U.PORTO
FEUP FACULDADE DE ENGENHARIA
UNIVERSIDADE DO PORTO

APPLICABILITY CONDITIONS FOR THE IMPLEMENTATION OF BRT SYSTEMS.

Case study of Coimbra

JHONNY RODRIGO ROJAS MORALES

Thesis submitted for partial fulfillment of the requirements for the degree of

MASTER IN SPATIAL PLANNING AND URBAN PROJECT

Supervisor: Professor PhD. Álvaro Fernando de Oliveira Costa

JUNE OF 2016

MASTER IN SPATIAL PLANNING AND URBAN PROJECT_2014/2016

DEPARTAMENT OF CIVIL ENGINEERING

Tel. +351-22-508 1901

Fax +351-22-508 1446

✉mppu@fe.up.pt

Edited by

FACULTY OF ENGINEERING OF UNIVERSITY OF PORTO

Dr. Roberto Frias Street

4200-465 PORTO

Portugal

Tel. +351-22-508 1400

Fax +351-22-508 1440

✉feup@fe.up.pt

http://www.fe.up.pt

I dedicate this works to:

To God,

To my family,

To my close friends and colleagues from the master program,

To my different professors in the faculty

For the support and incentive received.

ACKNOWLEDGEMENTS

The concretization of this work would not be possible without the help received from a specific group of people, which have contributed directly or indirectly.

The constant encouragement of my family was important for the conclusion of this research; my mother María and my brother Ivan were constantly supporting me and for that reason I feel so grateful with them.

I want also to give thanks to my professor and supervisor, the professor Alvaro Costa who contributed with his guide and expertise during the realization of this work.

My colleagues and personal friends were important during the whole duration of the master course. I want to acknowledge their constant help in the academic area and their emotional support also.

Finally I want to give thanks to my scholarship program and their respective coordinators here in Porto and also in Valladolid. The help provided by Ana Paiva and her team was important since the beginning of the master program.

To all them, thanks.

RESUMO

Ao longo dos últimos anos, o conceito de BRT (Bus Rapid Transit) tem ganho relevância um pouco por todo o mundo e atualmente é considerado uma alternativa válida de transporte público. Este modelo foi amplamente promovido a partir de 2000 e desde então um número considerável de sistemas BRT foram implementados, sobretudo em cidades de países em desenvolvimento.

A disponibilidade de estudos de investigação sobre projetos de BRT tem crescido na literatura, sendo possível identificar duas linhas de pensamento relativamente aos resultados que podem ser obtidos através da implementação deste tipo de sistema. Quando comparado com as opções de transporte sobre carries (Metro e LRT), alguns investigadores sugerem que os sistemas BRT permitem a obtenção de um desempenho igualmente satisfatório relativamente às opções tradicionais de transporte, enquanto outros recomendam a restrição de sistemas BRT a cidades em desenvolvimento, particularmente as que não dispõem de recursos suficientes para a construção de outros meios de transporte sobre carries, visto que os sistemas BRT não são capazes de produzir os números obtidos com sistemas de metro de alta qualidade.

Projetos de BRT implementados em cidades como Bogotá ou Curitiba demonstraram que é possível obter optimos resultados com o uso deste sistema relativamente novo. É notório que tanto o custo quanto o tempo despendido para a implementação do sistema BRT é consideravelmente menor se comparado a outros modos de transporte. No entanto, embora irrefutáveis, as vantagens anteriormente mencionadas não são suficientemente válidas para considerar o sistema BRT como a melhor opção de transporte público. As configurações de mobilidade das cidades são fenômenos complexos e, desta forma, não é possível afirmar que uma alternativa específica de transporte público alcance os mesmos resultados em diferentes contextos urbanos. Portanto, é necessário encontrar as condições ideais para que a implementação do sistema BRT ocorra com sucesso.

Os resultados deste trabalho foram sistematicamente ordenados em tabela, de modo a apresentar as condições que uma cidade deve reunir para que a implementação do sistema BRT produza resultados positivos. Este trabalho também procurou estudar de forma exaustiva cada aspecto relacionado aos sistemas BRT, além de apresentar análises independentes de projetos BRT implementados em diferentes contextos e que produziram tanto resultados positivos quanto impactos negativos sobre a expansão urbana.

PALAVRAS-CHAVE: BRT, sistemas de transporte público, condições de implementação, planeamento, mobilidade urbana .

ABSTRACT

During the last years the BRT (Bus Rapid Transit) concept has gained relevance around the world and nowadays is being considered as a valid alternative for massive transportation. This system has been strongly promoted since the year 2000 and a considerable number of BRT systems were implemented since then, especially in cities from developing countries.

The literature and research about the BRT projects has also increased and is possible to notice two thinking lines among the planners about the results that can be achieved implementing this kind of systems. When the BRT system is compared with the rail based options (Metro and LRT) it is possible to distinguish between who argue that the BRT systems can achieve a high performance similar to these traditional options and on other hand there are those who suggest that the BRT systems are more suitable for developing cities which cannot afford a rail based alternative and they say that BRT systems cannot reach the numbers of the high quality metro systems.

The BRT projects implemented in cities like Bogotá or Curitiba demonstrated that is possible to achieve positive results using this relatively new type of system. It is impossible to deny that this alternative has a considerable lower cost and shorter implementation time when compared to the other options. These advantages are undeniable but at the same time they are not enough valid to establish the BRT systems as the best option. The mobility configuration of the cities is such a complex phenomenon that is not possible to affirm that one specific alternative is going to achieve the same positive results in different urban contexts, so there is a need to find the ideal conditions in which a BRT system could be implemented successfully.

The findings of this work were systematically ordered in a matrix that presents the conditions that a city should accomplish in order to implement a BRT system that could achieve positive results. Also, in this work it was studied into an exhaustive way main aspects related to BRT systems and with an independent point of view we analyzed BRT projects implemented in different contexts, which produced positive but also negative impacts over the urban sprawl.

KEYWORDS: BRT, massive transportation systems, implementation conditions, planning, urban mobility

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SYMBOLS AND ABBREVIATIONS

BRT – Bus Rapid Transit

LRT – Light Rail Transit

BID – Banco Interamericano de Desarrollo

ITDP – Institute for Transportation and Development Policy

CEPAL – Comisión Económica Para America Latina y el Caribe

SMM – Sistema de Mobilidade de Mondego

WRI – World Resources Institute

GPS – Global Positioning System

RIT – Rede Integrada de Transporte

UN – United Nations

CBD – Central Business District

NYC – New York City

PTUS – Plan de Transporte Urbano de Santiago

IPPUC – Instituto de Pesquisa e Planejamento Urbano de Curitiba

JICA – Japan International Cooperation Agency

USD – United States Dollar

TOD – Transit Oriented Development

IRTP – Integrated Regional Transport Planning

NMT – Not Motorized Travels

AVL – Automated Vehicle Location

BHLS – Bus with a High Level of Service

ITS – Intelligent Transport Systems

1
INTRODUCTION

1.1. General framework

During the last century, most of the cities experienced the largest growth in their history and some of them started to get overpopulated and this was affecting many aspects of the urban life, including the transportation. These new metropolis required larger capacities of services provision (water, energy, transportation and others) to supply the demand of the population. In the case of urban mobility, the conventional public systems were not able to satisfy the mobility of the population that was growing very fast. The private transport could not solve the problem and the new mega cities started to deal with congestion and other problems in their mobility context.

It was in this context where the massive transportation systems (metro, LRT) appeared, and some pioneer cities in the world implemented these transportation systems to solve their problems. In Europe the first metro systems achieved good results and this boosted to other cities in the world to adopt this system also. With large budgets many cities of developed regions could implemented a rail based system but on the other hand, cities of developing countries had to search for other alternatives more according to their lower budgets and the BRT (Bus Rapid Transit) concept emerged as a possible solution.

It was Curitiba in the 1970's decade the first city to implement this new concept. The BRT was presented as a cheaper solution than metro and the results obtained in Curitiba boosted other cities from South America to implement this system also. Few decades later other successful BRT systems were implemented in the region (Bogota, Quito, others) achieving positive results also. Other cities from developing regions started to adopt the BRT concept and during the last years the system has expanded around all the continents.

Since 2009 some European countries like Portugal started to suffer a financial crisis and consequently this crisis affected also important mobility projects. There are cities like Coimbra that have projects to implement rail based systems but the economic reality became a barrier for these mobility projects. Nowadays the cities in this situation are looking for affordable solutions and the BRT concept started to gain a relevance that didn't have in the past in the developed regions.

1.2. OBJECTIVES

The main objective of this work is to find the applicability conditions that a city should accomplish in order to implement a BRT system successfully. The results will be presented in a systematic order to provide clear concepts about BRT systems.

The work covers important aspects related to the BRT systems and in order to achieve the main objective, the next secondary objectives were set

- To understand the origins, expansion and history of this relatively new massive transportation system;
- To make an extensive study of the BRT concept, their characteristics and their components, in order to comprehend the main advantages and disadvantages that the BRT system presents when is compared with the rail based systems;
- In order to get practical concepts from different points of view the results of seven different BRT systems implemented in different cities around the world will be studied.

Once the main objective is achieved, the resulting criteria will be applied in the case of Coimbra with the intention to analyze the viability of a BRT alternative for this city.

1.3. METHODOLOGY

To accomplish the objectives of this work a methodology based in the study of main aspects related to the BRT systems was adopted.

