Curitiba, the cradle of Bus Rapid Transit

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ABSTRACT

Curitiba is the only city in Brazil that has directed its growth by integrating urban transportation, land-use development and environmental preservation. Since the 1970s Curitiba's administrators have constantly achieved innovations with the city's bus-based transit system through performance and capacity improvements. Originally, the bus system evolved from conventional buses in mixed traffic to busways, which were later fitted with at-level boarding, prepayment and articulated buses, creating the first full bus rapid transit system in the world. Later, the city introduced high capacity bi-articulated buses and the electronic fare ticketing systems. In 2009 the integrated bus system was upgraded, again, with the introduction of the Green Line, its sixth BRT corridor which includes the operation of 100 per cent bio-diesel articulated buses. In 2010 retrofitting of one of the existing corridors, improving its performance to levels that are typical of metro systems. System operation will be further enhanced with advanced traffic management and user information systems.

INTRODUCTION

Curitiba has a long history of innovations in transport, land use and environmental management. The successful implementation of its citywide transit system and integrated land use plan over the last four decades, has received further enhancements in 2009 and 2010 with new corridors and capacity improvements on one of the existing busways. This paper presents the current conditions of the city and summarizes the bus improvements over time. Then, it details the integrated transport network and the recent improvements: the new corridor known as the Green Line and the capacity improvements in the *Boqueirão* Corridor. With these projects, Curitiba resets the standard for high performance bus systems and transit oriented development.

CITY CONTEXT

Curitiba, with 1.8 million inhabitants occupying a total area of 435 km^2 (about 4,200 inhabitants per square kilometre), is the 7th most populated city in Brazil and the largest in the southern region of the country. The city stands right at the centre of a metropolitan area that includes 26 municipalities with a total population of 3.17 million inhabitants. The population of Curitiba´s metropolitan area has increased 9.3 times over the last 50 years (4.6% annual growth) and 2.1 times over the last 20 years (3.8% annual growth) (IBGE, 2010).

Curitiba has one of the highest private car ownership rates in Brazil with almost 400 cars registered per 1,000 inhabitants (DETRAN-PR, 2010). Nevertheless, there is no reliable source for estimating Curitiba´s urban modal split, as the city is one of the very few large cities in Brazil

yet to conduct a comprehensive transportation study based on home-based origin destination surveys.

Curitiba is one of the finest examples of integrated transportation and land use development (Fouracre, 1975; Cervero, 1998). Curitiba achieved what other cities in Brazil did not when facing similar opportunities. Cities like São Paulo, Belo Horizonte, Recife, Porto Alegre and Rio de Janeiro used the federal funding available in the 1970s for bus systems performance improvements only (Lindau et al, 2008), whereas Curitiba used the investment opportunity on busway corridors to direct its future growth.

Most bus corridors in other Brazilian cities have been implemented in isolation from a firm and coherent system of regulation, political stability, and comprehensive long term planning and land use strategies. The result: partial, inefficient or overcrowded systems, that cannot adequately meet demand (Hensher, 1999). Furthermore, in the majority of the large Brazilian metropolis, far too many public spaces and streets located in their city centers were transformed into open bus terminals. Curitiba is then a remarkable exception, and an example for the world.

BUS TRANSIT IMPROVEMENTS OVER TIME

There were three key periods in the history of modern Curitiba (Cervero, 1998; Ardila, 2004, Lindau et al, 2010): (i) 1943 to 1970, planning principles and vision was forged; (ii) 1972-1988, plan execution that led to the consolidation of a city wide integrated bus transit system, denominated Integrated Transit Network (RIT); and (iii) 1988 – today, metropolitan expansion and improvements in the integrated bus transit system.

Curitiba is the cradle of the BRT concept with the introduction of busways and feeder services in the 1970s and the Integrated Transit Network (RIT) in the 1980s, including prepayment, level access and large buses with multiple doors. The gradual approach based on a single urban development indicative plan (Curitiba´s Urban Master Plan, approved in 1966) led to a highly sophisticated system with a range of services for metropolitan coverage (Ardila, 2004).

