change in the O/D survey mode share, producing both Public and Private Transportation O/D matrixes.

The present public transport network was based on the existing city and intercity bus lines. The private transport network was based on the main city and intercity transport axis. Future projects were introduced in both networks according to their expected year of construction/operation, as well as future plans of public transport reorganization. A trip allocation model allowed estimation of public and private transportation demands. It also allowed identification of the most congested segments, Figure 1.

2.1.2 Urban insertion and sustainability

The corridor plan makes use of existing streets and avenues. In some parts, it uses the space of a deactivated energy transmission line. These tactics were employed in order to minimize expropriations.

A field survey showed that there are no archeological sites in the area. However, one historic site was spotted along the plan: an old railway station from 1875 in Americana in front of where the new bus terminal is expected.

Also, there are no significant protected green areas and water sources that cross the corridor plan.

The area is almost completely urban, with different population densities. The main activities are from the industrial and service sectors. There are also agricultural activities, mainly sugar cane plantations, on the outskirts.

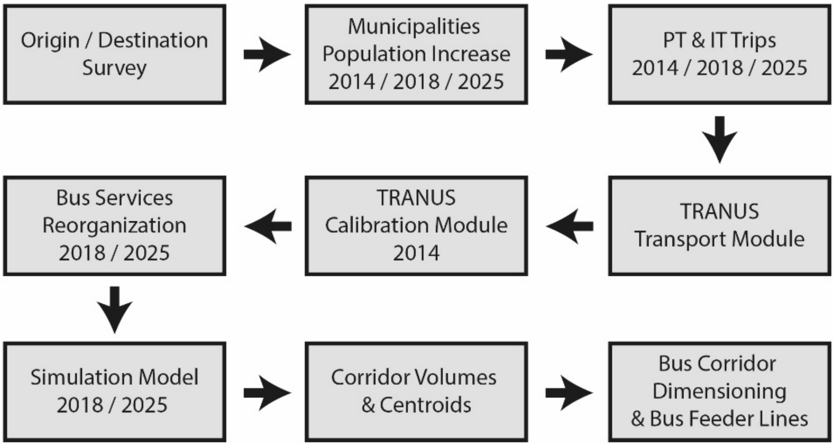

Figure 1: Demand study's methodology.

2.1.3 Evaluation and analysis

Economic evaluation (under society's point of view) followed the traditional procedure (the "with" and "without" criterion) of balancing discounted values of forecasted benefits and forecasted costs along the project's lifetime [2].

The estimated benefits include: time and fuel savings; bus fleet investment savings due to the system reorganization; and reduction in air pollution emissions. The values were estimated from results obtained through the utilization of simulation models.

Costs and resulting investment requirements were estimated considering bus fleet requirements and preliminary construction and maintenance costs.

The project's internal rate of return was 9.48%.

The corridor's financial evaluation (under the bus operator's point of view) was also performed balancing discounted values of operational and non-operational revenues and forecasted operational and maintenance costs plus bus acquisition costs.

For this analysis, the internal rate of return was 12.35% and the investment pay back will occur on the ninth year of the project's lifetime.

Forecasted externalities were mainly positive: better accessibility to urban services, increased real-estate value, more job opportunities, commercial undertakings, increased attractivity and improvement of urban spaces.

2.1.4 Conceptual design

Santa Barbara Avenue is the only link connecting this city to Americana and is the most congested location with commercial and services activities.

In light of this, planners proposed a new link connecting both cities through a large agricultural area to be urbanized [3].

This existing bus lines are to be reorganized, providing a new and faster service.

The corridor plan has two also different patterns. One is along the central median of wide avenues. In these cases, bus stops and a bikeway will be located at the central median. The other pattern occurs when the plan crosses downtown areas: existing streets are used and bus stops are located on the sidewalks; in these cases there is no bikeway.

Terminals were located according the existing bus lines systems and municipality development plans. The Nova Odessa Terminal is an existing and renewed building located 1 km from the corridor. Because of this distance, a bus shuttle service was proposed between the terminal and the corridor.

The Americana Terminal is located downtown, close to the city's CBD (Central Business District). The Santa Barbara d'Oeste Terminal is on a highway, far away from the denser urban areas. This is because its main use will be for intercities buses.