It is true that a BRT system is a much cheaper system than a metro or a LRT, but this feature is not enough reason to choose the BRT instead of other systems, there is also the need to identify which other advantages and disadvantages are possible to find when a BRT is being compared with the traditional rail systems. For this reason firstly will be analyzed deeply the BRT system, their special features and the evolution of this concept during the last decades.

It was in South America that the system was implemented for first time and it was in this region where were obtained positive results with the implementation of BRT, for this reason is needed an study of this region where the BRT concept started to gain importance.

In order to do an independent analysis, we selected case studies that obtained positive but also negative results, some of them were implemented in cities that already had other massive systems but in other cases the BRT systems became the first and only massive alternative. Some of the BRT projects studied are simple BRT systems (just one corridor) but in other cases the BRT system consist in complex networks with many corridors.

With the findings obtained in the previous steps a table or matrix of the applicability conditions for BRT systems was elaborated. This criterion will be applied in the practical case of Coimbra.

1.4. STRUCTURE OF THE WORK

The present wok is divided by chapters organized as follows:

- The first chapter includes the initial guidelines of the work which are the general framework, objectives, methodology and the current structure adopted;

- The second chapter comprehends a deeper analysis of the origins of the BRT system, the evolution of the BRT concept and the importance that this alternative gained during the last decades;
- In the third chapter is studied, in an extensive way, the characteristics and components of the BRT systems. This chapter also includes a systematic comparison of the BRT systems with the traditional rail based systems;
- The fourth chapter comprehends a critical analysis of relevant BRT systems implemented around the world.
- In the fifth chapter are explained the concepts and criteria obtained in the previous chapters. This chapter includes the findings of the entire work; this means the applicability conditions for the successful implementation of BRT systems;
- The sixth chapter is about the practical case of Coimbra, the case study of this work. In this chapter is explained the current situation the LRT proposal “Sistema Metro do Mondego”. Applying the concepts obtained in the previous steps, the viability of a BRT alternative in the case of Coimbra will be analyzed;
- Finally, the seventh chapter contains the conclusions of the work and the suggestions for future studies.

2
THE IMPORTANCE OF THE BRT CONCEPT NOWADAYS AND ITS EVOLUTION DURING THE LAST DECADES

2.1. INTRODUCTION

In the past, many countries tried to deal with their mobility problem with a criteria more focused to improve the features of the private sector; that is, trying to provide better infrastructure for the private vehicles, looking to improve the circulation and the efficiency of the road system, but over the years this focus was not having results, on the contrary was aggravating the congestion problem, because the private vehicle sector growth and was overcrowding the system.

Nowadays the perspective is to improve the public transport provision, looking to provide an efficient and sustainable system able to satisfy the demand of the population. So, planners and governments are trying to invest larger budgets in the public transport rather than in the private transport. In this scenario the massive transportation systems appear as efficient solutions.

Traditionally the focus was in the rail based systems, those are the metro and the light rail transit (LRT), due to the positive results obtained in different metropolis around the world. Even not all the rail system had satisfying results, or the expected results, these systems are considered by many planners as the best alternatives to move a large quantity of people but is also needed a large budget to implement them, specially the underground systems.

There are few cities in the world with financial capacity able to implement a large metro system, because this system tends to be the most expensive alternative. Although the LRT alternative is cheaper than metro, there are many cities (especially in developing nations) that are not able to fund this other alternative. So, a city without a large budget but with urban mobility problems can't afford the implementation of a rail based system, and some cities prefer to wait to get the budget needed for one of these solutions.

The Bus Rapid Transit (BRT) appeared few decades ago as an affordable alternative able to satisfy the transport demand of the cities and nowadays there are a considerable number of cities that are extending, implementing or planning a BRT system. Due, to the positive results obtained in some pioneer cities as Curitiba, Bogotá, or Quito, the BRT concept is expanding quickly around the world.

2.2. HISTORY OF THE BRT CONCEPT

Although, Curitiba was the first city that implemented a BRT as a system in the year 1974, the concept of the rapid transit, that means, the idea of moving large quantities of people using a wheel based system, had its origins many decades before.

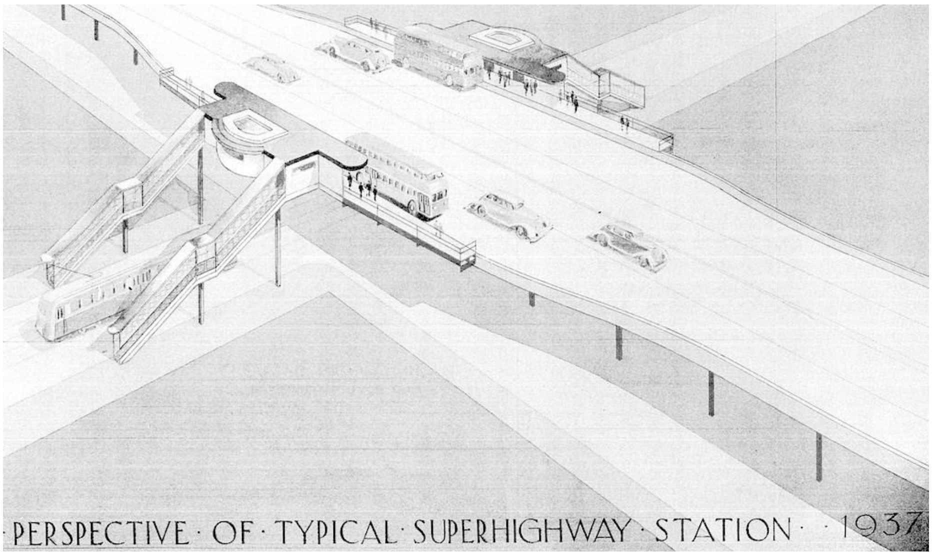


Fig.2.1 - The transportation plan of Chicago of 1937 [1]

In 1937, the city of Chicago elaborated a plan to replace three rail lanes by an express bus corridors, and in two years, this city implemented that plan establishing the first exclusively lanes for buses (Figure 2.1). Different planning organizations agree that the origin of the BRT concept is linked to this innovative measure implemented in Chicago. Similar busways were developed in other cities of United States since then, as Washington, DC and St.Louis in 1959 and Milwaukee in 1970.

Few years before of the BRT implementation in Curitiba, important major metropolis like New York and Paris also implemented exclusive bus lanes, in 1936 and 1964 respectively. In this way the concept about the improvement of the bus priority, was expanding and some European cities started to adopt the idea. At the same time as St. Louis, in 1966 the city of Liege (Belgium) implemented medium busways converted from its tram system infrastructure. England eventually was implementing bus lanes in some cities as Runcorn (1971) and London (1972).

Lima was the first city that adopted the bus corridors concept in Latin America. In 1972, the city opened the “Via Expresa” corridor, an exclusive busway of 7.5 kilometers that was converted into a BRT system decades later (2010).

All these improvements to the bus services, in all these different cities, were modeling a new concept for massive transportation, a new system that was implemented for first time in 1974 in Curitiba where the local authorities wanted to implement a rail based system, but the financial reality of the city didn’t allow accomplish that objective, so when Jaime Lerner, assumed his functions as Mayor, he was looking for a solution according to the budget available and he and his team developed a cheaper but effectively solution, a BRT system.

The system was planned in 1972 and two years later started to working with 20 km initially and nowadays the systems has 65 km of exclusive busways. It is for this reason that Curitiba is considered pioneer in this system, because was the first city that took the risk of implementing a new massive transportation system based on buses, instead that typical rail based systems. The positive results achieved in Curitiba, impulse other Brazilian cities to also implement BRT systems in the same decade (São Paulo, Goiania, Porto Alegre and Belo Horizonte).

It was not until the 90's decade that the BRT system started to spread around the world. In 1996, Quito (Ecuador) implemented a BRT system, becoming the first non-Brazilian city in South America to implement the system. It was also in this decade that the first Asian cities, Taipei (Taiwan) and Kunming (China) implemented bus corridors in 1998 and 1999 respectively, but was not implemented a complex BRT system in Asia until some years later.

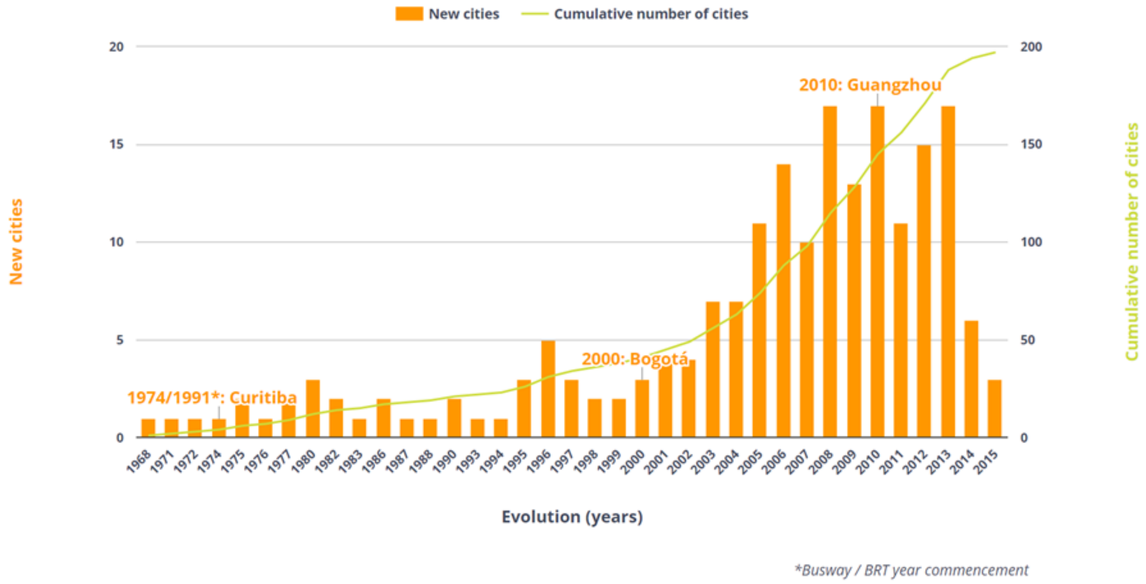


Fig.2.2 - Evolution of the BRT and busways concept through the years [2]

At the end of the 90's the BRT was accepted as a solution for medium size cities with small budgets but the BRT system "Transmilenio" implemented in Bogotá (Colombia) in 2000 was very important to change this way to see the BRT. When this system was implemented, Bogotá was a large and dense city with nearly 7 million of inhabitants. Similar to what happened in Curitiba, the Mayor of the city, Enrique Peñalosa was looking to implement an efficient transportation system but according to the financial capacity of the city, and then to analyze and visit other BRT implemented in Brazil and Ecuador, he decided to implement a BRT system in Bogotá.

