**BUS RAPID TRANSIT: AN ALTERNATIVE FOR DEVELOPING COUNTRIES**

Monica T. Leal and Robert L. Bertini

**Abstract:** Bus Rapid Transit (BRT) combines the benefits of light rail transit with the flexibility and efficiency of bus transit. The goal of BRT development is to enhance ridership and reduce operating costs with increased service levels and quality. A BRT system combines the technology of intelligent transportation systems, traffic signal priority, cleaner and quieter vehicles, rapid and convenient fare collection, and integration with land use policy. BRT has demonstrated improvements in public transportation service and enabled improvements that can be implemented at relatively low cost. This paper presents the benefits of the BRT system in developing countries using the BRT system in Bogotá, Colombia as a case study.

**INTRODUCTION**

The mission of Bus Rapid Transit (BRT) is to combine the flexibility and low implementation cost of bus service with the comfort, efficiency, cost-effectiveness, land use influence and versatility of light rail transit (LRT). Various projects around the world have indicated that BRT is an effective alternative for congested cities at a relatively low construction and operation cost.

Cities in developing countries have struggled with the problem of how to upgrade and improve existing transit services at a low cost. Developing countries with high transit-dependent populations and limited financial resources have increasingly attempted the use of BRT systems because of their low costs and relatively fast implementation times. The cost of a BRT project is considered to be approximately one-third of a LRT project, which is a cost that developing countries can afford. After construction the system is practically self-financing with fares of about $US0.50 per trip. BRT has proved that it allows low fares and reduced travel times for low income users. BRT systems such as Curitiba in Brazil and Transmilenio in Colombia are great examples of the success that the BRT system has had in Latin American countries.

This paper defines the most important characteristics of a BRT system using the system in Bogotá, Colombia as a case study. First, a definition of BRT is given. Second, the transportation characteristics before the implementation of the BRT system are described. Third, aspects of the BRT system in Bogotá, Colombia, such as operational and infrastructure elements, fare collection and the most important impacts of the implementation of the BRT system in Colombia are discussed. Finally, the most important results of the first phase of operation are presented.

**BUS RAPID TRANSIT DEFINITION**

BRT is a public transit mode that uses buses to provide a light rail quality of service. BRT combines the flexibility and low cost of bus service with the comfort, efficiency, cost-effectiveness and versatility of LRT. BRT can operate with exclusive rights of way, quieter and cleaner vehicles, rapid off-board fare collection, correct and attractive infrastructure and short dwell times. The cost of a BRT project can be about one-third the cost of a LRT project. BRT can be considered as a hybrid transit service falling between traditional rail and bus modes.
A BRT system includes the following characteristics:

- Exclusive right of way
- Rapid boarding and alighting
- Clean, secure, and comfortable stations and terminals
- Fast and efficient fare collection, including fareless zones, collection at stations or on board vehicles.
- Effective regulations for bus operators
- Use of Intelligent Transportation Systems
- Transit priority at signalized intersections
- Integration with other modes of transportation
- Adequate marketing
- Good customer service

When these characteristics are met, a BRT system can be considered to be as versatile, flexible and comfortable as LRT systems.

**CASE STUDY: TRANSMILENIO, THE BRT SYSTEM IN BOGOTA, COLOMBIA**

Bogotá is the capital of Colombia, with a population of 6.5 million people, about 15% of the total population of the country. Sixty two percent of the population ranges between 15 and 54 years old. Bogotá has a high density of 3,700 people per km². Bogotá is located 2,600 meters (8,500 feet) above sea level. It has no district seasons and the temperature ranges between 8°C (46°F) and 20°C (68°F) year round. Bogotá has about 13,000 lane-km of roadways, of which 10,000 lane-km are paved. Demand in Bogotá is concentrated in two distinct peak periods, the morning peak from 6:00 to 8:00 AM and the afternoon peak from 5:00 to 7:00 PM. There is also a small midday peak (Hidalgo, 2002).

For the past 20 years, the Colombian government has discussed the need for a new transportation system in Bogotá. Possibilities such as a LRT were considered. However, LRT was never implemented because of the high cost and the protests made by private companies that operated the existing public transportation system.

