

Exploring the BRT Systems of Curitiba and Bogota

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Exploring the BRT Systems of Curitiba and Bogota

Curitiba and Bogota



Exploring the BRT Systems of Curitiba and Bogota

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Executive Summary

The South American cities of Curitiba and Bogota provide the world with a model in how to integrate sustainable transport considerations into business development, road infrastructure development, and local community development. This study researches and analyzes the history, implementation as well as the successes and challenges of both cities' BRT systems.

The BRT systems of Curitiba and Bogota are examples of effective urban transportation planning. Urban planners recognized that even if growth in population cannot be controlled, the development of infrastructure in the city can guide the city's expansion. By approaching transportation as a tool used to attain a greater solution rather than as a solution to an advancing problem, they were able to implement an efficiently constructed, cost-effective transportation system that finances itself. The cities use buses because they had traditions of using buses. While the systems are powered by diesel, the reduction of the number of cars used compensates, if not surpasses, the difference in carbon monoxide emissions. Like every city, both Curitiba's and Bogota's BRT system is plagued by overcrowded buses during peak hours, but this is a relatively minor inconvenience in comparison to the extent of service the BRT systems offer to residents.

Some lessons learned from both Curitiba's and Bogota's BRT systems are applicable to the United States. There are differences in city structure, economic prosperity and income levels, automobile ownership, public perspective and image of public transport, and other factors, which make it essential that local conditions be evaluated. One of the great advantages of a BRT system is that it can be planned, designed, and operated in a flexible manner and thus can be geared to local conditions.

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The characteristics of both the Curitiba and Bogota BRT systems are precisely those necessary for *any* fully successful transit scheme – rail or bus. Prerequisites of any system that is to be well used and financially viable should include protection of the transit right-of-way from traffic congestion, good and preferential access to areas of high demand (such as city centers), and planning transportation and land use to provide a potentially high passenger demand. In order to fully incorporate a successful BRT system in United States cities there are some policies and principles that are applicable:

1. *Transit First Policy*: Public transport needs to be a priority in large cities and to integrate public transport with community development wherever possible.
2. *Busways as a Mass Transit System*: Curitiba and Bogota both show that with good planning and organization busways can carry high volumes of passengers at reasonable commercial speeds – equivalent to those of Light Rail Transit or tram technology under the same operating environment. Even if corridor travel demand is high, busway capacity is not usually an issue. The capacity issue would be especially true in a U.S. context.
3. *Interconnection of Services*: The BRT systems of Curitiba and Bogota were built for different reasons and at different times during each cities growth. Curitiba's BRT system was developed as Curitiba was emerging as a major metropolitan city, which allowed the system to connect services and dictate land use designations according to transit stops. It also allowed development to plan transit stops around important nodes throughout the City. Bogota has less interconnection of services due to the fact that the BRT system was developed after the Bogota was an established metropolitan city. Bogota's TransMilenio developed along routes and nodes

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already established throughout the City. That is not to say TransMilenio is disconnected with services, however, they are at a greater disadvantage compared to Curitiba.

4. *Priority treatment and mixed traffic conditions:* Both BRT systems operate on established roadways that are utilized by personal vehicles. Both systems, as illustrated in earlier sections, use separated bus lanes and give signal priority to the buses. The buses try to operate much like a subway system without the needed underground infrastructure.

Chapter 1

Introduction

The South American cities of Curitiba and Bogota provide the world with a model in how to integrate sustainable transport considerations into business development, road infrastructure development, and local community development. This study researches and analyzes the history, implementation as well as the successes and challenges of both cities' BRT systems.

Study Purpose

Today, the impact of climate change is being felt globally. The increase of greenhouse gases (GHG) has resulted in a higher global temperature. While there are many GHGs to consider, the major contributor in the United States is carbon dioxide related to vehicle emissions. Land use planning and travel behavior in the U.S. have made Americans highly dependent on their private vehicles. Many states throughout the U.S. have proposed various ways to reduce their GHGs. Because California is often seen as a leading force advocating for environmental needs, California has passed several bills that, in essence, will aim at reducing GHGs.

Although, climate change has often been disputed in the past California State Law makes it mandatory to set targets to reduce emissions. On October of 2008, Governor Arnold Schwarzenegger signed Senate Bill 375, the anti-sprawl bill. The law aims to reduce GHG emissions by discouraging sprawl development and dependence on car travel. SB 375 requires regional transportation plans to include a "sustainable community strategy" (SCS) to meet GHG reduction targets for vehicle travel set by the California Air Resources Board (The Public Blawg).

California is now obligated by law to find attractive alternatives to the private automobile. One solution that has gained notoriety is the Bus Rapid Transit (BRT) system. BRT systems are utilized

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globally. The purpose of this case study examines two very different systems, Bogota, Colombia and Curitiba, Brazil.

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Chapter 2

Curitiba, Brazil

Curitiba is the capital of the state of Paraná, Brazil. With about 1.8 million people, it has the largest population and economy in Southern Brazil. Its metropolitan area is comprised of 26 municipalities with a total population of over 3.5 million (IBGE estimate, 2006). Curitiba is an important cultural, political and economic center in the country. The city sits on a plateau at 3,058 ft above sea level. It is located 65 miles west of the seaport of Paranaguá and it is served by the Afonso Pena International Airport. (Hamilton, 2009).

The transit system in Curitiba, Brazil, has attracted worldwide attention for remarkable accomplishments with limited resources. In the U.S., Curitiba has become the poster child for bus rapid transit.

History of Planning

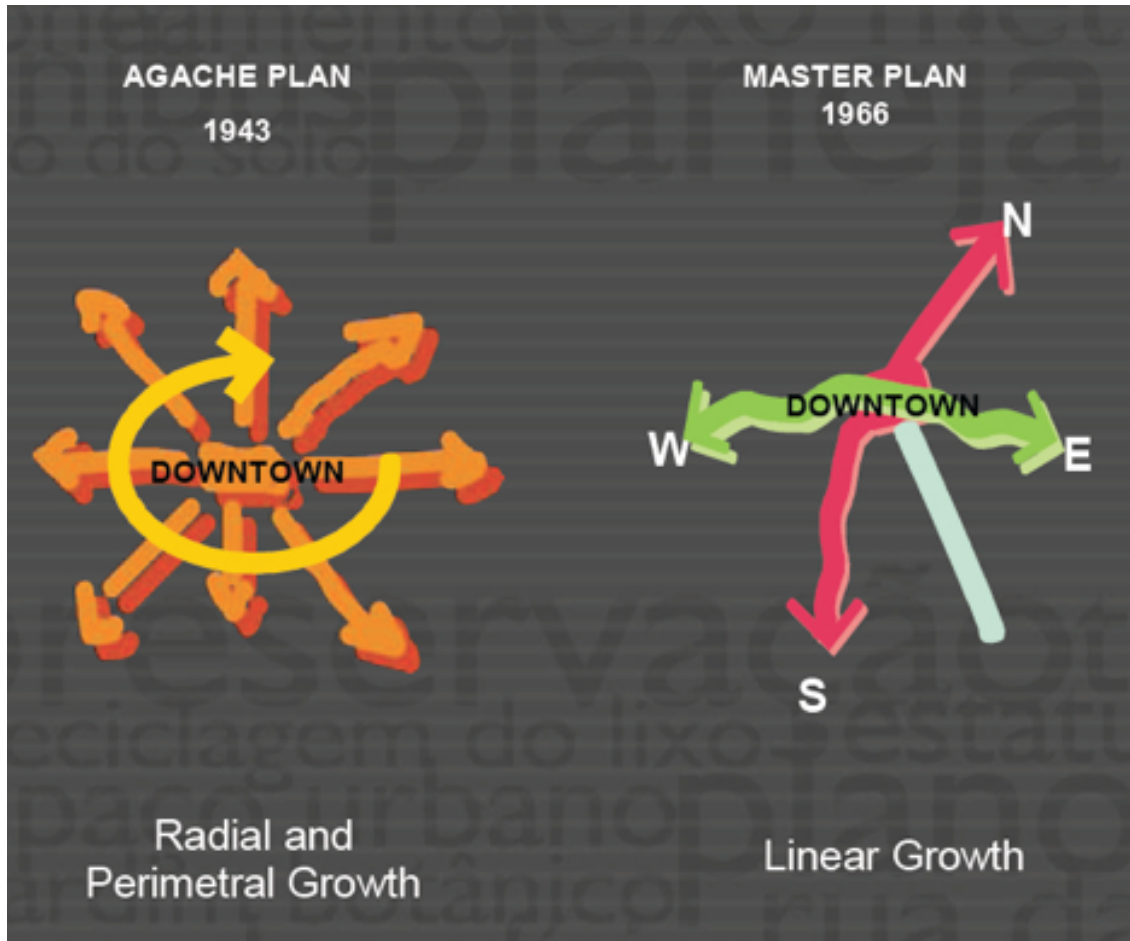
The formal history of Curitiba's urban planning started in 1934, with the creation of The Agache Plan. This was one of Brazil's first urban plans, which included sanitation measures, housing, services, industrial zoning, and a restructuring of the street network. Initial parts of this plan that included large avenues, an obligatory setback of five meters from the curb as a buffer zone for new buildings, an industrial district, the civic center and the municipal market still remain today.