The positive results reached with the Transmilenio system showed to the world that this system can be applied also in large cities and can be a valid alternative to other massive transportation system. Nowadays the Transmilenio in considered one of the best BRT systems in the world according to many studies and organizations, and is considered a pioneer of the BRT concept similar to Curitiba. As it's possible to see in the Figure 2.2, since the Transmilenio, the number of cities that implemented BRT systems, started to growth rapidly in the last years.

The Table 2.1 shows the history of the BRT concept following a time line that is divided by the origin of the concept and by the min innovation that boosted the expansion of the BRT system.

Table 2.1 - Innovation and Diffusion of BRT around the world (brtdata.org) [2]

Creation of the concept	First Innovation	First Diffusion	Main Innovation	Main Diffusion	
Chicago (1937)	Curitiba (1974)	Lima (1972)	Bogotá (2000)	Brisbane (2000)	Ecatepec (2010)
Lima (1972)		Curitiba (1974)		Rouen (2001)	Barranquilla (2010)
		Belo Horizonte (1975)		Utrecht (2001)	Sumaré (2010)
		Goiânia (1976)		Nancy (2001)	Bucaramanga (2010)
		Porto Alegre (1977)		Caen (2002)	Hefei (2010)
		Pittsburgh (1977)		Amsterdam (2002)	Nice (2010)
		São Paulo (1980)		Boston (2002)	Brampton (2010)
		Fortaleza (1980)		Helsinki (2003)	Londrina (2010)
		Recife (1982)		Seoul (2004)	Yancheng (2010)
		Ottawa (1983)		Jakarta (2004)	Zaozhuang (2010)
		Campinas (1986)		Beijing (2004)	Rio de Janeiro (2011)
		Adelaide (1986)		Edinburgh (2004)	Buenos Aires (2011)
		Campo Grande (1987)		Las Vegas (2004)	Urumqi (2011)
		São Paulo - Metropolitan area (1988)		Mexico City (2005)	Blumenau (2011)
		Paris (1993)		Olinda (2005)	Brasília (2011)
		Quito (1995)		Hamburg (2005)	Medellín (2011)
		Madrid (1995)		Los Angeles (2005)	Rosario (2012)
		Leeds (1995)		Santiago (2006)	Winnipeg (2012)
		Vancouver (1996)		Guayaquil (2006)	Yinchuan (2012)
		Dublin (1997)		Hangzhou (2006)	Caracas (2012)
		Taipei (1998)		León de los Aldama (2006)	Lanzhou (2013)
		Stockholm (1998)		Pereira (2006)	Puebla (2013)
		Kunming (1999)		Luton (2006)	Lahore (2013)
				Istanbul (2007)	Isfahan (2013)
				Guatemala (2007)	Barquisimeto (2013)
				Lorient (2007)	Nezahualcoyotl (2013)
				Merida (2007)	Haifa (2013)
				Tehran (2008)	Bhopal (2013)
				Cali (2008)	Chihuahua (2013)
				Changzhou (2008)	Juárez (2013)
				Xiamen (2008)	Indore (2013)
				Jinan (2008)	Belfort (2013)
				Lagos (2008)	Guarulhos (2013)
				New York (2008)	Belém (2014)
				Dalian (2008)	Córdoba (2014)
				Zhengzhou (2009)	Taichung (2014)
				Ahmedabad (2009)	Yichang (2015)
				Guadalajara (2009)	Islamabad - Rawalpindi (2015)
				Johannesburg (2009)	Pachuca (2015)
				Guangzhou (2010)	Uberaba (2015)
				João Pessoa (2010)	Pune - Primpi-Chinchwad (2015)
				Niterói (2010)	
				Ecatepec (2010)	

*Included only Busways and BRT systems that achieve at least a daily ridership of 30 000 passengers per day

During the last decades many new systems were implemented, some of them are enormous projects with also positive results, for instance the BRT systems implemented in Mexico City (2005), Istanbul (2007) and Guangzhou (2010). Although the successful results obtained in many BRT systems, there are also some cities which didn't' achieve positive results, this means, systems that are working but they are not achieving the results expected.

2.3. BRT SYSTEMS AROUND THE WORLD

The BRT concept has been studied by many authors and from different perspectives: institutional, social, economic, urban planning, technical and environmental perspective. Many authors agree on the fact that nowadays, the BRT concept is accepted as a viable solution for many cities with mobility problems (Mejia et al, 2013) [3].

Table 2.2 - BRT systems and Busways around the world [4]

	Number of Cities	Extension (km)	Passengers/day
Africa	3	83	262000
Asia	42	1489	9293372
Europe	58	944	2017347
Latin America	66	1789	20464549
North America	28	948	1043326
Oceania	6	96	430041
TOTAL	203	5347	33510635

As it is possible to notice in the Table 2.2, Latin America is the region with most cities that adopted either the busways improvements or a BRT system, and was in this region were the BRT systems had positive results. It is important to notice that the largest BRT systems were developed in regions with high density, large population and not large budgets, for this reason Latin America and Asia are the regions with the most passengers transported per day and with the largest kilometers of systems constructed.

2.4. THE SUCCESS OF BRT IN LATIN AMERICA

Since the 70's, Latin America was facing urban problems, because the region was suffering an accelerated population growth due in part to many people migrating from rural areas to the most relevant cities in their countries (Figure 2.3). So the capitals and other cities became larger and denser, putting pressure over the governors and planner to improve the infrastructure services, including the public transport.

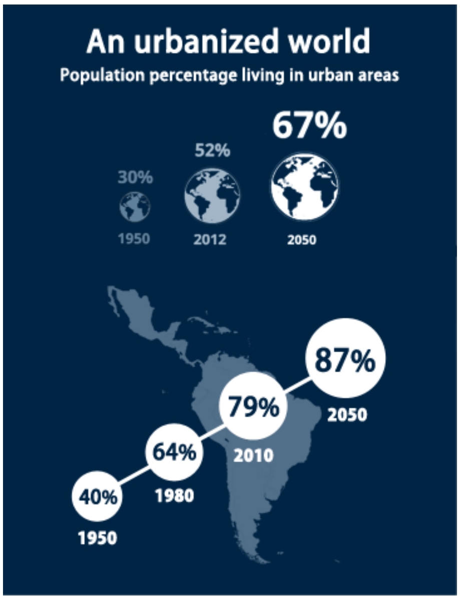


Fig.2.3 - Percentage of people living in urban areas [5]

According to the BID (Banco Interamericano de Desarrollo), this trend continues and is expected that inside 35 years, around 9 of about 10 persons will live in urban areas (Figure 2.3). So, the challenges related to transportation in this region had some differences with the urban context of cities in developed countries, which have less dense urban areas.

A study elaborated by the CEPAL [6] noticed that during the last decades, the factors that put pressure over the mobility management in the Latin America cities were: Disorganized urban expansion, fast growth of private vehicles, congestion and the low quality of the public service, managed by private syndicates of operators.

There was an increasing need to provide quality transport infrastructure, and despite some cities that already implemented metro systems, there were many other cities with not so large budgets but with the same problems and those cities could not wait many years to get the needed funds to implement an LRT or a Metro When the BRT system was implemented in Curitiba, the major Jaime Lerner said: “When you have little money, you learn to be creative” [7].

2.4.1. Pioneer Latin American cities

Many important and successful BRT systems are located in Latin America, and some of the cities in the region are considered the pioneers of the this system, specially Curitiba and Bogotá, because the first that implemented a BRT system in the world was Curitiba and because of the good results of the system implemented in Bogota, the BRT concept was accepted as valid massive transportation system, not only for medium cities but also for large metropolis like Bogotá.