In the 1970s, when Curitiba had only 400,000 inhabitants, plans for implementing a light rail transit (LRT) system were prepared. The idea was aborted due to LRT's high capital costs. Instead, IPPUC (Institute for Research and Urban Planning of Curitiba) conceived a trunk-and-feeder bus system operating along segregated median flow lanes as the central component of axial transit ways. This bus system was gradually upgraded until reaching the status of the first full BRT system in the world (Arias et al, 2008; Lindau et al, 2010).

In 1980, with the implementation of the east-west corridor, Curitiba consolidated the basis for the RIT. A single flat fare enabled a cross subsidy between short and long displacements by allowing users to interchange between trunk and feeding services at terminals and tube stations. In 1990 a series of legal arrangements between the State of Paraná and the City of Curitiba empowered URBS (Urban Development Authority of Curitiba) to plan and manage all the transportation modes within the Curitiba metropolitan area.

Curitiba´s approach is quite unique in Brazil as IPPUC and URBS play a key role to guarantee continuity in terms of transit and traffic solutions as well as urban planning. While URBS is responsible for planning and controlling transit in the metropolitan area and conceiving permissions to bus transit operators, IPPUC consolidates urban development plans, programs and projects of different administrative units of Curitiba and its metropolitan area. Curitiba became

Latin America´s iconic city for urban planners in providing one of the rare cases where the realization of plans transcends political administrations.

INTEGRATED TRANSIT NETWORK (RIT)

The RIT is originally a municipal initiative that sought integration of transportation and land use in the city of Curitiba; today RIT covers 14 of the 26 cities of the metropolitan area (URBS, 2010). RIT was conceived around structural axles that provide the backbone of a transit-oriented development (TOD) initiative through relatively low cost and high impact interventions.

A typical structural axis includes two side blocks and three roadways and is thus called a "trinary" system. Figure 1 displays the concept and the reality along one of the key arterial corridors. The central avenue is dedicated to bus transit (median busways and tube stations) and local traffic that accesses buildings and parking. The parallel streets are dedicated to higher speed traffic (including direct buses), with each street providing traffic in one direction (towards the city center and towards the suburbs). The side blocks are zoned as mixed use, high density development. Blocks further away from the "trinary" system are zoned for lower density. As result, urban development is linear along the structural axles. Over time the concept proved successful in achieving linear TOD.

Figure 1. Conceptual linear TOD plan that became a reality. (Source: URBS)

The RIT, schematically described in Figure 2, includes a series of components (URBS, 2010):

- median busways longitudinally segregated.
- tube stations with fare prepayment and level access.
- physical and fare integration among diverse services (mid points and terminal stations).
- dispatch control at terminal stations.
- differentiated services:
    - express radial routes (*expresso*) and accelerated radial routes with limited stops (*ligeirão*), in the median busways, using large capacity bi-articulated buses.
    - direct radial routes (*ligeirinho*) in the fast streets of the trinary system, with integration at terminals and mid-point stations along the structural axles, using articulated and conventional buses.
    - inter-neighborhood circumferential routes (*interbairros*), integrated with the radial routes (express and direct) at terminals and mid-point stations. Bus size according to the demand includes articulated and conventional buses.
    - feeder services (*alimentador*) connecting local neighborhoods to the radial and circumferential routes at terminals and mid-point stations, using articulated and conventional buses according to the demand.
    - downtown circulator using small buses.
    - special services for students, hospitals and tourists.
    - centralized fare collection, using off-board ticketing at tube stations and terminals, and on-board ticketing for feeder and inter-terminal services. An electronic fare collection system, introduced in 2002, replaced a coin based system used since the early 1980s.