All terminals and some bus stops (transfer points) are intended to provide multimodal integration. In the case of public transport, time and fare integrations are planned.

The new bus operational plans propose two trunk axes. The new axes will provide 3 intercity services (Santa Barbara, Americana and Sumaré), operated by articulated two sided doors buses (capacity: 150 pax) with frequencies ranging from 2 bus/hr to 6 bus/hr.

The former transport axis by Santa Barbara Avenue will be maintained as well as the use of a small urban terminal and will provide 6 intercity services (Nova Odessa city included) operated by articulated two sided doors buses with frequencies ranging from 2 bus/hr to 4 bus/hr.

All intercity buses will be equipped with automatic fare collectors and real-time remote monitoring.

A new operation plan was also proposed to reorganize local bus lines within the cities. Some of the city bus lines are to operate as feeder lines at terminals and transfer points and will operate single buses (capacity: 80 pax).

Estimates indicate that the corridor's daily demand will be of 13,600 passengers; buses will perform 246 daily trips on average, and the average travel time will be 32 minutes.

2.2 The corridor design

This section summarizes the corridor's design premises [3].

2.2.1 Architecture design: bus stops and terminals

There are 24 standard bus stops and 4 larger ones (transfer points) located on the central median and 31 bus stops on the sideways.

The main purpose of the architecture design was to have modern bus stops provide comfort and safety to its users. All bus stops are well lighted and ventilated, have seats, displays with real time operational information as well as traditional operational information, such as lines, schedules and maps. Bus stops located on the central median have closing platform doors in order to avoid fare evasion.

The Americana multimodal terminal is a two story building (9,413 m^2) located downtown close to the city's CBD. Both intercity and city bus lines will operate on the street level providing safe access to pedestrians, bikes and taxis. Users can board the buses using their prepaid fare card or with single tickets bought at terminal booths. This terminal will house 12 intercity lines (160.0 m long platforms) and 46 city bus lines, being 36 through bus lines (160.0 m long platforms).

The terminal's modern architecture is intended to constitute a landmark and also help the beginning of an urban renewal process in the surrounding area.

The second level is intended to shelter a popular market which was displaced by the terminal's construction. This second floor is accessible by stairs, escalators and elevators, and houses a central control office as well as public WC.

The Santa Barbara d'Oeste multimodal integration terminal (13,300 m^2) is located a state highway, outside of the city's downtown area, Figure 2.

Figure 2: Santa Bárbara D'Oeste terminal.

This terminal will house 4 city bus lines (40.0 m long platforms), 2 intercity (metropolitan) bus lines (40.0 m long platforms) and 2 long distance bus lines (67.0 m long platforms).

Due to its location, the terminal has an overpass, making it accessible to pedestrians and bikes, as well as car and taxi users. Drivers can park in a nearby parking lot. The platform level there has seats, displays with bus lines operation/ lines/schedules/maps/information as well as ticket booths, a coffee shop, rest area, central control office and public WC.

The terminal's location is aligned with city plans that intend to create new development areas out of the city center.

All terminals and bus stops on the avenues central median will have bicycle parking facilities. Landscape works were also provided as well as bus stops naming landmarks.

Both terminals were constructed with a rainwater reservoir to be used for cleaning purposes.

2.2.2 Engineering design: corridor and street network infrastructure

The standard section of the bus corridor along avenues' central median (extension: 17.9 km) will be a segregated bus lane (width: 3.5 m) and two general traffic lanes (width: 3.0 m). The central median is very wide (width ranging from 10.0 m to 60.0 m). Therefore, all enlargements needed will be made towards the central median space in order to avoid expropriation.

Bays were proposed to accommodate bus stops wherever possible using the central media space. No extra bus lane was proposed at bus stops otherwise. A bikeway (extension: 7.8 km) is also proposed in this space.

Segments of the corridor use existing downtown streets (extension: 7.1 km) in both Americana and Santa Barbara d'Oeste.

These are narrow streets (9.0–10.0 m wide) and geometric, drainage and pavement adjustments were provided. In this case, smaller open bus stops will be located on the sidewalks.