There is an important factor of the success in these cities, in both cases their Mayors and their respective teams studied the options and they decide to take the risk to implement a new system that was not implemented before (Curitiba) or that was not implemented with such large magnitude (Bogotá). The BRT planning guide of the ITDP [7], notices the next about this situation: *“Both former Mayor Enrique Peñalosa of Bogotá and former Mayor Jaime Lerner of Curitiba came to office with a strong intent to improve public space and transport. They also possessed a base knowledge on these topics and brought with them highly trained professionals as their core staff”*

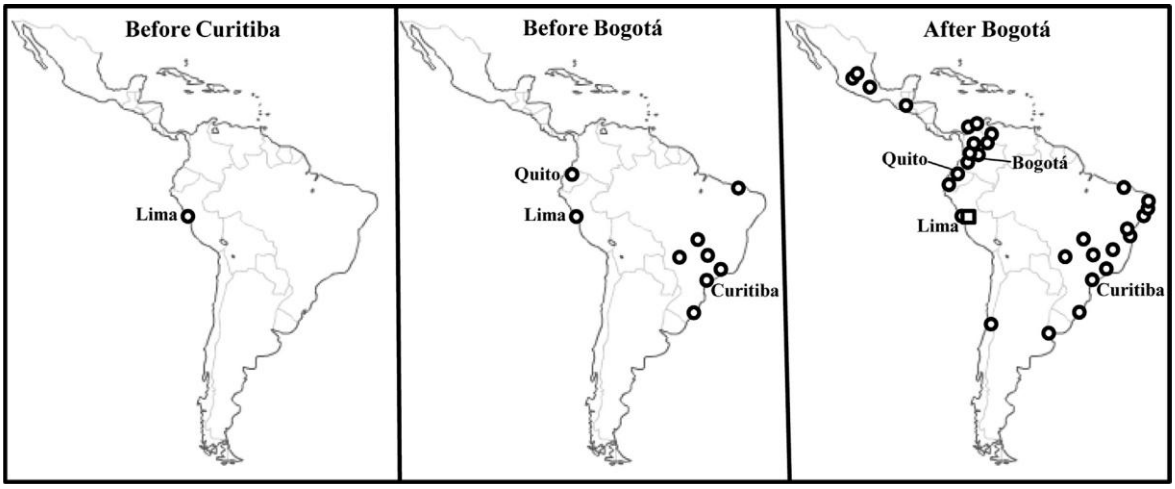


Fig.2.4 - BRT projects in Latin America in 2011 [3]

*Lima has two markers, representing both its condition as a pioneer of prioritized public transport and its implementation of BRT in 2010.

Some authors like Mejia et al (2013) [3] remark that other cities were also pioneers of the BRT systems with their own contribution to the development of this concept (Figure 2.4). In 1972, before the implementation of the BRT in Curitiba, the city of Lima (Peru) opened the first busway in Latin America, named “Via Expresa”, a basic segregated lane dedicated for public transport. This busway was not considered a BRT but was close to reach that tittle, and in 2010, then to do some improvements to this busway, the system was converted to a BRT system. In 1960, Quito (Ecuador) implemented a BRT system, but the vehicles used there were trolley-buses that worked with electricity. In this way Quito did a contribution to the concept adopting this new system but at the same time showing the flexibility of the system.

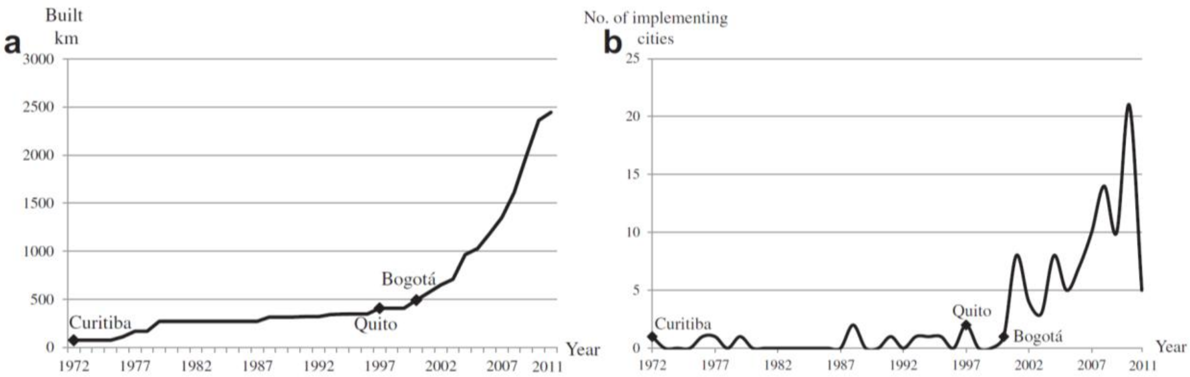


Fig.2.5 - The impact of the Latin America cites in the expansion of the BRT concept [3]

Lima and Quito did their own contributions to the concept but they didn’t such a positive impact as it’s possible to appreciate in the Figure.2.5 and was Bogotá the city that boosted the expansion of the BRT concept.

2.4.2. BRT VERSUS RAIL BASED SYSTEMS IN LATIN AMERICA

During the century XX, important cities of the region did the effort to implement metro systems, sometimes very expensive and brought debts due the high cost of the system and also due to the operational costs. The most relevant cases of metro systems in the region are Buenos Aires (1913), Mexico City (1968), São Paulo (1974), Santiago (1975), Rio de Janeiro (1979), Caracas (1983) and

Medellin (1995). In general, these systems had positive results and some of them achieved very good performance like São Paulo and Santiago, but since the 80’s the popularity of metro decreased because many cities could not implement this expensive systems when in the region there were other needs like health or education which also needed investment. One obstacle in the region is the lack of national technologies to implement these systems.

Although that Latin America is a main promoter of the BRT concept, during the last few years the Rail based systems are recovering the popularity they lost for some decades. Some cities like Bogotá and Quito, that already implemented successful BRT systems, are looking to implement metro systems also. Other cities are trying to expand their current metro systems, like Buenos Aires, Santiago and Lima. About the LRT systems, there are few examples of this kind of system in the region.

3
CHARACTERISTICS OF THE BRT SYSTEM AND COMPARISON WITH OTHER TRANSPORTATION SYSTEMS

3.1. INTRODUCTION

There is a lack of consensus related to an official definition of the BRT system, due in part to the flexibility of the system. Nowadays, there are a considerable number of systems implemented but although all they have the same main characteristics there are some differences in how each one of those systems were implemented. For instance, the buses normally work with fuel, but in other cases the vehicles are trolley-buses adapted to the system. In the most of the cases the busways are located on the surface, but in some specific cases there are underground sections like in a metro system. Some systems were intended to be the largest transport mode of the city, and other situations the BRT systems were created as a complement to a rail based system. Some systems are large and complex network of corridor with high capacity vehicles (bi-articulated buses) and two corridors for each direction; instead other systems are smaller and simpler with just one lane per direction and with vehicles of lower capacity. These are some differences noticed during the study of different cases but the concept still being the same.

3.2. DESCRIPTION OF THE BRTSYSTEMS

3.2.1. DEFINITION ON THE BRT CONCEPT

Some authors defined a BRT (Bus Rapid Transit) system as *"a flexible, rubber-tired rapid-transit mode that combines stations, vehicles, services, running ways, and Intelligent Transportation System (ITS) elements into an integrated system with a strong positive identity that evokes a unique image"* (Levinson et al., 2003, p. 12) [8] or BRT as a *"rapid mode of transportation that can combine the quality of rail transit and the flexibility of buses"* (Thomas, 2001) [9].

Probably the most complete definition is the one made by the ITDP in its BRT Planning Guide, published in 2007: "*Bus Rapid Transit (BRT) is a high-quality bus-based transit system that delivers fast, comfortable, and cost-efective urban mobility through the provision of segregated right-of-way infrastructure, rapid and frequent operations, and excellence in marketing and customer service. BRT essentially emulates the performance and amenity characteristics of a modern rail-based transit system but at a fraction of the cost."* [7]

According to the complexity of the system the BRT could be considered as lite, standard or full system, as it is possible to see in the Figures 3.1 and 3.2.

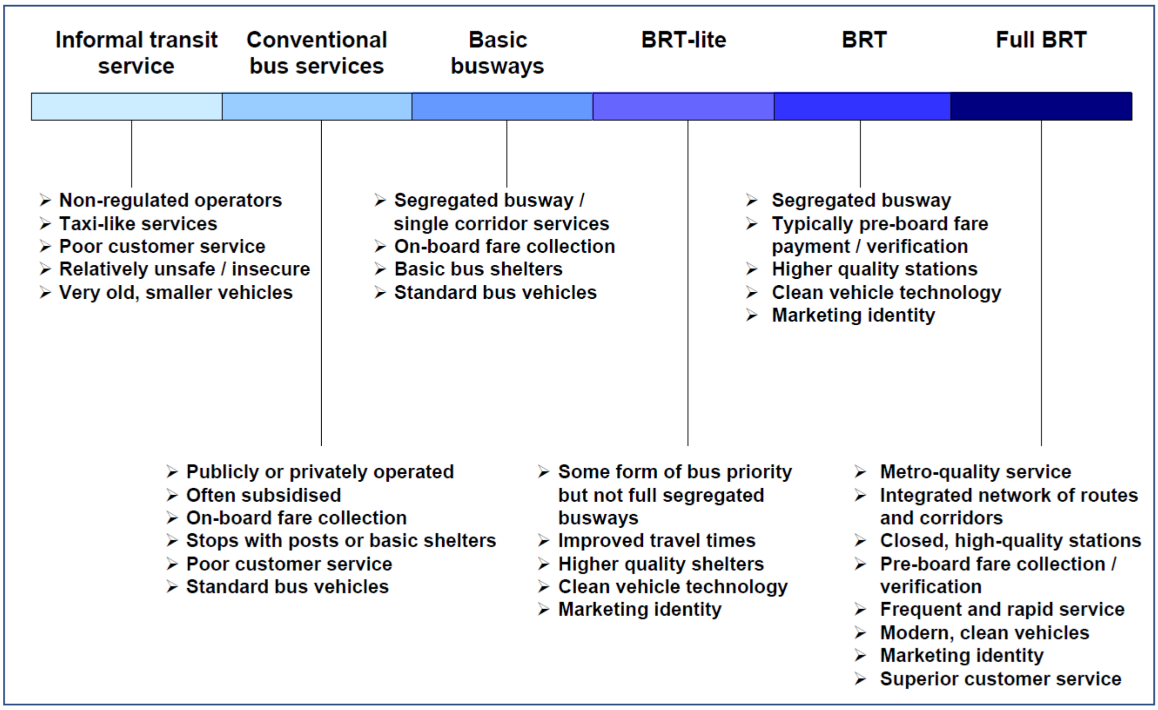


Fig.3.1 – From informal bus services to full BRT systems [7]

In this classification range it is important to notice the difference between a busway and a BRT lite. A busways consists in a segregated corridor for buses but with the characteristics of a conventional bus service (on board fare collection and basic bus shelters) but if a system or corridor want to be categorized as a BRT, they need to provide better service and achieve higher performance (vehicles with more capacity, speed, time travel) this means, better stations, pre-board fare collection and real time information of the system.