In 1998 Bogotá initiated a mobility strategy in order to overcome its transportation problems. Since 1998 the city has implemented some strategies to reduce congestion such as a reduction of 40% of the automobiles used during the peak hours through plate number restrictions, implementation of a bikeway network, pedestrian walkways, and the creation of the Transmilenio BRT system. Transmilenio is a high-capacity transportation system that provides the same quality of a LRT service. In 2000, Transmilenio began operation.

**BEFORE THE BRT IMPLEMENTATION**

This section describes the transportation conditions in Bogotá in 1998, (before Transmilenio) in order to understand the positive transportation changes made in the city.

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1 Transmilenio means transportation for the third millennium.
Ninety-five percent of the road network was used by 850,000 private vehicles, which transported about 19% of the population. Close to 70% of trips shorter than 3 km were made by car. Buses occupied a low percentage of the roadway network. Seventy-two percent of trips were made by public transit on about 21,000 buses. The average trip by bus was about 1 hour 10 minutes in duration with an average speed of 10 km/hr. The majority of the buses were more than 14 years old with an average of 50% occupancy. A total of 48% of public transit vehicles were medium sized buses (40-80 passengers), 37% small buses (20-40 passengers), and 15% were minibuses. The fares ranged between US$0.30 and US$0.40 depending of the type and age of the buses (Transmilenio S.A., 2000). In general buses did not have comfortable seats, ventilation or security. There were no defined bus stops, therefore, buses picked up and dropped off passengers at any location along the route. There was no motivation for car owners to switch to public transportation because of the low quality of the system. Figure 1 shows some of the buses previously used in the public transportation system in Bogotá.

Figure 1: Bogotá, Before the BRT Implementation

The transportation system was operated by multiple private operators, which perceived their income as a function of the number of buses in their fleet. The bus system growth was very fast and disorganized. Between 1993 and 1997 the demand for bus service increased 27%. On the other hand, the bus supply increased 72%, which shows the lack of control and planning of the system supply (Transmilenio S.A., 2000). This unbalanced growth brought a phenomenon known as “la guerra del centavo,” which can be translated as “the war of the cent.” The war of the cent refers to the aggressive war of the drivers for picking up the maximum number of potential passengers. This aggressive competition between buses was permitted in the streets. Since the revenue earned by the operators depended on the number of passengers served, the war for passengers was very competitive. Because of the excessive number of buses, these private operators had excessive consumption, tires, and other operational requirements. In addition, the lack of maintenance and renovation of vehicles brought excessive operational costs and increased contaminants and noise.
Fare collection was performed by the driver, which produced distractions that in many cases ended in accidents. In addition, this increased the travel time making the service less attractive to the public.

Other problems included high pollution levels of 750,000 tons of atmospheric pollutants per year generated by traffic and noise levels above 90dB on major streets. Air pollution was a serious issue due to the higher altitude (27% less available oxygen than at sea level) and the lack of pollution control. In addition, a high number of accidents (52,764) and 1,174 fatalities were recorded in 1998 (Transmilenio S.A., 2001).

AFTER THE BRT IMPLEMENTATION

Transmilenio was created in order to reduce accidents, shorten travel times, reduce pollution, provide accessibility for young, elderly, and people with disabilities and to provide affordable, high quality and advanced transportation technology. The infrastructure, management, controls and planning are supplied by a new transit authority. The fare collection and operation systems are controlled by the private sector. The new transit authority, Transmilenio S.A. was created in October 1999 in order to manage, control and plan the system. Transmilenio S.A. is supported by 3% of the fare revenues and other activities, such as commercial advertising (Hidalgo and Sandoval, 2001).

Financial resources for the implementation of the BRT system came from a fuel tax, local revenues, a credit from the World Bank and grants by the national government. Resources were planned to fund the BRT infrastructure until 2006 with a possible extension to 2018.

The project was planned, designed and constructed by local and international firms. It took about eighteen months to finish the studies and develop detailed plans for the system. Examples of BRT systems in other Latin Countries, such as Quito (Ecuador), Curitiba, Sao Paulo, and Goiania (Brazil), and Santiago (Chile) helped to identify important elements for the planning and design of the system.