City growth, however, was beyond the limits anticipated in the Agache Plan. Curitiba's population grew from 140,000 to 500,000 in 1965. In July 1965, Decree 1,000 launched a series of public debates, called "Curitiba de Amanhã" (Curitiba of Tomorrow), to discuss the proposals of the plan conceived in partnership with The Research and Urban Planning Institute of Curitiba (IPPUC). The plan

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proposed the transformation of the city's radial development format, as it had been conceived by the Agache Plan, into a linear model of urban expansion. See Figure 1: Organized Growth. (Curitiba, 2008).

Figure 1: Organized Growth



On June 31, 1966, Law 2,828 instituted the Curitiba Master Plan and approved its basic directives. The main goals of Curitiba's Master Plan included limiting central area growth and encouraging commercial and service sector growth along two structural north-south transport arteries, radiating out from the city center. The Master Plan aimed to provide economic support for urban development through the establishment of industrial zones and to encourage local community self-

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sufficiency by providing all city districts with adequate education, health care, recreation, and park areas. The Master Plan also called for the integration of traffic management, transportation, and land-use planning to achieve its goals, and maintained flexibility in its regulations to allow for different future development scenarios.

IPPUC's plan revolutionized the city. In the 1970s, zoning laws were set in place and structural avenues were designed to direct linear growth by attracting residential and commercial density along a mass transportation lane. In 1974, the main mass transit line began to operate along those avenues. Curitiba's bus rapid transit (BRT) system was developed as an integral part of an overall master plan whose basic objectives included radial expansion of the city along five corridors (structural axes), integrating land use and transport, and protecting the traditional city center. As shown in Figure 2: Map of Curitiba's Major Arterials. In Curitiba's case, its planners recognized that transportation systems can serve as the foundation for the development and growth of the city in the future. (Curitiba, 2008).

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Figure 2: Major Arterials



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History of Transportation Planning

On November 8, 1887, Curitiba introduced its first public transportation system. The system included open horse drawn carriages that were used until the introduction of the electric trolleys in 1913. Curitiba continued to grow and more public service programs were developed. Within the first decade of the 20th century, streets were paved and widened. It wasn't until 1928 that a company called Companhia Força e Luz began to explore the possibility of using buses as a means of transportation and creating regular bus lines. Unfortunately, at the time, the outlandish cost of riding the bus rendered this mode of transport publicly unfavorable compared to the electric trolleys that still were in use. In 1938, 10,975,699 people used the trolley system in comparison to 2,678,638 who rode the buses. Even with the addition of bus lines in 1942 the majority of the population preferred using the trolleys because they were cheaper. For the duration of the 1940s there arose a fierce competition between trolleys and buses. It was also during this time that the city started looking into various types of efficient mass transportation systems. Slowly, bus routes began to replace trolley routes. In 1951, the trolley system stopped transporting passengers completely. Following a public revolt against the highly priced buses, the city government regulated bus fares putting the cost of all rides to 50 cents/cruzeiros, the first unified fare in Curitiba (Rabinovitch and Hoehn, 1995).

The most significant changes in the transportation system took place in 1974 with the creation of the road hierarchy and land control system. In coordination with the Master Plan they began to construct the first two out of five arterial structural roads that would eventually form the structural growth corridors and dictate the growth pattern in the city. These structural corridors were composed of a triple road system with the central road having two restricted lanes dedicated to express buses (Rabinovitch and Hoehn, 1995).

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Parallel to the express bus lanes were two local roads running in opposite directions. They allowed local traffic to pass through the city. In 1982, all five structural corridors were completed with inter-district and feeder lines. In accordance with these structural roads, zoning laws were set in place to structure the growth of the city. Large buildings holding a high density of people were permitted to be built along these corridors, but, as one moved away from these central corridors, the admissible densities declined from urban apartment buildings to residential neighborhoods (Rabinovitch and Hoehn, 1995).

This revolutionary approach in public transportation was first put into action along an axis linking the Santa Cândida and Capão Raso districts as the Norte-Sul (North-South) axis became operational. Curitiba invented the Ternary Road System which created large traffic arteries for public and private transportation. The exclusive lane, better known as the canaleta (channel), was a concept implemented from 1974 onward, with the Expresso bus line. And both, the canaleta and the expresso, would be the first step in a series of different and carefully planned measures that made up the Rede Integrada de Transporte or RIT (Public Transportation Integrated Network).

In 1980, a local decree established the Single Fare, defined as a self-sustainable subsidy mechanism, generated by the system itself, whereby shorter bus trips subsidize longer ones, serving low-income population neighborhoods. In that same year, the Integrated Transportation Network was implemented, consolidating the system with fully operative boarding stations, with destination/fare integration and, as of 1982, with the implementation of five structural axes, whereby 51% of all users rode buses ran by the RIT - Integrated Transportation System (Joseph Goodman, 2007)

In 1991, the “Ligeirinho” Line started circulating, a direct line with buses with the capacity to carry 110 passengers per trip, on a route with few stops, and Tube Stations for boarding and disembarking.

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In 1992, Articulated Buses are put in operation, vehicles with a greater carrying capacity and reduced travel time. The articulated bus system led to a reduction of approximately 50% in energy consumption (Joseph Goodman, 2007).

BRT System

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

Curitiba's BRT system includes about 37 miles of median busways and carries about 2 million people per day. The system carries up to 11,100 passengers one way on the busiest busways in the peak direction during the peak hour. Bus speeds average 12 mph along the busway and about 19 mph on the "direct" express routes. Development costs have been estimated at \$2.4 million per mile. (Leroy W. Demery, 2004). About 70% of Curitiba's commuters use the bus system even though Curitiba's automobile ownership and per capita incomes are significantly higher than the national average for Brazil.

Curitiba's transit system is managed by the *Urbanização de Curitiba* (URBS, Urbanization of Curitiba), owned privately but managed publicly. URBS administers publicly-owned transport infrastructure, contracts with private companies that operate the buses and monitors their performance. URBS establishes schedules and service standards, sets fares, collects revenues and distributes payments to each private company. The system, termed the Rede Integrada de Transporte

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(RIT – Integrated Transport Network), provides a hierarchy of types of bus service citywide, and all are operated under an integrated tariff system. Bus services are linked through integration terminals and at on-street stops where bus passengers may interchange between bus services without additional payment on the system (Leroy W. Demery, 2004).