BRT-Lite in Rouen (France)
www.citytransport.info [10]

BRT-Estándar in Mexico City (Mexico)
www.obrasweb.mx [11]

Full BRT in Curitiba (Brazil)
www.brtdata.org [2]

Fig.3.2 – From BRT Lite to Full BRT systems

3.2.2. What is not a BRT?

As the BRT became famous worldwide just some years ago and due to the wheel based vehicles used in the system, the BRT could be wrongly considered as an improved version of the conventional bus service, but in the reality the BRT performance is closer to an LRT system rather than to the conventional bus services.

It is important to notice another concept found in the literature and is the BHLS term which means "Buses of High Level of Service" and this concept was introduced by European authors around two decades ago to refer to the European applications of enhanced bus services rather than to refer to a BRT system (Finn et al., 2011) [12]. Actually, this term could refer to a different variety of improved bus services but which don't accomplish the requirements or the performance needed to be considered a BRT system. For instance the "Basic busways" of the range classification made by the ITDP in the Figure 3.1, could be considered as BHLS.

It is important to remark that a BRT system is not an "enhanced bus service", and the results obtained in many systems around the world demonstrate that the BRT concept is a massive transportation system, and a valid alternative to the rail based systems. A conventional or an enhanced bus service could not reach the values showed in the next table:

Table 3.1 - Maximum values reached by the BRT systems (Hidalgo and Gutiérrez, 2013) [13]

Maximum values for some performance indicators in selected BRT systems.

Performance indicator	Definition	Value (year)	System, city	System features
Commercial speed	Distance/time as perceived by the user on board (km/h)	42 km/h (2011)	Metrobüs, Istanbul, Turkey	Fully segregated busway on expressway, stations every 1.1 km
Peak section load	Passengers/hour/direction (pphpd)	45,000 pphpd (2011)	TransMilenio, Bogotá, Colombia	Median busway, level access stations with 5 platforms, overtaking lanes and combined services – local, express, 7 standees per square meter, dense urban area
Infrastructure productivity	Passenger boardings/ km of busway	35,800 (2011)	Guangzhou BRT, China	Median busway, with long station, overtaking lanes, open operation 40 routes, very dense urban area
Capital productivity	Passenger boardings/bus/day	3100 (2010)	Macrobús, Guadalajara, México	Median busway, overtaking lanes relatively dense, mixed use urban area
Operational productivity	Passenger boardings/bus-km	13.2 (2010)	Metrovía, Guayaquil, Ecuador	Median busway, dense urban area, very low fare (USD 0.25 per trip)

Source: Hidalgo (in press).

3.3. COMPONENTS OF A BRT SYSTEM

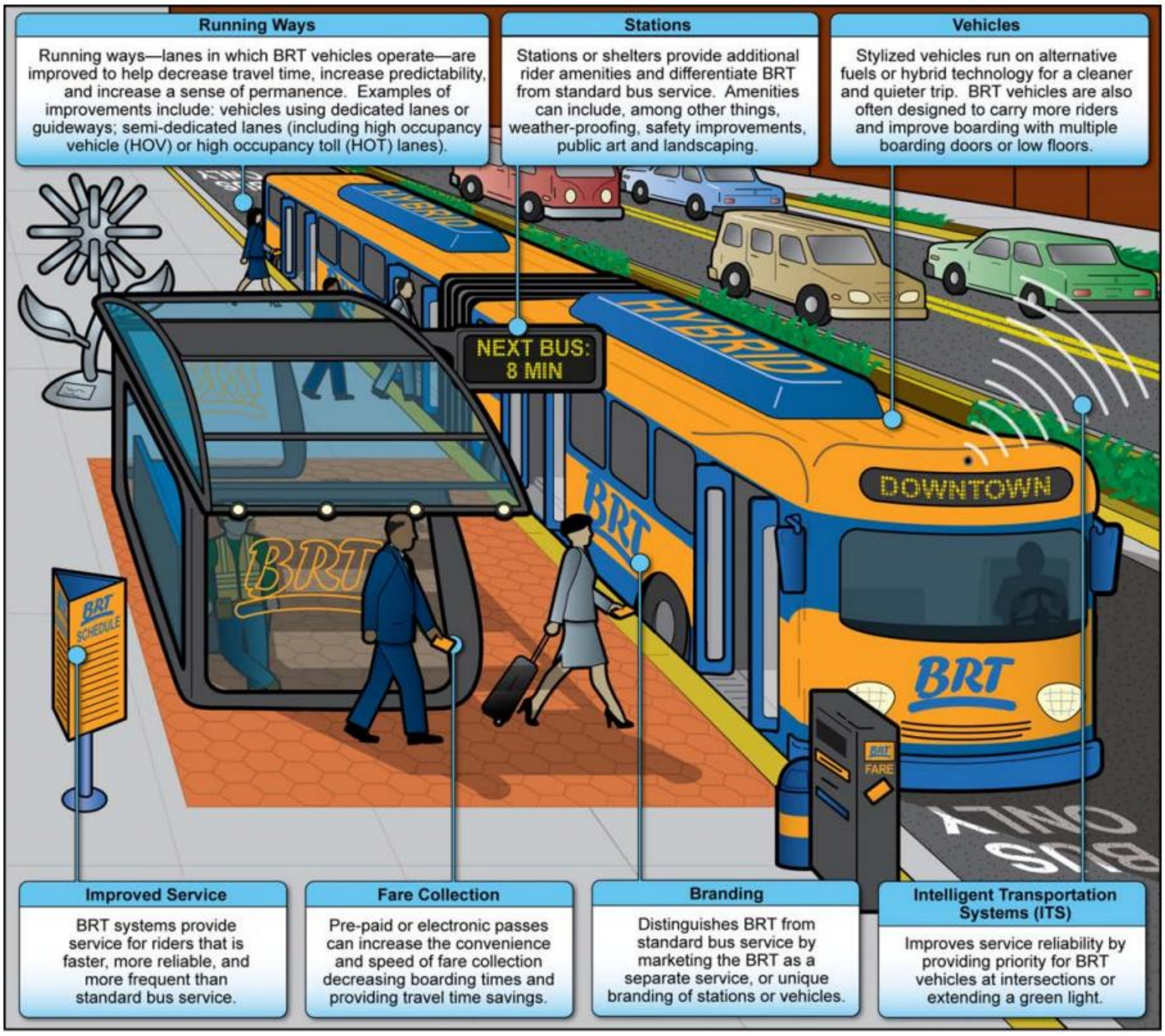


Fig.3.3 – BRT Elements (US-GAO, 2012) [14]

The BRT was implemented in different parts of the world and despite of some specific differences in how some systems were adapted to their cities, in general they keep the similar elements of the BRT concept. The main elements of a BRT system are:

- Exclusive corridors or running ways
- Stations
- Vehicles
- Off-Board fare collection and ticket validation
- Intelligent Transportation Systems (ITS)
- Branding and marketing strategy
- Improved service

3.3.1. Exclusive corridors or running ways

The design of the corridors (type, material, location and size) is an important factor that influences the cost, performance and success of the systems.

3.3.1.1. Separation from the rest of the traffic

To achieve better performance the corridors must be dedicated exclusively to the buses and preferably should be physically segregated from the rest of the traffic. As it is possible to see in the Figure 3.4, the separation from the rest of the traffic could be physical (Busways) or could be just demarcated on the surface of the corridor (Bus-lanes).

A BRT Bus-lane (New York) (www.transportnexus.com) [15]

A BRT Busway (Istanbul) (www.brtdata.org) [2]

Fig.3.4 – Bus lane and Busway

The busways are more secure than the bus lanes but also more expensive and this physical separation could be achieved with a line of blocks, cones, metal fencing or even walls in order to not let other vehicles enter to the corridor. For the case of bus-lanes in the most of the cases, paint over the lane and traffic signs are enough to demark the segregation of that lane. These bus-lanes are less safe than the busways but could be more useful in some situations, for instance in many systems some other special vehicles could enter to this lane in special circumstances, like the ambulance or firefighters.