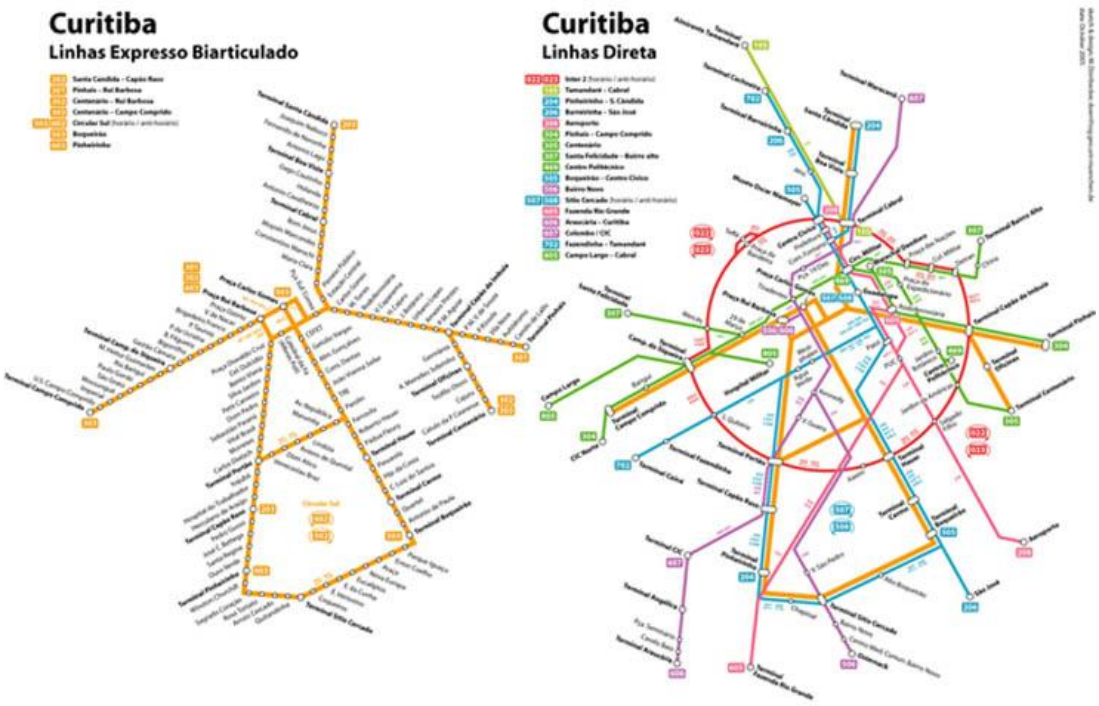

Figure 2. Schematic representation of RIT. (Source: URBS)

In terms of urban transit, the city was divided into 13 regions or selective areas, each one operated by one private bus company. Some companies have merged over the years and, very recently, amalgamations occurred between urban and metropolitan operators. Inter-neighborhood circumferential services are jointly operated by all companies. Company operators used to have permits granted by URBS, the sole concessionary of the system. But in 2010, as result of a bidding process, URBS became the manager for RIT and payment to operators changed from logged bus-mileage to a passenger-transported basis.

In 2007, RIT totaled 2.26 million trips per working day transported by a fleet of 2,200 buses (on average of 5 years old) and produced 483,000 km per day (IPPUC, 2010). Maximum peak load in the North-South axis is around 18,000 passengers/hour/direction (does not include parallel direct services), commercial speed is 17.5 km/h, and operational headway is 50 s/bus (Almeida, 2007). Other performance indicators include 4.7 boardings/bus-kilometer and 1,027 boardings/bus/day. Diesel consumption is reported as 0.12 liters/pax (Almeida, 2007).

The RIT infrastructure includes 72 km of busway corridors, 347 tube stations (level access, pre-payment, see Figure 3) and 29 urban terminals with integration for feeding services (IPPUC, 2010). Services include several vehicle types: bi-articulated (270 pax), articulated (160 pax), conventional (90 pax), microbuses and special buses (hospitals, students, tourism). The initial costs of the RIT infrastructure in 1999s USD were (Ceneviva, 2000): 900,000 USD per terminal, 800,000 USD per kilometer of busway and 40,000 USD per tube station.