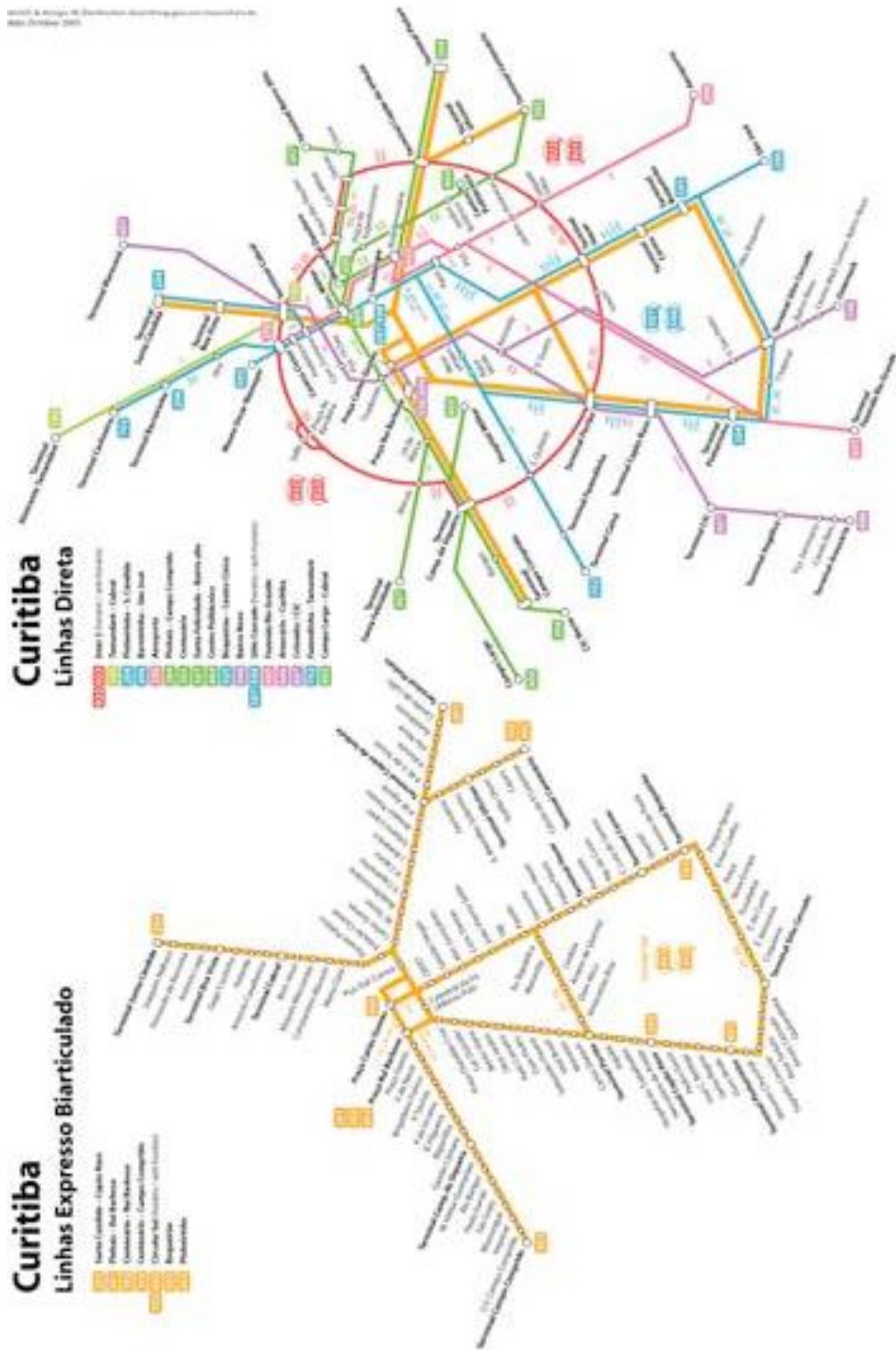
Curitiba's BRT is composed of a hierarchical system of services. The downtown area is the focal point of the bus system, although major destinations are served along each structural axis. The bus services form an integrated, bus-based, mass transit system for the city.

Minibuses routed through residential neighborhoods feed passengers to conventional buses on circumferential routes around the central city and on inter-district routes. The backbone of the system is composed of the Bus Rapid Transit, operating on the five main arteries leading into the center of the city. Figure 3: Routes Map, illustrates Curitiba's hierarchical BRT Routes and the five structural axes. Figure 4: Color-Coded Transit System depicts the buses operating the various RIT services. These are color-coded by function and include the following:

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

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Figure 3: Curitiba Route Map



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Figure 4: Color-Coded Transit System



Regional Buses

These **orange**-colored buses carry passengers from outlying neighborhoods to Curitiba's 21 regional terminals, seven of which serve as transit hubs, offering basic services and shopping.



Above-Ground Transit

These large **red** express buses with two or three cabins strung together like accordions carry up to 270 passengers along main transit routes. The buses travel on dedicated traffic lanes and stop at tube stations, elongated clear plastic and metal elevated passenger landings.



City Street Buses

Curitiba's **yellow** conventional buses travel the secondary streets of the city, shuttling passengers between main transit routes and residential neighborhoods.



Express Service

These **grey** *ligerinho*, or speedy buses, offer express service between Curitiba's suburbs and its downtown. They are mostly used by those commuting to and from work.



Health Care Transit

The **blue** interhospital buses run service between Curitiba's medical centers.



Tourist Buses

These **white** comfore, mid-size coaches offer visitors an easy way to see Curitiba's sights. The bus takes tourists on a sightseeing loop of the city's most popular parks, woods and museums. Tickets are more expensive than normal fare 10 reais, or just over US\$3 -- and allow passengers to get off and back on the bus up to three times, enabling tourists to spend more time at destinations along the sightseeing loop.

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- “Metropolitano” (serving out of city destinations – blue)

The scale of the citywide operation is demonstrated by some key statistics:

- 340 bus lines
- 2,100 buses
- 1,100 kms of bus route
- 60 kms of segregated busway
- 29 major and moderate size integration-interchange terminals
- Passenger demand of 1.9–2.1 million trips per day. (Leroy W. Demery, 2004)

Passengers pay a single fare equivalent to about 60 cents for travel throughout the system, with unlimited transfers between buses at terminals where different services intersect. Transfers occur within the prepaid sections of the terminals, so transfer tickets are not needed. Also, located within these terminals are conveniences, such as public telephones, post offices, newspaper stands, and small retail facilities.

Buses running in the dedicated lanes stop at cylindrical, clear-walled tube stations with turnstiles, steps, and wheelchair lifts. Passengers pay their fares as they enter the stations, and wait for buses on raised platforms. Instead of steps, buses have extra wide doors and ramps that extend out to the station platform when the doors open. The tube stations serve the dual purpose of providing shelter from nature’s elements and facilitating the simultaneous loading and unloading of passengers, including wheelchairs, efficiently. This system of same-level bus boarding, plus the pre-boarding fare payment, results in a typical dwell time of no more than 15 to 19 seconds at a stop.

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Twenty-two private bus companies, which run the actual buses, are paid by distance traveled rather than passenger volume to allow a balanced distribution of bus routes and eliminate clogging of main roads. After ten years, the city takes control of the buses and uses them for transportation to parks, or as mobile schools. (FTA, 2008).

Infrastructure

Public transportation became a priority for Curitiba and was used to promote development along the structural roadways. The first bus terminals were implemented as passenger boarding stations and fully-equipped bus stop shelters. Stations, typically bearing the name of the neighborhood or street crossing nearby, were to be perceived as a vital part of the city. The express lines that run on the central thoroughfare of the ternary system, transport 54,000 passengers per day. (TRB, Curitiba, Brazil, 2008).

Busway

The Curitiba busways are located along “structural axes” that comprise three roads, the central one of which is a busway and service-access road. Busways are continuous along five corridors or structural axes with a total length of 37 miles. Busway characteristics are the following:

- The track is used exclusively by trunk line buses.
- The track is separated from other service-access traffic by continuous physical islands or by island bus stop platforms.
- Busway crossings with other roads are generally at grade and signal controlled (it is believed bus traffic signal actuation exists).

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- The track is located in the center of the bus and service-access road, and thus, the busway-road, unlike many attempted adaptations of the “Curitiba principle” in other cities, is not a major traffic-carrying route. Passenger access to/from stops does not involve crossing through dense, possibly fast moving traffic.
- The curb-to-curb envelope contains eight lanes; it is about 85 feet wide.
- Tube stations preempt the parking lanes adjacent to the busway.