3.3.1.2. Materials

Normally the construction of the corridors is the most expensive part of the implementation stage and they represent around 50 percent of the infrastructure costs. The type of material used in the corridor is directly linked with the cost of the construction and maintenance of the system. A low quality material could reduce the construction cost but also could increment the maintenance cost.

As the system use high capacity vehicles the weight in their axes is also high, for this reason the kind of pavement used in these systems should be strong enough to resist these large loads, especially in the stations where the acceleration and deceleration have a higher impact on the surface but also because in the stations the road must keep their depth to permit the “at-level boarding”, a mandatory requirement for any massive transportation system.

Considering the maintenance times, the concrete tends to be a better option than asphalt although this is more expensive. The concrete can work in good conditions ten or more years with just little maintenance and the asphalt normally needs resurfacing more often, especially in tropical regions. According to the BRT planning guide (2007) a good option could be the use of concrete at stations, where the surface need to be stronger and then use asphalt on the rest of corridor.

3.3.1.3. Configuration and size

The corridor could have just one lane for both directions, one lane per direction and even two lanes for each direction. In this last case, the system present an advantage compared with the rail based systems, because with two lanes per direction, the system can offer regular and express services simultaneously and also can avoid complete interruptions of the system.

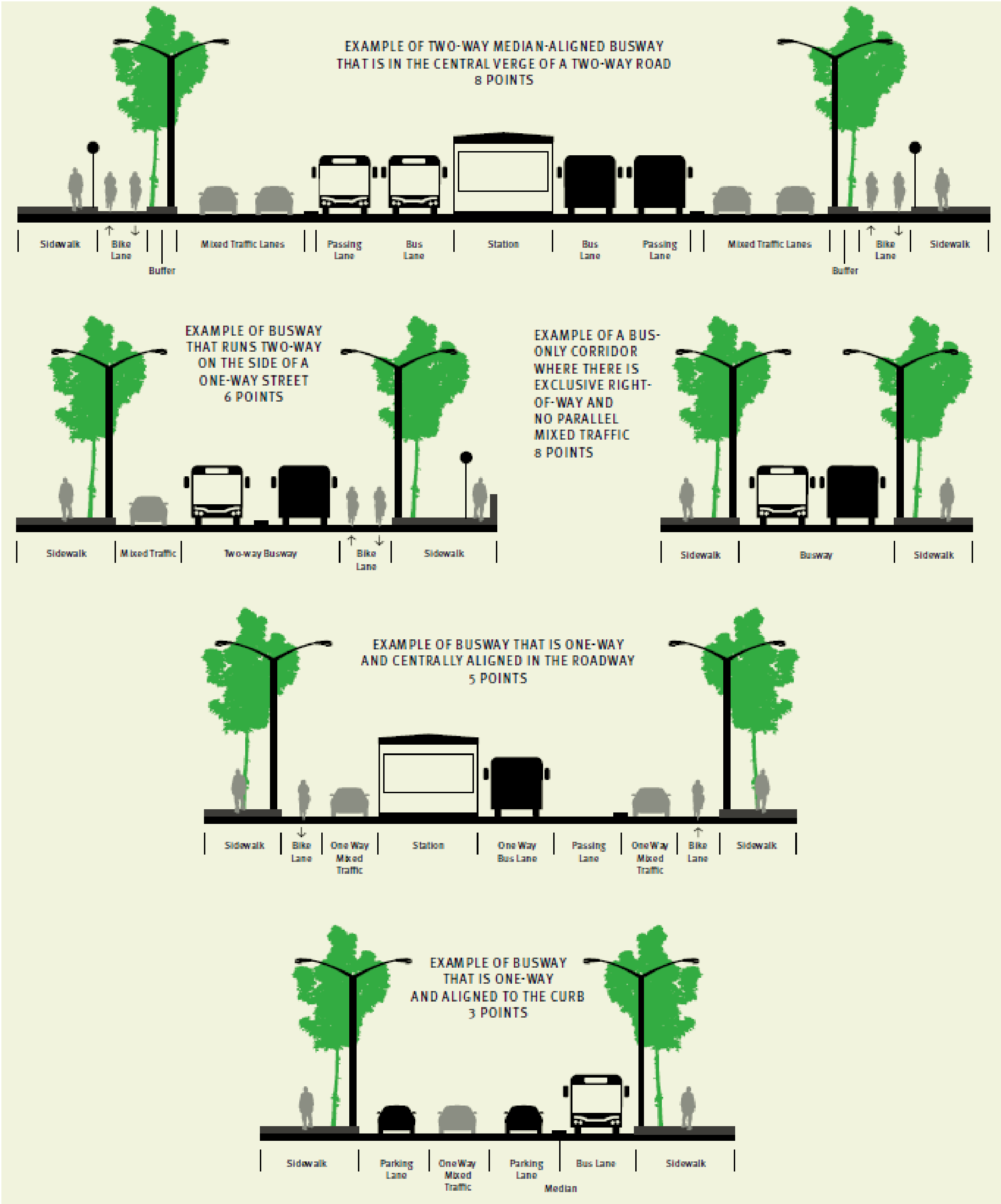


Fig.3.5 - Different corridor configurations [16]

Normally each lane requires 3.5 meters of width and the stations need from 2.5 to 5 meters according to the capacity of the system, so a busway with one lane per direction need around 10 meters of width and a more complex corridor with two lanes per direction normally require around 20 meters. The total width sometimes is reduced around 1 meter per direction removing the physical barrier that separates the BRT vehicles from the rest of the traffic.

3.3.1.4. Location

In superficial systems like BRT and LRT, the places where the corridors are going to be implemented are very important because of the impact they will produce over the urban sprawl. The built environment restricts the size of some corridors, especially in historical centers. The construction of wide corridors in narrow and dense roads could mean a considerable impact for the urban life of a city but also could mean a considerable increment in the cost of the project due to the expropriation and compensation.

On the other hand a network planned efficiently could contribute to transit oriented development along the corridors as occurred in Curitiba and Bogotá, where the development reached along the corridors is considerable.

3.3.2. STATIONS

The stations of a BRT system are located on the surface and are similar to the stations of a LRT system. The stations have the next elements:

- Pre-board fare collection and fare verification devices: Similarly to any massive transit system, the machines for the payment and the verification of the tickets are located in the stations
- Platform level boarding: The platforms are designed to have the same height as the vehicle floor in order to reduce the boarding time but also with the objective to let the access of people in wheelchair, strollers, children and the elderly.
- Signpost and system information: The information is physically distributed around the station (maps, routes, schedules and travel times). The station also has a size placard or a signpost identifying the name of the station and normally is located above the station to be easily recognized from distance.
- Real time data: Panel or screens which provide real time information as the waiting times, arrivals and departures or some announcements in special circumstances.
- Protection from weather: The stations normally have a roof to protect customers against rain or snow.

At-level boarding (Santiago)

Access barriers (Guangzhou)

Real time information (New York)

Signpost (Cali)

Closed station (Guadalajara)

Fig.3.6 - Elements of a BRT station [2]

The size and capacity of the station depends of the configuration of the system, for instance the transfer stations (where is possible to change the line or route) are larger because they receive more users than a simple station. The sizing and design of the station also depends of the projected number of passengers, especially in peak hours, for this reason the stations are larger in high demand corridors, especially in trunk lines with normal and express services (two bus-lanes for each direction).

The stations can be closed or opened. The first option use to be more applied in places with medium and low temperatures and also in this type of station is easier to control the fare payment through the use of access barriers at the entrances. On the other hand the opened stations are a good solution for warm regions with elevated temperatures but at the same time they are more vulnerable to fare evasion. Normally the style of the BRT station tries to distinguish them from the stations of other transportation systems and for that reason in some cities, the stations were designed with local architectural style.

3.3.3. Vehicles

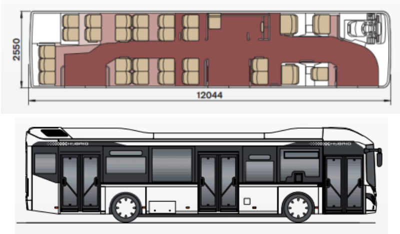
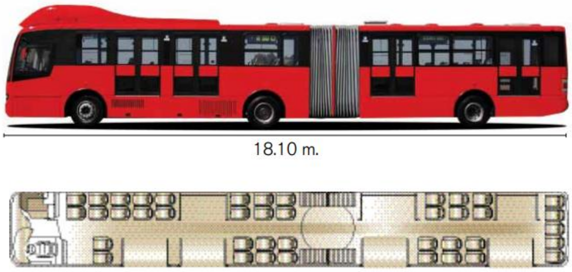
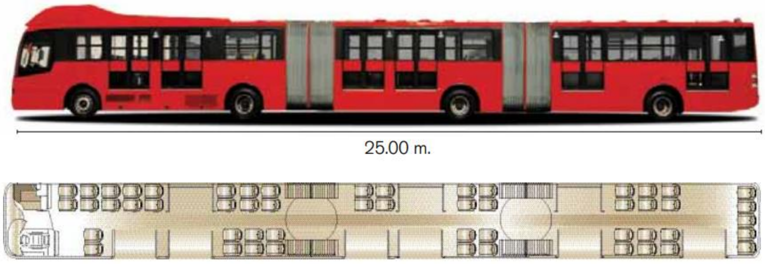
In general, the vehicles of a BRT system are larger buses with higher capacities than the conventional buses but there are also systems (with little demand) that use the standard buses with two axes. According to the BRT planning guide the vehicles or buses used in the system are:

Table 3.2 – Vehicles and their characteristics [7]

Vehicle Type	Vehicle Length (meters)	Number of axis	Capacity (Passengers per vehicle)
Standard	12	2	60 - 80
Articulated	18.5	3	120 - 170
Bi-articulated	24	4	240 - 270

The size of vehicle adopted for the system depends of many factors like the operational cost, projected number of passengers, frequency of the service and others. The most used vehicle in BRT systems is the articulated bus (18.5 meters length) because this vehicle is enough to reach a balanced and positive performance translated in travel times, short waiting times, efficient frequency, and also permits easy access and exit from the vehicles in the stations.