Figure 3. A typical Curitiba's tube station. (Source: CTS-Brasil)

The approach for implementing RIT was gradual, not only in terms of coverage but also in components. Table 1 depicts the key changes over time. Electronic ticketing was introduced in 2002 through contactless smart cards. Express and direct services require access via prepayment in tube stations and terminals. Feeder buses have on board validation of electronic cards or direct payment to a conductor. Around 46% of the fares are paid with smart cards (URBS, 2010). The fare is flat allowing the passengers to transfer between any service of the RIT. The flat fare is

equivalent to 1.10 USD in 2010, except for Sundays when it costs 0.50 USD. In the city center of Curitiba, the system operates a special circular line that charges 0.60 USD.

TABLE 1 Key components of RIT development over time

1970s	1980s	1990s	2000s	2010
Bus stop shelters	Tube stations			Real time information
Conventional buses	Articulated buses	Bi-articulated buses	Cleaner buses	B100 articulated buses
Open terminals	Closed terminals (paid area)			
Paper and coin based ticketing (manual)			Electronic ticketing	
Trunk-and-feeder services	+Inter-neighborhood +Direct (Ligerinho)	+Special services		+Overtaking at busway stations
Urban services		Metropolitan services		
	Dispatch at terminals			Real time control

Source: the authors, (URBS, 2010, Ardila, 2004; Rojas Parra, 2006; Levinson et al, 2003)

There are a number of free services: elderly (65+), children under 5 years old, disabled, officers of the ministry of labor, military policemen, local policemen, transit system workers, postmen, and workers of the judiciary system, as well as reduced fares for students. Gratuities represent 16% of the flat fare (IPPUC, 2010).

Today the system does not have a centralized automatic control. But this situation is about to change with the implementation of a transit management system by the end of 2010. The Mobility Integrated System (SIM) comprises a set of tools and equipment that shall allow, once fully implemented, a centralized control as well as provide, among other traffic and transit innovations, smart traffic lights capable of prioritizing buses over other vehicles.

GREEN LINE (*LINHA VERDE*)

The Green Line (*Linha Verde*) is the 6th BRT corridor of Curitiba and is the first to incorporate, since its early conception stages, overtaking lanes for a mix of express and direct BRT services. This latest RIT corridor displays every aspect of a modern full BRT system. It is the backbone of a linear TOD urban renovation program implemented along a former federal roadway (BR-116) whose heavy traffic was diverted to a recently opened ring road. The former roadway is wide enough (60 to 80 m) to accommodate 10 traffic lanes under the trinary concept developed in Curitiba, i.e. lanes for local access, for fast traffic, and lanes segregated to buses, apart from dedicated spaces to grass and trees, pedestrians and cyclists (City of Curitiba, 2010).

The Green Line was conceived in 2002. Operations started in May 2009 along a 9.4 km initial stretch. Implementation costs of this stretch are estimated at 60 million USD. A 20,000 square meter linear park is being constructed along the Green Line, including 2,600 trees, leisure facilities and a 6 km cycle-way. The Green Line, when fully implemented, will have 18 km connecting 23 neighborhoods and 287,000 inhabitants (City of Curitiba, 2010).

Figure 4 presents a view of the former BR116 roadway and Figure 5 shows a sketch of what the corridor will look like in the future once buildings are constructed. When the city law that enables densification along the Green Line was approved, real-estate prices of former underutilized depot and land used for the provision of truck related services increased by a factor of three (URBS, 2010). Under the Law of Curitiba, an owner of a metropolitan area, designated by the public authority as to be preserved, can sell its construction rights to builders willing to increase the construction potential of plots along transit corridors.