Stations

Stations, typically bearing the name of the neighborhood or street crossing nearby, were to be perceived as a vital part of the city and are the trademark of Curitiba’s BRT System. They can serve three times as many passengers per hour as a conventional bus. “Tube” stops are used both on the trunk line busways and on the express buses (off the busway). Stop details are as follows:

- On busways, tube stops are located at about 0.3-mile spacing.
- The tubes include raised platforms (low-floor buses are not in operation) and provide passenger weather protection; the stops are constructed from a plexiglass-type material with steel ribs.
- The tube stops are equipped with doors to enter/exit buses; these are coordinated with doors on the buses – five doors on the trunk line bi-articulated buses (and two on express buses).
- Disabled and wheelchair access to the high-level stops is made through a small elevator at each stop.
- Passenger boarding and alighting of buses is gap free and level; this is achieved by the use of fold-down steps from bus doors, which deploy automatically as bus doors are opened and position onto the threshold of the platform; it is understood that bus-platform positioning door-

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to-door is done visually by the driver, and there is adequate tolerance to ensure safe operation of the system.

- The stops are designed to speed passenger handling, and fares are paid by passengers at the entry to the stop – similar to a metro. Each stop is equipped with turnstiles (numbers depend on size of stop) and are manned by a ticket collector–inspector. Typical dwell times at stops are less than 20 seconds.
- On busways, tube stops are on line with no special provision for bus-on-bus overtaking. Theoretically, the busway is wide enough to allow overtaking by buses entering the opposing bus stream, but this is not normal operational practice.
- Stops for both directions are generally located opposite each other and close to junctions. As stops are located on the central road of the tertiary axes, access and traffic issues are less critical than on a busway introduced into an existing road. However, as with any stop, there is a need to balance safety, junction capacity, and busway capacity.

Vehicles

The busway system is operated by a fleet of dedicated -bi-articulated diesel buses. The bi-articulated buses were introduced in 1992, and there is a busway-dedicated fleet of about 115. Characteristics of the bi-articulated buses are the following:

- They are manufactured by Volvo Brazil.
- They are 24.52 m [80.4 ft] long, 2.5 m [8.2 ft] wide, and 3.415 m [11.2 ft] high.
- There are five double-width doors on the conventional (right) side of the bus.
- The buses are bi- (or doubly) articulated with four axles.

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- Motive power is conventional diesel.
- Passenger capacity is about 270 including standees. Buses are configured with only about 57 seats, because the aim of the trunk line buses is to move large volumes of passengers. Journey times on trunk line busways from outer terminals to the city center are relatively short (about 20 minutes).
- Buses are high floor, but because of the raised platform stops and fold-down ramp/door, passenger boarding and alighting is level and gap free.
- There is no on-vehicle fare collection or display of travel passes to bus drivers; all payments are made at terminals or as stop platforms are entered.
- Although it is necessary that buses stop accurately at “tube” stops to coordinate bus doors and stop doors, no automatic vehicle guidance is provided; this is achieved by the drivers without automatic aids. There is some tolerance laterally (because of the fold-down step) and longitudinally (because of the width of stop doors), but observation indicates that the arrangement works well.

Fare Collection

The “tube” stops and integration terminals are planned to avoid all fare collection on buses. Payment of fares at stops (which applies to the express services off the busway as well as the busway services) is at a manned turnstile at the stop entrance. Clearly, this has labor cost implications, and smart card fare payment systems are scheduled for imminent introduction. (TRB, Curitiba, Brazil, 2008).

Challenges

With the evolution of the transportation system there increased a need for an effective mode of payment. Curitiba’s city hall wanted to expedite bus service and recognized that one of the factors that

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generated delays is the hold-up in the mode of passenger payment. Over the years there have been many forms of payment implemented. A new system to avoid delays was created in which the city eliminated transfer payments and substituted them with transfer tokens made of paper. But after seven months of implementation, the city discovered major forgery of the paper transfers. The city then tried to install a two-fare payment, separating the express fares from the feeder fares (fares for the outlying buses connecting to those going to the city center). This system was repealed after one and a half years because it favored the rich who resided closer to the center and paid only one fare over the poorer population who resided on the periphery of the city and would have to pay two passages to arrive in the center.

Realizing the social imbalance imposed by this fare mode, the city dropped the feeder fare and allowed passengers to ride the feeder buses for free. After a while the city received public complaints about the unsanitary conditions on the feeder buses. They became sleeping places for the homeless and bus drivers refused to drive these buses. The city then decided to return to the one fare method and built fences between stops for the express and feeder buses. This method proved to be successful until they became overcrowded. They became unsanitary and were often referred to as “pig stalls.”

In 1980, the city finally developed and constructed transfer terminals that operated like subway stations. The terminals, constructed with telephone accessibility, attracted newsstands and flower shops and became aesthetically attractive and user friendly.

It was also at this time that the city introduced automatic ticketing to the system. This form of payment allowed passengers to purchase metal tokens at terminals, newsstands or shops, or pay with money at the bus terminals. They hoped to increase the speed of transfers and boarding of passengers

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which would expedite bus circulation. The city believed that under careful planning of transfers, passengers could travel throughout the system for only one fare. Despite the fare issues, the city had to deal with the overwhelming attraction of the express system. Upon its implementation in 1974, its novelty and popularity resulted in overcrowded buses that caused delays in boarding at stops and terminals. To compensate for the loss in time, bus drivers would increase speed, creating potentially dangerous situations and accidents. The city found it necessary to implement speed control monitors, create boarding tubes and tailor bus designs to accommodate the growing demand.

The city also had to create a system in which individual bus companies that catered to the various zones in the city could share revenues without competing with each other. Traditionally the city was partitioned in different zones that were serviced by individual bus companies. But, with the creation of the inter-district routes and the implementation of the Integrated Transportation Network along with the unified fare, passengers could pay one company at a terminal located in a particular zone and ride the system without paying the other bus companies. In 1987 the city addressed this problem by distributing transportation revenue based on the number of kilometers traveled by vehicle type for any given company. With each company given a number of route kilometers and a timetable, each company competes with the schedule not with other companies (Rabinovitch and Hoehn, 1995).

Measures of Success

The measures of success of the Curitiba's BRT system are evaluated under three categories: Funding, Infrastructure, and Performance as shown in Table 1 and 2 below.

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Table 1: Curitiba's Measures of Success

	Curitiba
<i>Funding</i>	4
<i>Infrastructure</i>	4
<i>Performance</i>	5

KEY: 5 = most successful; 4 = very successful; 3 = fairly successful; 2= functional; 1 = needs improvement

Table 2: Summarizing Curitiba's BRT Successes

Running Ways	37 miles of exclusive median busways (one and two lanes in each directions)
Stations	351 tube-stations (high platforms, enclosed with sliding doors)
	29 integrating terminals
	5,000 bus stops
Vehicles	2,100 articulated & feeders
ITS	Control center tracking vehicle location using loop detector and station sensors
	Passenger information signs
Fare Collection	Approx US \$0.60 flat fare
	Contactless fare cards
Service and Operations Plan	8 Express Lines and 19 Direct Lines
Ridership (boardings)	2 million daily
Capacity (Maximum)	65,000 during peak hours and direction
Accessibility	Stations are fully accessible with ramps from streets and level boarding between the stations and vehicles.

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Included in the *Funding* category is:

- Institutional arrangement, how it is funded.

Curitiba's Bus Rapid Transit System was scored a **4** because of the efficiency of owning the buses privately but managing them publicly. URBS establishes schedules and service standards, sets fares, collects revenues and distributes payments to each private company.

Included in the *Infrastructure* category are:

- Physical operation
- Station infrastructure

Curitiba's Bus Rapid Transit System was scored a **4** because Bus Rapid Transit is made a priority in Curitiba. With a wide range of routes, Busways used exclusively by buses and many, easily accessible tube stations BRT is convenient and user-friendly as possible.

Included in the *Performance* category are:

- Percentage of income used towards transportation
- Overall fuel use levels
- Automobile use levels
- Ridership fare cost levels

Curitiba's Bus Rapid Transit System was scored with a **5** because of the affordability; a flat rate of about 60 cents (US Dollars).

BRT Ridership levels Curitiba's planners designed its public transit system to be economical. Rather than building a new train or subway system and pay exorbitant construction costs, Curitiba's designers worked with existing roadways to create a convenient, comprehensive and affordable bus system. It's

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been so successful in Curitiba that dozens of cities worldwide have adopted the model. Figure 5 shows Curitiba's BRT system's lane designation and infrastructure set-up.