Table 3.3 - Different models produced by Volvo [17]

	Type: Standard Model: Volvo 7900 Hybrid Fuel: Diesel and electricity Capacity Seated: 32 Capacity Standing: 70 Wheelchair: 1
	Type: Articulated Model: Volvo 7300 Fuel: Diesel Capacity Seated: 41 Capacity Standing: 119 Wheelchair: 1
	Type: Bi-articulated Model: Volvo 7300 Fuel: Diesel Capacity Seated: 53 Capacity Standing: 187 Wheelchair: 1

According to the Volvo technic specifications, the 7300 bi-articulated bus can replace around 225 private vehicles. Due to their high capacity (Table 3.3), larger vehicles use to work efficiently in main corridors with high passengers demand and also permit a reduction in operating costs like the driver costs, but in lower demand routes the use of these larger buses means a lower frequency and therefore, longer waiting times. Also it is important to notice that only few companies produce the bi-articulated buses. For all these reasons explained the bi-articulated vehicles are being used just in important corridors of few systems.

The type of fuel used depends of the own reality of each city, for instance the lack of a specific fuel or energy can boost the use of other alternative. Electric and diesel motors are the most used in the buses but there are also other options than could be used to propel the vehicles as the oil natural gas, bio-fuels or hydrogen.

3.3.4. Off-board fare collection and ticket validation

Fare collection refers to the payment of the tickets and fare validation is the process of checking if a customer paid for the ticket. The BRT fare structure and the technologies used for the collection and verification are the same used in the rails based systems (LRT and Metro), differencing the BRT from the conventional bus services. There are many variables in the way that a system collect and validate the fares and they are represented in the next graphic:

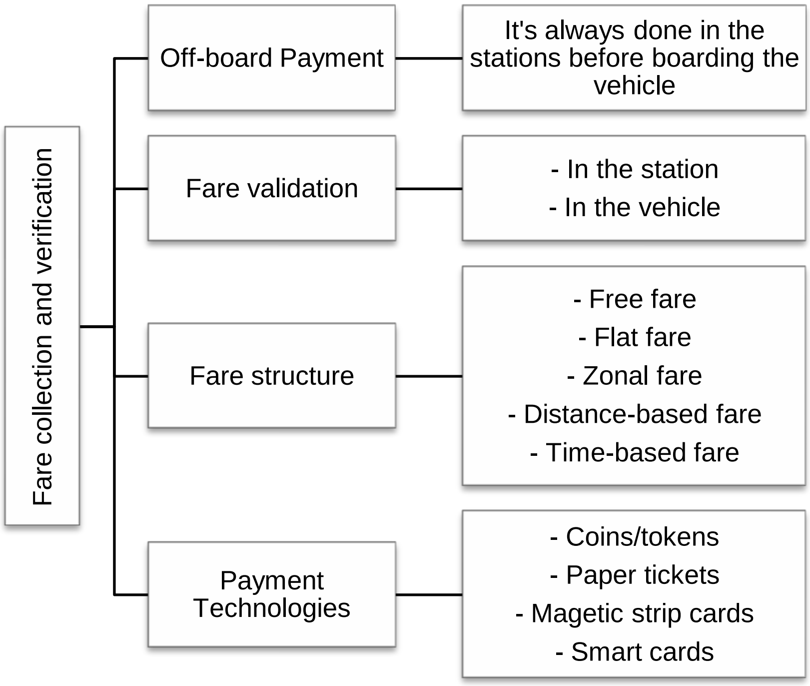


Fig.3.7 - Features of the fare collection and verification (adapted from BRT planning guide, 2007) [7]

Similar to other massive transportation systems, the fare must be paid outside the vehicles before boarding to let many people enter to the vehicles in a short time and avoiding the delays generated by the on-board payment, so an efficient fare collection is fundamental to achieve a positive performance similar to the rail based systems. The best systems has both, the fare payment and validation outside in the station and both are done before boarding but some systems with open stations prefer to do the payment of the ticket in the station and do the verification inside the vehicles due the fact that open stations are more vulnerable to the fare evasion. This verification system inside the vehicle is made with verification devices or is made by public transport staff, which can impose penalties to the customers that avoid the fare payment.

Fare payment machine (Las vegas)

Ticket office (Bogotá)


Off-board fare validation (Cali)

Validation inside bus (Santiago)

Fig.3.8 – Fare collection and validation [2]

Typically for the fare collection are used machines that let the user to do the payment through cash or bank card, but there are also other ways to pay the tickets and in the largest stations of many BRT systems there are ticket offices for this purpose (Figure 3.8). In some cities with many transportation modes, the fares are integrated and through the use of a card (normally magnetic or smart cards) a person who paid some amount of money, can use this card to access to a BRT, metro, train, bus or any other system also integrated.

3.3.5. Intelligent Transportation Systems (ITS)

This term refers to all the communication and information technologies used in the BRT systems to ensure a high quality service for the customers. This is a very important component of any massive transportation system, included the BRT because this technologies permit to any system to reach high efficiency levels. In the BRT systems the ITS is implemented in three areas and they are:

3.3.5.1. Control centers

The BRT control centers are needed to make a real time management of the system and its elements, in order to ensure an efficient service. The control and tracking of the vehicles along the different routes is made through Automated Vehicle Location (AVL) and with this tool the control centers manage the different operations and eventual situations that could happen to the system.

For the AVL, the Geographical Positioning Satellite (GPS) is the technology most used in the BRT systems because these devices can provide real time information of the vehicles as their situation or location with high precision. The TransMilenio system has a positive performance due in part to the application of GPS combined with wireless communication.

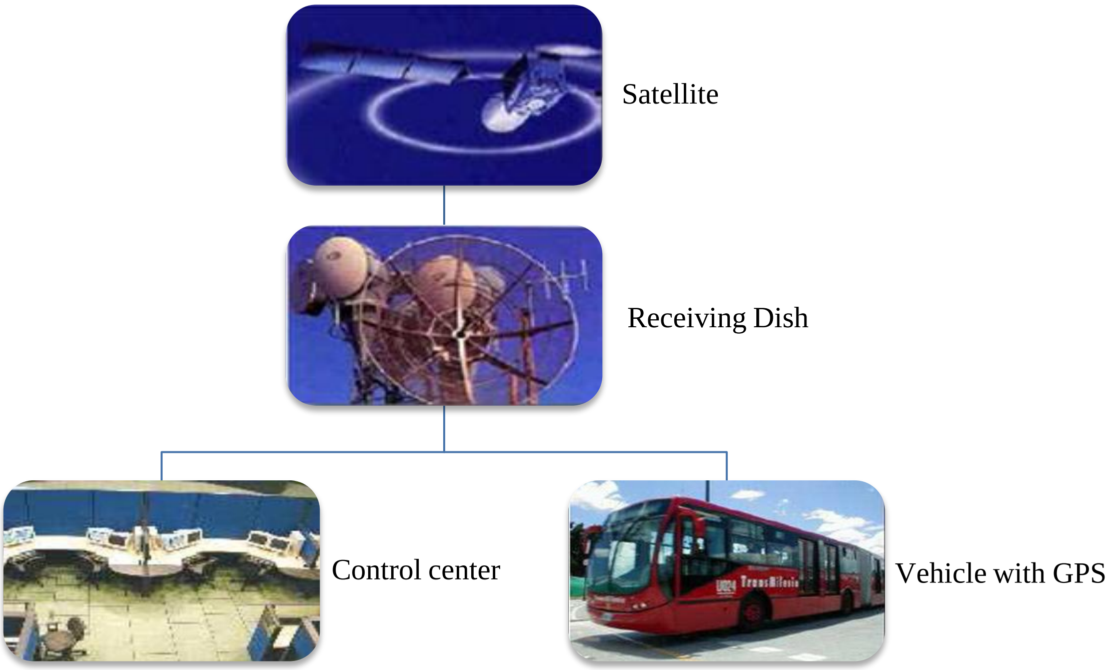


Fig.3.9 - TransMilenio's Automated Vehicle Location (AVL) [7]

Even GPS is the most popular technology used for AVL, there are also other non-satellite based options adopted by different systems as the infrared technology, especially in places without high quality satellite based communications. On BRT lite systems a radio or a mobile phone can be enough to provide information of the vehicles.

3.3.5.2. Traffic signal control

In a BRT system, the intersections are the most problematic part of the corridors because in those points the BRT vehicles interact with the rest of traffic and for this reason is required an adequate design of the intersections to permit the system achieve the expected performance. The BRT systems use the traffic signal control to give priority to the BRT vehicles at intersections, and this signal control could be passive or active.

The passive signal priority is the control of the regular traffic signal applied to give priority to a BRT corridor above other streets or avenues or sometimes is implemented to give priority to a BRT lane from the rest of traffic inside the same corridor. In general this priority is reached through the extension of the green light times and the shortening of the red light times for a BRT corridor that is crossing some streets. This kind of prioritization is used in the less congested intersections of high frequency BRT corridors (2,5 or less minutes).