Along all avenues and streets, drainage and asphalt pavement will either be replaced by a new one or restored when possible. At both terminals and bus stops a concrete pavement will be used. New traffic signals, public lighting and landscape will be also provided.

The corridor segment between Nova Odessa and Americana required major works, since the only link between the two city passes under a state highway and is very busy.

A new design was proposed with a rotary and a one direction (Nova Odessa to Americana) two lane overpass (300 m long).

An underground technical trench to house cables (telephone, cable TV, optical fiber an also an Intelligent Transport System – ITS) was proposed along the avenues central medias.

2.3 Construction costs

The estimated corridor's construction budget, to be sponsored by the São Paulo State Government, is R$180,000,000.00 (US$ 60,000,000.00) (May 2015).

The corridor is presently under construction and is expected to operate in mid-2016.

3 The Guarulhos Corridor

The Ticoatira–Vila Endres segment (4.0 km long) is a segment of the Guarulhos Corridor (total length: 20.00) and has a strategic role because it connects São Paulo's eastern sector to Guarulhos, both of which are part of the São Paulo Metropolitan Region. This project will cater to a total population of 2.6 million inhabitants and also will provide access to the São Paulo International Airport [4].

3.1 Feasibility analysis

3.1.1 Transport demand studies

These studies follow the same steps presented for the Northwest Corridor (item 2.1.1) [5]. In this case, EMME was the mathematical simulation model used and forecasts were made for 2014, 2018 and 2025.

The transport service network included city and intercity bus lines as well the metro and the commuter train.

The peak hour public transport demand estimates following were: 2.98 million pax/hr (2014), 3.22 million pax/hr (2018) and 3.54 million pax/hr (2025).

The Ticoatira–Vila Endres segment was the most congested section. It carries 1,875 pax/hr (Guarulhos to São Paulo direction), Figure 3.

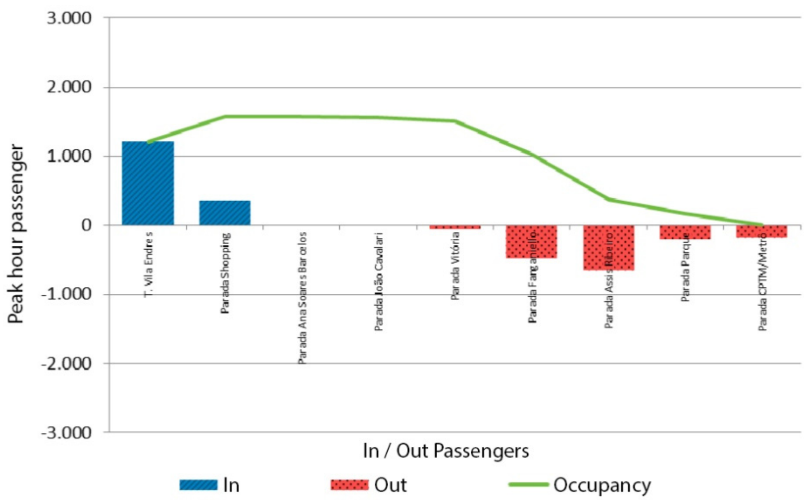

Figure 3: The Vila Endres–Ticoatira in/out peak hour passengers.

3.1.2 Urban insertion and sustainability

The Ticoatira–Vila Endres segment shall pass through a consolidated, dense, hilly urban area. Expropriation minimization and commerce/services activity disruption were the main concerns when studying alternative plans.

The selected alternative plan follows mainly along Guarulhos and Gabriela Mistral avenues, the main arterial roads in the area.

Since this is an already-built environment, no sustainability study was conducted. However, "green roofs" were proposed for all bus stops.

3.1.3 Evaluation and analysis

Both economic and financial evaluation followed the same methodology presented for the Northwest Corridor (presented in section 2.1.3).

The results for the economic evaluation showed a 25.75% internal rate of return. The financial evaluation resulted in a 66.2% internal rate of return and pay back on the third year [5].

3.1.4 Conceptual design

Guarulhos Avenue, on the Guarulhos side, is one of the most important connections between the two cities and houses many commerce/services activities [6].

This avenue is a half-hillside construction, so its widening would cause large expropriations and accessibility and connectivity problems. Since the central median is narrow, each bus stop was split into two parts: one for each traffic direction. In this case, there is no bikeway.