Figure 5: BRT in Curitiba



Funding

Curitiba's buses make more than 21,000 trips a day, traveling more than 275,000 miles. Curitiba is able to finance the system through a mix of private and public resources. Although managed by the city's transit authority, the city contracts out the service to 22 private companies, who operate the buses and taxis and share revenues with the city to support road maintenance and upkeep of the terminals (Curitiba, 2008).

Infrastructure

Today, Curitiba's Public Transportation Integrated Network maintains 2,100 buses that transport 2.04 million passengers each workday along 385 different lines that cover the city and surrounding regions. There are 5,000 bus stops, 351 tube-stations and 29 integrating terminals. Eighty percent of

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travelers use the express or direct bus services. Some of these buses carry 270 passengers each, at the same speed of a metro or subway rail system, but at 1/80 of the construction cost. Curitiba's mould-breaking elevated access platforms load passengers onto in 1/8th of the time of previous systems (Curitiba, 2008).

Performance

The popularity of Curitiba's BRT has affected a modal shift from automobile travel to bus travel. The buses account for 55% of the city's transport demand. Based on 1991 traveler survey results, it was estimated that the introduction of the BRT had caused a reduction of about 27 million auto trips per year, saving about 27 million liters of fuel annually. In particular, 28 percent of BRT riders previously traveled by car. Curitiba has a population of 3.2 million people, and 85% of the commuters use the BRT system. Compared to eight other Brazilian cities of its size, Curitiba uses about 30 percent less fuel per capita, resulting in one of the lowest rates of ambient air pollution in the country. Best of all, Curitiba citizens spend only about 10 percent of their income on travel—much below the national average.

Other policies have also contributed to the success of the transit system. Land within two blocks of the transit arteries is zoned for high density, since it generates more transit ridership per square foot. Beyond the two blocks, zoned residential densities taper in proportion to distance from transit-ways. Planners discourage auto-oriented centers and channel new retail growth to transit corridors. Very limited public parking is available in the downtown area, and most employers offer transportation subsidies, especially to low-skilled and low-paid employees (Curitiba, 2008).

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Ridership

Reports of the passenger volumes on the complete citywide system vary from about 1.9 million passengers' trip per day (including transfers as two trips) to 2.1 million per day. (Curitiba, Brazil, 2008).

Reported daily busway ridership volumes are approximately 188,000 passengers in the north-south corridor, 80,000 in the Boqueirao corridor, 52,000 in the east corridor, and 19,000 in the west corridor.

In 1974, the first BRT service operated along two arterial busways and carried 54,000 passengers per day. By 1982, the bus service along five structural axes carried 400,000 passengers per day. After improvements in fare collection and distribution, vehicles, and route extensions, the busway system carried more than 1,000,000 passengers per day (TBA, Curitiba, Brazil, 2008)

Bus Speeds–Travel Times

Buses on busways operate at a commercial speed (including stops) of about 12mph. As buses are fully segregated from other traffic, speeds appear to be controlled by bus stop spacing at about 500 m and junction spacing. The advantages of longer stop spacing coupled with the facilities (both physical layout of stops and the method of fare collection) can be seen in the direct/"ligeirinho" (express) services that operate at a commercial speed of about 19 mph along the parallel one-way arterial streets. The direct line services save an average of 15 minutes travel time for each segment of a work trip (TBA, Curitiba, Brazil, 2008)

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Chapter 3

Bogotá, Colombia

Bogotá, Colombia is known for its diverse culture, heritage and architecture. Located approximately 8,300 feet above sea level, Bogotá has a total area of about 1,076 square miles with just over 6.6 million inhabitants, and is nicknamed “The Gateway of South America” for its location near the geographic center of Colombia. Bogotá is a cosmopolitan city in constant growth. It is one of the fastest growing metropolitan areas, not only in Colombia, but in South America. The city has immigrants from many parts of the world making the city the “microcosmos” of Colombia (International Exhibition Center). Rapid growth in Bogota has been occurring for over sixty years.

History of Planning

Bogotá has seen sustained, rapid growth through waves of rural-to-urban migration in the wake of impoverishment and violence. In 1938, increasing levels of rural violence and inequitable distribution of land motivated migration city-ward toward Bogotá. During the 1940s and 50s the City was growing five percent annually and during the 60s and 70s at almost seven percent annually (Gilbert, 1996). Bogota now accounts for twenty percent of Colombia’s total urban population. Colombia’s transformation from predominantly rural to predominantly urban permitted Bogotá to grow from an intermediate-size city into a large metropolis (Mohan, 1994). Bogotá was not well equipped to handle the rapid growth.

As in most cities around the world that host slum areas, the slums of Bogotá were largely the result of rapid population increase without housing and service provisions that such growth demands. Bogotá expanded rapidly through illegal subdivisions, occupation and the development of marginal areas by immigrants. Bogotá’s inner-city slums, on the other hand, are mostly the result of urban

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transformation processes, which underwent progressive social and physical deterioration (Rueda-Garcia). This set the stage for one Mayor's campaign for change.

History of Transportation

Traditionally, independent bus operators provided public transportation in Bogotá. Revenue was based solely on passenger fares, causing intense competition among drivers (Rodríguez & Mojica, 2008). Under the traditional system, there were about 21,000 registered public transit vehicles and around 9,000 illegal vehicles. These private entities provided 64 different routes making money by leasing routes to bus owners. Routes were then assigned through a permitting process. However, insufficient resources within the Secretary of Traffic and Transport (STT) suggest that permit regulations were not adequately enforced (National BRT Institute).

The traditional system allowed for extensive route coverage and frequent service, particularly in the arterial streets in and around the Central Business District. Passenger volumes could be as high as 25,000 passengers per direction per hour (ppdh), however, poor regulation by the STT resulted in extremely high levels of competition for passengers. Locally, known as the "Penny War," the high levels of competition resulted in low service quality, long travel times, high pollution levels, and high accident rates (National BRT Institute).

Mayor Penalosa launched a near-obsessive campaign to reform the City's transportation system declaring a virtual war on cars, restricting traffic during peak hours to reduce rush hour traffic by forty percent and convincing City Council to increase the tax on gasoline dedicating half of the revenues generated by the increase into the bus system. Penalosa's campaign for reform was much needed under the conditions existing in Bogota and Colombia.

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Colombia was a nation plagued by a twenty percent unemployment rate, widespread destitution, declining exports and political instability (Jones, Lisa). “The nation's environment is threatened by...most prominently deforestation, pesticide use, and air pollution -- particularly in the capital city” (Jones, Lisa) Widespread urbanization in the region lead to an explosion of slums, many of which lacked basic services. Because the growth was generally unplanned, urban areas suffered from inadequate means of disposing of wastewater, severe groundwater pollution, and water shortages. Air pollution was a serious concern, with some of the worst smog in the world. Lead emissions, primarily from leaded gasoline but also from industrial pollution, were also a significant problem.

For many years, the suggested solution to Bogotá’s inefficient public transportation was to build a heavy rail metro system. There were a total of 10 attempts to implement heavy rail in Bogotá between 1947 and 1997 (Lleras, 2003). These attempts were continually unsuccessful because of high capital costs and opposition from the operators of the traditional public transportation system (National BRT Institute, 2006).

When Enrique Peñalosa was elected Mayor of Bogotá in 1997, he proposed an integrated transit system that featured both heavy rail and a network of busways. However, over time, it became clear that the national government did not have the necessary funds to build the rail, and the rail became indefinitely postponed (National BRT Institute). The administration proceeded with a busway-based approach, modeled on the busway networks already operational in Sao Paulo and Curitiba, Brazil. “Mayor Peñalosa envisioned the new bus system as being the centerpiece of an overarching mobility strategy to encourage non-motorized travel, discourage private vehicle use, and facilitate urban renewal through the redevelopment of the city’s public space” (National BRT Institute, 2006).