From the beginning of the BRT implementation the private transportation operators that provided transit service in Bogotá were involved in the planning process. Operators of the old system were offered the opportunity to be the operators of the new system. This strategy was implemented by showing them the opportunities and advantages of their participation. The operators’ experience was recognized and valued as a key aspect for the success of the new BRT system. Having the operators of the system as part of Transmilenio, protests and work stoppage possibilities for the service were avoided. Every time that a new Transmilenio bus was put in service, some old buses had to leave the system. The newer buses are used as feeder buses to take passenger from remote locations to the Transmilenio system.

In April 2000, four different firms created by local transportation operators associated with international investors received the contract concession to provide and operate 470 new articulated buses. Ninety-six percent of the private operators that provided transit service acquired stock in the four firms that were awarded the contracts. This shows the success of the program to include former transit operators in the Transmilenio operation. The fare collection
was awarded to a local firm supported by an experienced fare collection system provider. The control system was awarded to a Spanish firm. Feeder service and renovation of existing buses contracts were awarded to traditional transit operators (Hidalgo and Sandoval, 2001).

The new system infrastructure was constructed by local contractors under the supervision of the Institute of Urban Development (Instituto de Desarrollo Urbano, IDU). Their duties were to develop: 35 km of busways and complementary lanes, 4 terminals, 4 parking and maintenance yards, 58 stations, 17 pedestrian overpasses, plazas, sidewalks, built or rehabilitated 126 km of roads for feeder services, in a 24 month construction period. About 17,000 people are estimated to have participated in the project. On December 18, 2000, Transmilenio started operation (Transmilenio).

**TRANSMILENIO INFRASTRUCTURE CHARACTERISTICS**

The Transmilenio infrastructure consists of dedicated busways, streets for feeder buses, pedestrian access facilities, stations, points for bus parking and maintenance, and an advanced control system.

Busways are located in the center lanes of the main avenues of the city. These busways are physically isolated from the mixed traffic lanes, private vehicles, trucks, and taxis. There are two lanes dedicated for Transmilenio in each direction (See Figure 2). The two lanes in each direction were included to allow buses to pass one another, which improves the speed of the system and allows for express or skip-stop service. In a 15 year period, 22 busways or main lines covering 388 km are expected to be in operation. Table 1 shows the year and the number of km of busways that are expected until 2018 (International Seminar on Human Mobility, 2003). Figure 3 shows a map of Bogotá with the 22 busways expected through 2018.

<table>
<thead>
<tr>
<th>Year</th>
<th>Km of busways</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>130.4</td>
</tr>
<tr>
<td>2010</td>
<td>252.6</td>
</tr>
<tr>
<td>2015</td>
<td>384.3</td>
</tr>
<tr>
<td>2018</td>
<td>388.9</td>
</tr>
</tbody>
</table>

*Table 1: Km of Busways expected*
Figure 2: Infrastructure Characteristics

Figure 3: Twenty-two Busways Through the City
There are three types of stations:

- **Simple Stations**: They are located every 500 meters. At these stations passengers can purchase tickets and enter the system.
- **Intermediate Stations**: These stations are the contact points between the feeder buses and the main lines. Their objective is to provide smooth, fast and effective interaction between the Transmilenio and feeder buses.
- **Portals or Main Line Stations**: They are located at the beginning and end points of the main line routes. In these stations transfers are accomplished among Transmilenio buses, feeder and transportation routes. The fee is integrated with the feeders, so that when a transfer takes place double payment is not required. These stations are provided with bicycle parking facilities.

Walkways, plazas and sidewalks were constructed to provide adequate pedestrian and bicycle access. Parking and maintenance areas for the buses near terminal stations were also constructed. Each station is provided with maps and route information to facilitate the use of the system.

**OPERATIONAL SYSTEM**

The overall system includes main lines and feeder buses. The buses are an important element for the image of the system. The buses are operated by private contractors, but controlled by Transmilenio S.A.