Gabriela Mistral Avenue, on the São Paulo side, is the continuation of Guarulhos Avenue after crossing the bridge. It is an arterial road as well and is 10 m, with households and commerce on both sides. In this case, the construction of a two-way avenue with central median was proposed, although this will result in large expropriations on one side.

The most import characteristic of this plan is the elimination of two existing bottlenecks: the proposed duplication of a bridge crossing both a freeway and a river; and the construction of two underpasses on a railway crossing.

The Vila Endres terminal will be located in the middle of a rapidly expanding residential area and will integrate all Guarulhos corridor bus lines.

The Ticoatira terminal will integrate intercity and city bus lines with the metro and commuter trains network. Its location is not yet defined, so only a larger bus stop (transfer point) was proposed.

Bus services are to be reorganized: 8 trunk intercity bus lines will run along the corridor. There are also 11 passing-through intercity bus lines and 5 city bus feeder lines.

Trunk intercity bus lines will operate articulated two sided buses (capacity: 150 pax) and the remaining ones, single buses (capacity: 80 pax). All are supposed to be biodiesel powered and will be equipped with automatic fare collectors and real-time monitoring.

3.2 The corridor design

This section summarizes the corridor's design premises [6].

3.2.1 Architecture design: bus stops and terminal

There are 7 standard bus stops and one larger at Ticoatira (transfer point). Due to space restraints each bus stop was split in two parts, each one servicing one traffic direction.

The main purpose of the architecture design was to have innovative and modern bus stops fit to provide comfort and safety to its users. All bus stops will have a "green roof" and are well lighted and ventilated; have seats, displays with displays with real time operational information as well as traditional operation information, such as lines, schedules and maps. Bus stops located on central median have closing platform doors in order to avoid fare evasion.

The Vila Endres multimodal terminal is a one story building (11,000 m^2) located in the middle of a residential area. Both intercity and city bus lines will operate on street level providing safe access to pedestrians, bikes and taxis. Users can board the buses using their prepaid fare card or with single tickets bought at terminal booths. This terminal will house 8 intercity bus lines, 4 city bus lines and 36 intercity passing through bus lines.

The terminal modern architecture is intended to constitute a landmark and also provide a friendly insertion within the residential area, Figure 4.

Figure 4: The Vila Endres terminal.

3.2.2 Engineering design: corridor and street network infrastructure

The bus corridor standard section along Guarulhos Avenue (3.5 km long) will be a segregated bus lane (width: 3.50 m) and 1 x general traffic lanes (width: 3.60 m–4.00 m) in each direction.

Due to topography and space restraints proposed interventions in Guarulhos Avenue were restricted to drainage, pavement, lighting and traffic signal improvements. No extra lane was proposed at bus stops for overtaking. Bus stops will be located at the avenue central median.

Gabriela Mistral avenue will be widened and its standard section will comprise a segregated bus lane (width: 3.50 m) and 2 x general traffic lanes (width: 2 x 3.50 m). In this case, engineering design includes all activities needed for a new road.

A new bridge will be added beside the existing and congested one, going over a freeway and a river. This is a 300 m long bridge with a 95 m free span. The construction of two new underpasses at the corridor x commuter train line crossing will eliminate an existing bottleneck reducing travel times. The remaining 200 m corridor length will be of existing urban streets providing access to Vila Endres Terminal.

3.3 Construction costs

The estimated corridor's construction budget, to be supported by the São Paulo State Government, is R$ 170 million (US$ 57 million) (January 2014).

Due to the high cost, the State Government decided to split the corridor's construction in two stages. The first one comprises the bridge, two railway underpasses and the bus terminal. The second one comprises all corridor and urban streets infrastructure.

Construction works did not begun yet and there is not an operation start forecasted deadline.

4 Conclusions

Several BRT system are already operating in many Brazilian cities (Rio de Janeiro, Belo Horizonte, Goiania, etc.) with good performance indicators and users high satisfaction rates. Many other are under planning/design/construction.

The Northwest and the Guarulhos corridors are the only examples of metropolitan corridors and are to be tested. General goals of BRT corridors in Brazil are mainly to improve bus public transport performance and also discourage private car use.

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