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Mayor Peñalosa wanted to build, what looked like, a larger version of Curitiba's BRT system. Curitiba's highest demand is approximately 11,000 pphpd (Levinson et al., 2002) while the new transit system would be designed to carry up to 45,000 pphpd. The buses would run on exclusive runningways, and passengers would pay upon entering the station (Ardila-Gomez, 2004). Traditional buses would be banned from the busway corridors. The transport plan would also provide an extensive network of sidewalks and bikeways, public space improvements, and various disincentives to car usage. These included higher fuel taxes, on-street parking restrictions, and a car use restriction known as "pico y placa" ("peak and plate") which prohibited forty percent of the city's private vehicles from use during peak demand periods according to the last digit of the number plate (National BRT Institute, 2006). Mayor Peñalosa also envisioned a new public sector agency that would plan the system and oversee daily service. This agency would manage private contractors responsible for ticketing and operations. Contractors would be paid per service kilometer logged, not per passenger, eliminating the stimulus for the Penny War. Operators would be selected through a formal tendering process that evaluated experience, financial capabilities, and price offer (National BRT Institute, 2006). This culminated into what is now known as the BRT system, TransMilenio.

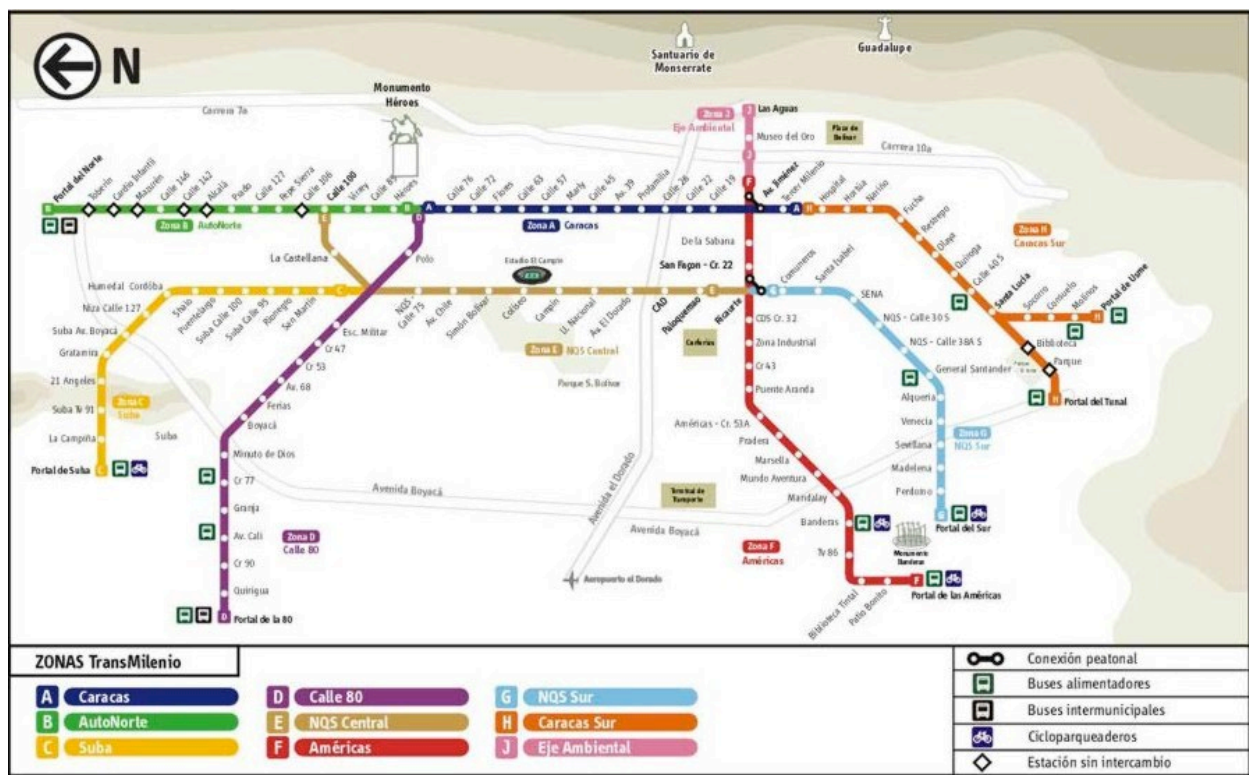
BRT System

This project was a huge undertaking and was divided into phases. In October 1999, the new transit authority, TransMilenio S.A., was established to oversee the planning and managing the construction of the TransMilenio project and its subsequent operations. The project was planned, designed and constructed by both local and international companies. Initial planning studies identified six busway corridors for construction. Three busways were constructed in each of the two phases, Phases I and II of the TransMilenio system. The first section of Phase I opened in December 2000, less

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than three years after the system was conceived, and 12 days before the end of Mayor Peñalosa's term of office. The remaining sections were constructed in 2001 and 2002, and the full 25.6 miles, the first three busways, were operational by early 2002 (National BRT Institute, 2006). Today, following completion of phase III, the system serves 145 kilometers, and phases IV to VIII will expand its reach to 388 kilometers. Figure 6 shows the TransMilenio bus routes.

Figure 5: TransMilenio Bus Routes



Infrastructure

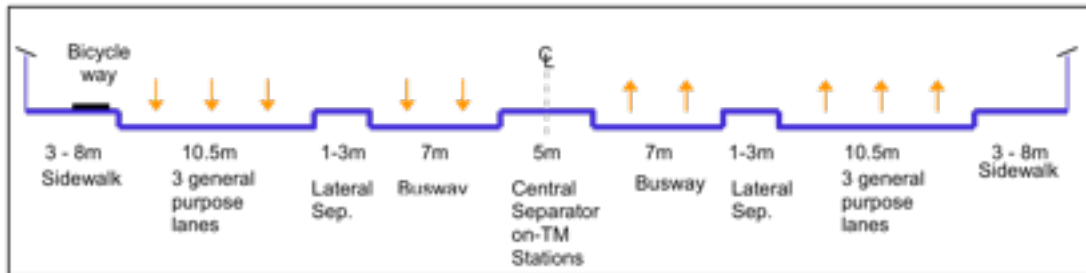
Runningway

TransMilenio services operate on exclusive, dedicated busways. There are essentially two types of segregated runningway, single carriageway and dual carriageway, both designed to high capacity transit vehicle specifications. The former usually has an additional passing lane provided at stations

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along the route. Dual carriageways are typically 7 meters (23 feet) wide, while single carriageways are 3.5 meters (11.5 feet) wide with passing lanes provided at each station. Feeder buses run in regular mixed traffic lanes (National BRT Institute, 2006).

Figure 6: TransMilenio Dual Carriageway Trunk Corridor Cross-Section



Source: TransMilenio S.A

Stations

The system contains four different station types. Portal stations are found at the end of each trunk corridor; these are the main stations for entering the trunk corridor and feeder routes. Intermediate stations are located along trunk corridors; their purpose is to allow passengers to quickly transfer between trunk routes and/or between trunk routes and feeder routes.

The third and fourth station types are very similar to one another and both are referred to as standard stations. Their main difference is in the layout of their platforms. The third type is the most common, providing access for passengers to travel from one platform to the other. The fourth station type has two totally separate platforms. One platform is for traveling in a specific direction, for example from north to south; and the second platform is for travel in the opposite direction. At these stations, it is not possible to cross from one platform to the other. (National BRT Institute, 2006, p. 9).

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Since the May 2006 expansion, the TransMilenio Route System changed dramatically, with new sections added to the system. Instead of being numbered, routes have a combination of letters and numbers. In order to fill the information gap TransMilenio made available an interactive guide that includes routes, stations, near by places and routes combination, in a simple and efficient form.

There are five types of stations:

- *Sencilas* (Simple): local service stations, located approximately every 500 m.
- *De transferencia* (Transfer): allow transfer between different lines through a tunnel.
- *Sin intercambio* (No transfer): do not allow transfer from the north-south line to the south-north line; located in a stretch of the Autopista Norte
- *Intermedias* (Intermediate): service both feeder and trunk lines.
- *Cabecera (Portal)*: near the entrances to the city. In addition to feeders and articulated buses, intercity buses from the metropolitan area also arrive at these stations.

Pedestrian access is provided through overpasses, tunnels, or signalized intersections, as shown in Figure 8. Walkways, plazas, and sidewalks are also constructed to supply pedestrian and bicycle access. Stations have platforms at the same height as the floor of the buses (i.e. 90 cms / three feet) for easy boarding of all passengers including the disabled. Automatic doors in the stations are coordinated with the buses for safety and efficiency reasons. Single stations have one to five platforms and one or two access points. They are between 25 and 190 meters (82 and 623 feet) long, depending on the number of berths, and usually five meters (16 feet) wide (National BRT Institute, 2006, p. 10).