Figure 4. View of the former BR116 roadway. (Source: URBS)

Figure 5. Sketch of what Green Line will look like in the future once buildings are constructed. (Source: URBS)

The Green Line includes overtaking lanes at the stations and is thus prepared for operations that may include a mix of local, express and direct services. Stations are long and wide enough to accommodate an articulated BRT on its median side and conventional feeder buses on the other side as depicted in Figure 6. The tube station concept became an icon of the city and it is even used in its official shop at the airport (*Leve Curitiba*, i.e. Buy Curitiba, Figure 7).

Concrete is the material used in the pavement of the busway. In the seven double tube stations implemented in the first stretch of Green Line, water collected from the rain is used to cool the interior. Thermal comfort for the waiting passengers at the tube stations is also improved by sun screen films and by using special isolation materials in the covering of the stations. Personal security at tube stations is enhanced by a system of cameras connected to a control center (City of Curitiba, 2010).

Figure 6. Current view of Green Line. (Source: CTS-Brasil)

Figure 7. Official Curitiba shop at the airport. (Source: CTS-Brasil)

In its first year, the Green Line is carrying an average of 18,000 pax/day. It is foreseen that demand will soon grow to 32,000 pax/day, alleviating the crush peak transit load of Curitiba´s south axis. According to URBS (2010), the Green Line is the first bus system in Latin America to operate with 100% biodiesel (B100). Since August 2009, six out of its total fleet of 18 articulated buses have engines that can be run either on biodiesel or normal diesel; during 18 months the performance of these six buses will be analyzed. Emission estimates are in the order of 30% less carbon dioxide and 70% less smoke when compared to similar buses (EURO III) running on normal diesel (URBS, 2010). Through the biodiesel experience, the original equipment manufacturers (OEM), operators, fuel provider and URBS will have the opportunity of fully assessing the costs and the extent of the environmental benefits associated to B100. In addition, from mid 2009 onwards all buses in Curitiba are using B4+S50 diesel – i.e. 4% biodiesel mixed to a diesel that contains 50 parts per million sulphur. Before that, Curitiba´s buses were running on a B4+S500 mix (URBS, 2010).

CAPACITY EXPANSION FOR EXISTING CORRIDORS

In March 2010, the *Boqueirão* Corridor was upgraded through the introduction of passing lanes at stations. The stations were displaced and parking eliminated to make room for an additional lane, making it possible to introduce the "*Ligeirão*" buses, which share the busway but are not

required to stop at every station. According to URBS officials, this new configuration (see Figure 8) increases the capacity of this corridor to 20,000 passengers per hour per direction and the average commercial speed to 25 km/h.

Figure 8. Capacity expansion for Boqueirão corridor.
(Source: City of Curitiba)

CONCLUSION

Curitiba is an iconic city for bus transit and integrating transport and land use planning. The launch of its sixth corridor, incorporating several environmental innovations, and the upgrade of existing corridors, indicate the strength of the concepts that have made Curitiba a best practice city over the last 35 years. The Green Line, the new corridor, takes full advantage of evolved BRT concepts such as cleaner vehicles and fuels and the introduction of passing lanes at stations to increase capacity and improve commercial speeds. It also promotes the renewal of the urban space based on a linear park and the redevelopment of low density industrial properties. The Green Line will provide the basis for a massive urban renovation in the city. The value of land and property along the corridor has already realized a substantial increase.

The success of Curitiba derives from a mix of political leadership, innovation, pragmatism, technocracy and continuity. Curitiba was the first city in Brazil to organize private bus operation in catchment areas and the first city in the world to implement a full BRT system. As with any other city in Brazil, Curitiba faced periods of turmoil when political administrations challenged the *status quo* in promoting big changes. But its solid technical entities in charge of urban planning, traffic and transit management – IPPUC and URBS – provided the technical support

for the launching and continuity of plans, programs and projects over city administrations run by different parties.

Over the years Curitiba has been demonstrating to the world its potential to produce creative and relatively low-cost solutions for urban mobility. With the inauguration of its sixth corridor and the capacity upgrades of existing corridors, Curitiba consolidates 35 years of continuous bus oriented development, and sets new standards for the future of high-performance BRT systems.

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