The main line circulates though exclusive corridors, starting and ending the routes at the Portals and Front End Stations (See Figure 3). On the main lines, Transmilenio is the only system operator. Feeder buses do not use the main lines. There are two types of service on the main lines: normal and express service. Normal service stops at every station along the routes; they are identified with the number 1. Express service does not stop at all the stations along the route, which reduces travel time and the size of the fleet because buses can complete more cycles. Express service is identified with the numbers 10, 20, 30, 40, and 50. The combination of the normal and express services allows the system to carry more passengers per hour per direction and divide the passengers according to their destination, which is more appropriate for the size of
the buses. Normal buses run every 5 minutes and express buses every 4 minutes. Passengers that use the express service can stop and take buses in the other directions as needed. Table 2 shows the year and the number of passengers that are expected through 2018 (International Seminar on Human Mobility, 2003).

<table>
<thead>
<tr>
<th>Year</th>
<th>Passengers/day</th>
</tr>
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<tbody>
<tr>
<td>2005</td>
<td>2,681,000.00</td>
</tr>
<tr>
<td>2010</td>
<td>4,136,000.00</td>
</tr>
<tr>
<td>2015</td>
<td>5,004,000.00</td>
</tr>
<tr>
<td>2018</td>
<td>5,295,000.00</td>
</tr>
</tbody>
</table>

Table 2: Number of Passengers Expected

The main line is served by articulated buses with a capacity of 160 passengers. They are 18 meters long, 2.60 meters wide, and have four doors of 1.20 meters each on the left side of the bus. The design of the buses was focused on customers, with inside comfort, easy entrance of passengers, clean air and noise emissions. They have pneumatic suspension, automatic transmission, and the engines use diesel and natural gas. Feeder buses have capacities of 80 passengers (Transmilenio). A total of 6,000 articulated buses are expected by 2015. Figure 5 shows a photograph of the buses that serve the feeder system.

Feeder buses have lower capacity than the main line buses. New or recent model buses are used as feeder buses with a capacity of 80 passengers. They serve areas that do not have access to the main lines. Passengers transfer from/to the feeder buses to/from Transmilenio though the stations.

Each driver works 6-hour shifts. Drivers are paid as a function of the kilometers served by their buses, and they are not involved in fare collection. The system operates from 5:00 AM to 11:00 PM.

The system is designed to serve 5,000 trips per day with a total investment of US$2.3 billion. This value does not include the fare collection system implementation costs and the cost of the buses.
FARE COLLECTION SYSTEM

Transmilenio uses a prepaid method of payment (off-board fare collection). The passenger pays the fare upon entry to the system in the stations. The passenger purchases a smart card at the ticket office located at the entrance of each station. The smart card can be yellow for one trip, red for two trips, or the capital card that permits several trips. It permits multiple boarding reducing dwell times, bus operating cost, and travel times for passengers. Access turnstiles are located at the entrances and exits of the stations to validate and register the number of passengers using the system.
ADVANCED CONTROL SYSTEM

An advanced control system is a very important part of the BRT system. A satellite control center allows continue supervision of the operation of the buses. Each bus has a Global Positioning System (GPS) receiver to report the bus location, a computer that contains the schedule, a tracking communication system that shares information with a control center located in Transmilenio, S.A. and the police, and a transponder that sends the information to receivers at the entrances and exits of every station. This communication system provides real time information and is the basis for the control of the system. This makes it possible to adjust the schedule and identify possible new routes into the system.

PHASE 1: THE RESULTS

INFRASTRUCTURE RESULTS:

Phase 1 was implemented between 1999 and 2002. The system began with 21 stations and was 15.5 km in length. In November 1999 there were 35 km of busways, 100 km of feeder routes, 401 articulated buses and 103 feeder buses (Hidalgo and Sandoval, 2001).

Three main lines were constructed within the city: Calle 80, Troncal Caracas, and Autopista Norte. Forty-one kilometers of new busways were built through the three corridors (See Figure 6 – This figure also includes phase II). Seven feeder zones with 309 kilometers of feeder routes within 74 neighborhoods were installed to move passengers from remote areas to the main BRT system. Along the main lines four terminal stations, four intermediate integration stations, and 53 simple stations were constructed. In addition, 30 pedestrian overpasses, plazas and sidewalks were constructed. In this phase there were US$240 million of investment (International Seminar on Human Mobility, 2003).