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Figure 7: TransMilenio Station Infrastructure



Vehicles

Articulated buses operate through the central corridors and regular buses run through feeder and local routes. The articulated buses are approximately 19 meters long, with a maximum capacity of 160 passengers. Figure 9 shows examples of trunk and feeder buses for TransMilenio. The articulated buses have high floors, automatic transmission, pneumatic suspension, and anti-lock brakes. All buses have a right side door with regular steps for access and egress in emergency situations or other times when the vehicle is not at platforms (i.e. garage). Feeder buses are assigned to routes in the outskirts of

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the urban area. Each feeder bus has a capacity of up to 80 passengers. All buses are equipped for people with physical needs, with specific seats reserved for the persons with disabilities, the elderly and pregnant women.

Figure 8: TransMilenio Trunk and Feeder Buses



All buses run on diesel in compliance with Euro II emission standards. However, fuel quality is poor, with sulfur content around 1,000 parts per million (ppm). Low-sulfur fuel is not available, and particulate matter emission is also a problem. These problems are exacerbated by heavy duty performance requirements, which demand that vehicles cover 350 km (217 miles) per day, fully loaded 75 percent of the time, at high altitude. A pilot program is currently underway to investigate the potential for bio-diesel or natural gas fuel options. Besides technology testing, another potential problem is the higher costs associated with switching to alternative fuels.

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Fare Collection

TransMilenio uses pre-paid contact-less smartcard technology. Cards are charged at nearby ticket booths and automatically debited at the turnstiles. Cards can only be purchased inside the stations, which can cause queuing problems. Turnstiles are used to direct passenger flow and automatically charge the contact-less card. A private concessionaire that deposits daily revenues in a trust fund, which is distributed weekly to system agents, and collects fares. The fare collection system includes producing and selling electronic cards, acquiring, installing, and maintaining equipment for access control, information validation, processing, and money handling. The full potential of the electronic fare system is currently underutilized. Multi-trip and time period discount options are not available, and the system has not been integrated with other services (e.g. parking, phone-cards, etc.).

Challenges

A study conducted by the US Department of Transportation examined the effectiveness of TransMilenio and found a variety of operational issues. The following is a discussion of their findings.

Ridership for phase II was lower than projected (1,260,000 versus 1,400,000 passengers per day) because of overcrowding in particular lines and hours of the days, but also from competition by *busetas* and *colectivos*. TransMilenio fares are 30 percent higher than most *colectivos*. These traditional vehicles are restricted from TransMilenio corridors, but are competing for passengers on some parallel roadways.

Overcrowding during peak periods has gotten worse because a more advanced control system based on vehicle location technology has not been operational since May 2006. The lack of precise location information makes it more difficult to balance transportation supply and demand. To address

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problems of overcrowding the contractor has been asked to provide more buses to alleviate the overcrowding increasing operating costs, however, overall vehicle occupancies have not improved. According to some operators, this reduced efficiency threatens the profitability of TransMilenio.

The implementation of the first phase in general was done in a very short timeframe and several system details had to be adjusted after TransMilenio started operations. Some segments of pavement are deteriorating prematurely because of inadequate design, installation or maintenance. The metal flooring and 5-meter width of certain stations have proven to be inadequate for the high passenger flows. Additionally, there were initial problems with fare collection system that could have been mitigated with more time and greater supervision. TransMilenio is currently reevaluating its system of selling and recharging fare cards to allow for an external network (US Department of Transportation, 2007).

Most users will agree that TransMilenio is a vast improvement over Bogotá's previous public transit system; however, there are a number of criticisms based on the way the system works.

- Buses and stations are often packed even during non-rush hour periods.
- The use of diesel buses has a greater polluting impact in a high-altitude city like Bogotá than at sea level (Bogotá is 2,600 meters/8,530.2 feet above sea level).
- Not all stations are covered leaving passengers vulnerable to weather conditions.
- Many users complain about pick-pocketing inside the buses, a problem which is made worse by the great extent to which the buses are packed.

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The implementation of the BRT system in Bogota impacted those affiliated with the traditional system of transportation, and on May 2, 2006, several groups of bus drivers, not affiliated with TransMilenio, held a strike protesting against consequences of the implementation of the BRT system. They disagreed with the amount of monetary compensation that they would receive in exchange for the disposal of old buses, traffic restrictions on the TransMilenio main lines, and a new mandate that restricted buses older than 10-year-old to early morning hours in order to reduce pollution in the city.

Bogotá's Mayor Luis Eduardo Garzón rejected the strike, firmly defended all of the measures as necessary for the City's transportation future, and stated that he was only willing to discuss the specific details of their implementation, as well as a further democratization of TransMilenio's operations, after the situation calmed down. During the second and final day of the strike, the local administration, the strikers and their companies agreed to begin talks (WikiNews, 2006).

Measures of Success

The measures of success of the BRT system is evaluated under three categories: Funding, Infrastructure, and Performance as shown in Table 3 and 4 below.

Table 3 : Bogota's Measures of Success

	Curitiba
<i>Funding</i>	4
<i>Infrastructure</i>	3
<i>Performance</i>	4

KEY: 5 = most successful; 4 = very successful; 3 = fairly successful; 2= functional; 1 = needs improvement

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Table 4: Summarizing TransMilenio Successes

Running Ways	52 miles of exclusive median busways (one and two lanes in each directions)
Stations	117 stations (high platforms, enclosed with sliding doors)
	13 terminals
Vehicles	900 articulated
	400 feeders
ITS	Control center tracking vehicle location using loop detector and station sensors
	Passenger information signs
Fare Collection	Approx US\$0.55 flat fare (30 percent premium over traditional services)
	Contactless fare cards
Service and Operations Plan	9 routes on 7 busways with express services and integrated feeder network
Ridership (boardings)	1.26 million daily
Capacity (Maximum)	45,000 during peak hours and direction
Accessibility	Station are fully accessible with ramps from streets and level boarding between the stations and vehicles

Source: US Department of Transportation, *Report on South American Bus Rapid Transit Field Visits*

Included in the *Funding* category is:

- Institutional arrangement, how it is funded.

Bogota's TransMilenio System was scored a **4** because like Curitiba's BRT, TransMilenio is managed publically but the buses are owned privately.

Included in the *Infrastructure* category are:

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- Physical operation
- Station infrastructure

Bogota's TransMilenio System was scored a **3** because although the TransMilenio services operate on exclusive, dedicated busways, there are too few of stations for the range. Also many of the stations have proven to be inadequate for the high passenger flows and are not fully equipped with handicap access or overhead protection against weather conditions.

Included in the *Performance* category are:

- Percentage of income used towards transportation
- Overall fuel use levels
- Automobile use levels
- Ridership fare cost levels

Bogota's TransMilenio System was scored with a **4** because of the affordability; a flat rate of about 55 cents (US Dollars). However the full potential of the electronic fare system is currently underutilized. Multi-trip and time period discount options are not available, and the system has not been integrated with other services.

The trunk-route system is accessible to all citizens, including people with physical disabilities, elders, children and pregnant women. It has been estimated the 1% of system users (9,500 people/day) have a disability or limitation (Official website TransMilenio).

Commercial public transportation speeds at Calle 80 and Avenida Caracas were between 7.45 and 1.24 mph respectively, before the implementation of the TransMilenio System. These rates have increased to an average 16.76 mile/hour speed, while the traveling times for users have reduced by 32%.

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Chapter 4 Comparison

Although Curitiba's BRT System was established in 1974 and Bogota's in 2000, both have: city strong leadership to mobilize necessary funds, state of the art technologies adopted to run the system, and an efficient single fare pricing system, privately operated ticketing system, articulated buses, designated bus lanes, etc. A major success for both BRT Systems' is the government's implementation of a concession contract-based system for regulating service operations. Providing operators with exclusive rights to specific routes and paying them on a per-kilometer basis as opposed to a per-passenger basis facilitated healthy competition for the open market. See Table 5.

Table 5: Comparison of Success

	Curitiba	Bogota
<i>Funding</i>	4	4
<i>Infrastructure</i>	4	3
<i>Performance</i>	5	4
Total	13	11

KEY: 5 = most successful; 4 = very successful; 3 = fairly successful; 2= functional; 1 = needs improvement

The performance of both BRT systems in Curitiba and Bogota are similar in many ways. See table 6.

Curitiba and Bogota have successfully reduced the number of private automobiles on the street.

Ridership fares are comparable to one another, however, as stated earlier Bogota's fare is about 30% higher than traditional bus system. Ridership for these densely populated cities averages over 1 million per day; Curitiba reaching over 2 million on occasion. Time travel has also improved from traditional modes of transportation for both Curitiba and Bogota, however, Curitiba's buses travel at about three to

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four kph faster than Bogota's average speed. Buses of Curitiba can hold a maximum of about 270 while Bogota buses can hold about 160 passengers per bus.

Table 6: Comparison Summary Table

		Curitiba	Bogota
Funding			
	Contract-based system for regulating service operations	X	X
	No government operating subsidies	X	X
Infrastructure			
<i>Physical operation</i>	Exclusive roadways	X	X
	Articulated Buses	X	X
<i>Station infrastructure</i>	Off-board fare payment	X	X
	Pre-paid card	X	X
	Level boarding & automatic doors	X	X
	Pedestrian accessibility	X	X
Performance			
	Curitiba	Bogota	
<i>Ridership fare</i>	~\$0.60	~\$0.55	
<i>Ridership</i>	85% of population	70% of population	
	1.9 to 2.1 million passenger trips per day	1 million passenger trips per day	
<i>Time travel</i>	19 to 20 kph	Average speed 16.6 kph	
<i>Capacity</i>	270 including standees	160 passengers per bus	

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Chapter 5

Lessons

Instead of succumbing to the demand of the population and addressing transportation as a service that caters to an ever prevalent and pressing demand, Curitiba essentially planned their system with the intention of dictating the growth of the city. Curitiba decided to use buses as its primary means of public transport because it was not only the choice of transport in the past; it was also the most cost effective means of transport. Bogota established its BRT system to address the transportation issues faced by the urban population. Mayor Penalosa created TransMilenio with hopes to achieve a system greater than that of Curitiba. However, Bogota could not achieve the same effectiveness because well established land uses dictated infrastructure placement and growth. The lessons learned from both BRT systems include the following:

- A low cost and less polluting metropolitan mass transport system is achievable. By utilizing the existing road infrastructure, a bus-based mass transit system can be built and operated more cost effectively than a railway system in an urban area.
- Efficient operation can be achieved by the private sector. The operation of the system by the private sector seems to be key to cost recovery through fare collection with no subsidies.
- Connection with existing road transport system is important. Efficient connection with existing road transport systems, such as feeder buses, enhances the quality of service and passenger convenience.
- Information campaigns are essential. It is necessary to create awareness of the transportation system for current and upcoming generations, to make the public feel ownership of the project.

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For instance, the system operated free of charge for the first three weeks, allowing more than 1million passengers to become acquainted with the system.

Single Fare Price: For instance with Curitiba's BRT system, riders pay the same fare, no matter how far they're traveling. That one fare covers an entire trip in the same direction regardless of number of transfers.

Exclusive Bus Lanes: If buses had dedicated lanes they travel much faster than the rest of the traffic as they will not have to compete with cars as illustrated in Figures 10 and 11 of Curitiba's and Bogota's BRT Systems.

Figure 9: Curitiba's BRT Lane Designation



Source: Vivanext <http://vivanext.com/blog/tag/curitiba/>

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Figure 10: TransMilenio Lane Designation



Source: http://www.rochestersubway.com/images/photos/bus_rapid_transit_bogota.jpg

Loading Platforms: Allows passengers to enter the loading area by paying a fare in a turnstile. The tubes not only serve as a fare collection function but also provide platforms for level boarding. Figures 12 and 13 shows Curitiba's and Bogota's elevated subway-like loading station.

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Figure 11: Curitiba's Loading Platform



Source: Urban Habitat

Figure 12: Bogota's Loading Platform



Source: terrapass <http://www.terrpass.com/blog/posts/bus-rapid-transit>

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Signal Priority: Allows buses to maintain a swift service and to better adhere to their schedules. Since transit vehicles can hold many people, giving priority to transit can also potentially increase the person throughput of an intersection.

- A **passive priority** strategy favors roads with significant transit use in the area-wide traffic signal timing scheme. Timing coordinated signals at the average bus speed instead of the average vehicle speed can also favor transit vehicles.
- An **active priority** strategy involves detecting the presence of a transit vehicle and, depending on the system logic and the traffic situation then existing, giving the transit vehicle special treatment. The system can give an early green signal or hold a green signal that is already displaying. An active system must be able to both detect the presence of a bus and predict its arrival time at the intersection.

Set Stops: Having buses that more closely resemble subways and having permanent stops not only creates permanence, but also creates efficiency.

Electronic Fare Payment: By allowing people to pay before boarding there is a huge efficiency advantage over most bus systems in the US.

Curitiba (Bogota to a less extent) was fortunate to still be developing as cities while they built much of their transit systems whereas most U.S. cities are already developed. Therefore, it maybe harder for any U.S. city to incorporate a BRT system. Illustrated in Table 7 are potential city problems and possible solutions for BRT systems.

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Table 7: BRT Strategies

Problem	Solution
Car traffic slows buses down.	Buses run along dedicated bus lanes.
It takes too long for passengers to board the bus.	Passengers pre-pay for their tickets, and board in parallel, from custom designed bus stops.
Buses waiting at stops block buses following along behind	At bus stops, use lay-bys to allow following buses to pass easily

Source: http://www.calccit.org/itsdecision/serv_and_tech/Public_transit_tech/brtsum_print.htm

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Chapter 6

Conclusion

The BRT systems of Curitiba and Bogota are examples of effective urban transportation planning. Urban planners recognized that even if growth in population cannot be controlled, the development of infrastructure in the city can guide the city's expansion. By approaching transportation as a tool used to attain a greater solution rather than as a solution to an advancing problem, they were able to implement an efficiently constructed, cost-effective transportation system that finances itself. The cities use buses because they had traditions of using buses. While the systems are powered by diesel, the reduction of the number of cars used compensates, if not surpasses, the difference in carbon monoxide emissions. Like every city, both Curitiba's and Bogota's BRT system is plagued by overcrowded buses during peak hours, but this is a relatively minor inconvenience in comparison to the extent of service the BRT systems offer to residents.

Some lessons learned from both Curitiba's and Bogota's BRT systems are applicable to the United States. There are differences in city structure, economic prosperity and income levels, automobile ownership, public perspective and image of public transport, and other factors, which make it essential that local conditions be evaluated. One of the great advantages of a BRT system is that it can be planned, designed, and operated in a flexible manner and thus can be geared to local conditions.

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

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use to provide a potentially high passenger demand. In order to fully incorporate a successful BRT system in United States cities there are some policies and principles that are applicable:

1. *Transit First Policy:* Public transport needs to be a priority in large cities and to integrate public transport with community development wherever possible.
2. *Busways as a Mass Transit System:* Curitiba and Bogota both show that with good planning and organization busways can carry high volumes of passengers at reasonable commercial speeds – equivalent to those of Light Rail Transit or tram technology under the same operating environment. Even if corridor travel demand is high, busway capacity is not usually an issue. The capacity issue would be especially true in a U.S. context.
3. *Interconnection of Services:* The BRT systems of Curitiba and Bogota were built for different reasons and at different times during each city's growth. Curitiba's BRT system was developed as Curitiba was emerging as a major metropolitan city, which allowed the system to connect services and dictate land use designations according to transit stops. It also allowed development to plan transit stops around important nodes throughout the City. Bogota has less interconnection of services due to the fact that the BRT system was developed after the Bogota was an established metropolitan city. Bogota's TransMilenio developed along routes and nodes already established throughout the City. That is not to say TransMilenio is disconnected with services, however, they are at a greater disadvantage compared to Curitiba.
4. *Priority treatment and mixed traffic conditions:* Both BRT systems operate on established roadways that are utilized by personal vehicles. Both systems, as illustrated in earlier sections, use separated bus lanes and give signal priority to the buses. The buses try to operate much like a subway system without the needed underground infrastructure.

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