Figure 6: Phase I and Phase II Main Lines
OPERATIONAL RESULTS:

In December 18, 2001, the mayor of Bogotá, Enrique Peñalosa, along with Transmilenio S.A. Company, inaugurated the new BRT service in the city. Until January 2001 the service was free. In November, 2000, the system demand grew by 550,000 passengers per week (Hidalgo and Sandoval, 2001).

During phase 1 the system moved an average of 770,000 passengers/day with 34,000 passengers per hour per direction on the busy sections of the system, averaging 5.3 passengers per kilometer. A total of 344,162,256 people were transported, and buses covered 66,035,715 kilometers through the main lines (International Seminar on Human Mobility, 2003).

There are 470 articulated and 235 feeder buses in use. They have an average speed of 26 km/hour in the main lines. The speed increased from 10 km/hour to 26 km/hour with the implementation of the system (International Seminar on Human Mobility, 2003).

TICKETING AND FARE COLLECTION

In phase 1, 90 ticket booths were installed, 359 barriers and 1.3 million smart cards have been used. The fare began at 800 Colombian pesos and ended at 900 Colombian pesos, which is about US$0.40. This low fare makes the system affordable for low-income users. This phase had daily revenue of about US$270,000 from about 770,000 passengers (International Seminar on Human Mobility, 2003).

ADVANCED CONTROL SYSTEM

Six control stations were implemented. Each station is able to monitor and control 80 articulated buses. Each articulated bus has a GPS system to track its location at six-second intervals and with +/-2 meter accuracy. Schedule adherence can be verified and adjusted accordingly. A total of 94 supervisors controlled the buses by the end of phase 1. Continuous communication between operators and the control center supervisors was achieved by the end of this phase (International Seminar on Human Mobility, 2003).

ACCIDENTS, POLLUTION AND SAFETY

The reductions in pollution and accidents as well as safety improvements were some of the most important impacts observed at the end of phase 1. There was observed a reduction of about 92% in fatalities, about 75% in injuries and about 79% in collisions. Robberies at transit stops were reduced by 47% (Hidalgo and Sandoval, 2001).

A monitoring study at the one of the main lines (Troncal Caracas) in 2000 and 2001 showed a reduction of about 43% of sulfur dioxide (SO2), 18% of Nitrogen Dioxide (NO2), and 12% of particulate matter of less than 10 microns (PM-10) (Hidalgo and Sandoval, 2001).
TRAVEL TIME

A reduction of 32% in the travel time for public transportation users was measured. The speed along the Calle 80 and Caracas main lines increased from 10 km/Hour and 18 km/hour to an average of 27 km/hour. Surveys show that 83% of the users perceive the increase in speed as the main reason to use Transmilenio. Thirty-seven percent of the users perceive that they spend more time with their families because of a faster commute (Hidalgo and Sandoval, 2001).

FUTURE IMPLEMENTATION

Phase II is expected to be completed at the end of 2004. The main goals of phase II are the following:

- Implementation of the BRT system in three main corridors, Troncal Americas, Troncal Avenida Suba, and Troncal NQS (See Figure 6).
- 13 kilometers of busways along the Troncal Americas with 1 main station, 1 intermediate integration station, and 15 simple stations
- 10 kilometers of busways along Avenida Suba with 1 main station, and 13 simple stations
- 19 kilometers of busways along Troncal NQS with 1 main station, and 22 simple stations

CONCLUSIONS

Various projects in Latin American countries indicate that obstacles have surfaced, but the BRT system is a good alternative to improve and upgrade the transportation system at a cost that developing countries can afford. Examples such as the BRT system in Bogotá, Colombia, demonstrate that the BRT system can be as efficient, cost-effective, comfortable and versatile as the LRT.

During the first phase of operation the transportation system in Bogotá became more organized and effective and with higher quality. There has been observed a reduction in travel time, pollution, and accidents as well as increases in safety and speed through the network when influenced by the BRT system. People are leaving their cars at home and users seem to accept and like the system. Surveys in Colombia show that the 49% of the users find the system very good and another 49% find the system good during the first phase of operation. The BRT system in Colombia can be taken as an example for other developing countries to follow in the future.

References


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