On the other hand, systems with high AVL efficiency prefer the active signal priority which refers to the real time adjustment of the traffic signals to give priority to the BRT corridors and normally this is reached using electronic devices able to identify when a BRT vehicle is close to an intersection and automatically adjust the traffic signal to permit the BRT vehicles to cross the intersection. This kind of control is often used in developed regions as US and Europe, in corridors with low frequency (5 or more minutes) and with considerable number of intersections. The active control doesn't work efficiently in corridors with high frequencies because the rest of the traffic could be affected producing many stops especially in peak hours.

3.3.5.3. Real time information displays

The BRT systems use displays or devices in the stations to inform about the available routes, waiting times or eventual situations like line modifications, instructions, incidents and delays. Normally these displays are located inside the stations, in a high place (Figure 3.10) but some systems also provide displays outside the stations reaching a more controlled movement in the stations.

Fig.3.10 - Display showing the waiting times in the TVM of Paris [2]

The devices or displays inside the vehicles also provide real time information as the next stations to arrive or the destination route. Nowadays a BRT system provide also real information in electronic devices as the mobile phones, tables and others, trough internet and applications for those devices.

3.3.6. BRANDING AND MARKETING STRATEGY

In general the conventional bus service has a negative image, especially in developing countries and this is an obstacle that faced the BRT systems, because even they use larger and more efficient buses, the population can relate these vehicles with the conventional bus service. It is for that reason that cities where it was implemented a new BRT system, there was also an effective branding and marketing strategy to explain this new system to the population and also to explain them the benefits of the project.

With the branding, a BRT system can distinguish from the other public transport systems existing in the public transport network. Successful BRT systems had created a strong identity with an own name, slogan and logo that shows the new system as a high quality reaching the users' acceptation. The BRT systems that reached high performance became a symbol in their cities. The name, logo and slogan are physical visible along the system in the vehicles, stations and offices providing instant recognition of the system (Figure 3.11).

Fig.3.11 - Branding of VIVA BRT system in York region, Canada [18]

With the different marketing strategies, a BRT system basically tries to increase the people's interest on the project, and answer questions and concerns about the operation of the system. These strategies are implemented constantly and not only at the beginning of the project.

3.3.7. Improved service

The most elements of the BRT systems already explained are important features that are not present in the conventional bus services and they permit to a BRT system to offer an improved service as the other massive transportation systems can offer. With the previous description of the system, it is possible to suggest that the BRT systems are more similar to the rail based systems (LRT and Metro) than to the conventional bus services.

There are also other elements that the conventional bus services normally don't offer, for instance, the participation of customer trough call centers. In the most successful BRT projects the customer satisfaction and acceptation was an important key for their success.

3.4. Comparison with other massive transportation systems

The advantages and disadvantages of the different transportation systems are visible when the systems are compared. In this part of the work, there will be a comparison between the BRT, the LRT and Metro to notice the most important differences of this relatively new system with these rail based systems. The conventional bus system will be compared also in order to demonstrate that the BRT is a valid massive transit alternative and not an improved bus service.

Table 3.4 - Factors in choosing a transportation system (adapted from BRT planning guide,2007) [7]

Category	Factor
Cost	***Capital costs*** ***Operation costs*** Planning costs
Planning and Management	***Planning and implementation time*** Management and administration
Design	Scalability ***Flexibility*** Diversity versus homogeneity
Performance	***Capacity*** ***Travel time/speed*** Service frequency Reliability Comfort Safety Customer service ***Image and perception***
Impacts	Economic impact Social impact Environmental impact ***Urban impact***

There are many factors to consider at the moment to choose a transportation system and different authors use a different range of variables. These massive transit systems have many common characteristics and for the comparison of the different systems, we selected the most relevant factors of this list (Table 3.4) in order to identify the main differences or similarities between the systems.

3.4.1. Construction costs

In this aspect the BRT systems stand out, because the BRT options are much cheaper than the rail based systems. In fact, the low implementation cost of the BRT systems is the most notable difference with the other massive systems. There is not an exact relationship about the cost between costs of BRT and rail based systems because each system have a wide range of projects implemented in different contexts with different complexity also.

- BRT = from 0,5 USD million to 15 USD million per kilometer
- LRT or Tram= from 13 USD million to 40 USD million per kilometer
- Metro = from 45 USD million to 350 USD million per kilometer
- Conventional Bus service = Less than 0,5 USD million per kilometer

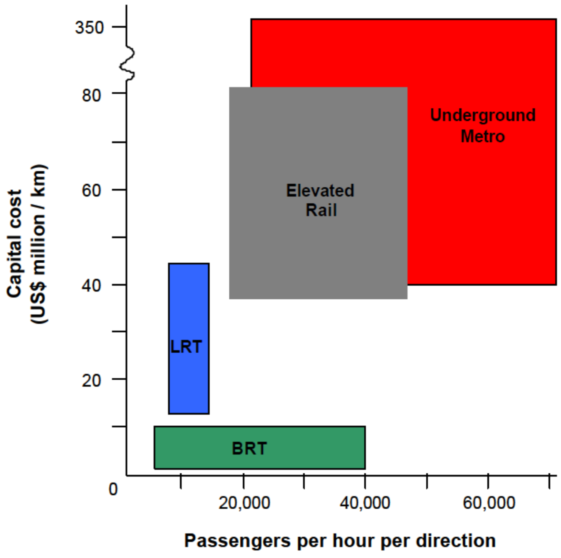


Fig.3.12 - Passengers capacity and capital costs (BRT planning guide, 2007) [7]

The BRT planning guide (2007) establish that a BRT system cost is between 4 to 20 times less than a LRT (Tram) and between 10 to 100 times less than a metro system, but it is important to notice that this proportions are just estimations. In a document elaborated by the UN and the CEPAL in 2009, the author Carlos Pardo [19] notices that the cost comparison between a BRT and the rail alternatives can vary according to the focus of the planners.

Medium values are closer to the real capital costs, for instance in the case of Bangkok, hypothetical implementation cases for each system were projected with the same budget of 1 USD billion and the results were:

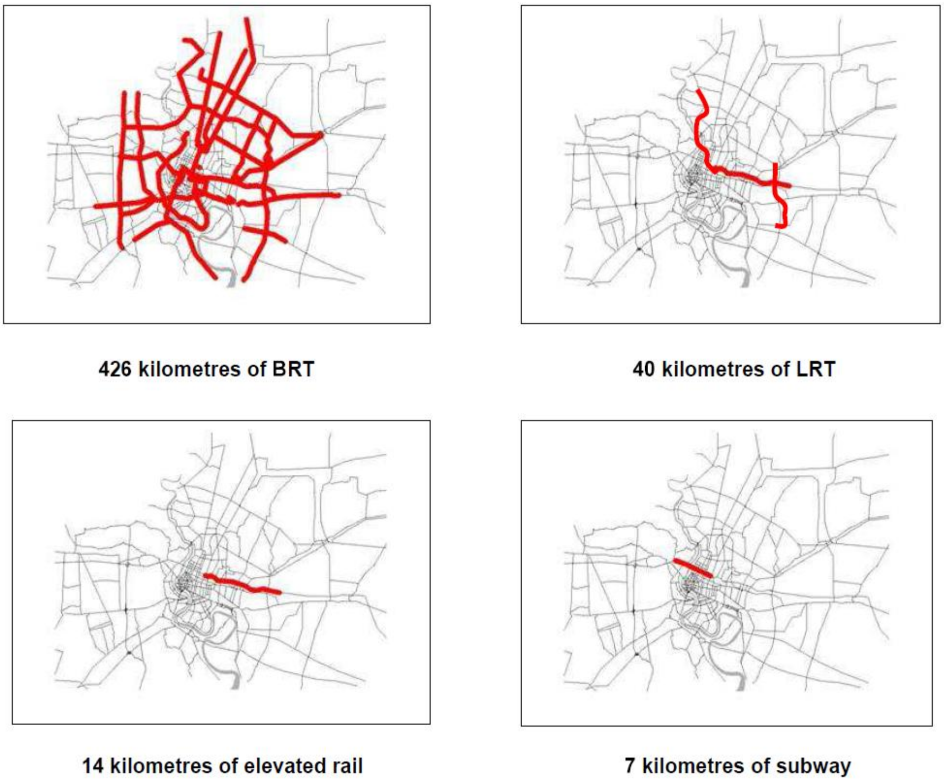


Fig.3.13 - Hypothetical implementation of different systems in Bangkok using the same budget [7]

So the BRT cost proportions of 1:20 and 1:100 times less LRT and Metro respectively are just reached when is compared a single BRT (implemented in optimal circumstances over preexisting infrastructure) with complex and large projects of rail based systems. And the opposite proportion values are reached comparing the costs of complex and full BRT systems with rails based systems implemented in favorable conditions with the lowest possible costs. Finally, it is reasonable and logic to affirm than a BRT system is at least 4 times cheaper than a LRT system and at least 10 times cheaper than a Metro system.

3.4.2. Operation costs and subsidies

Once the system begins to operate there are new costs that must be covered for the continuity of the system and the most relevant are:

- Vehicle depreciation
- Maintenance of vehicles and spare parts
- Maintenance of infrastructure
- Energy/fuel
- Salaries of the employees (drivers, administrative, maintenance, security and others)
- Employees benefits (insurances, compensations and others)

Almost all the rail based systems require subsidies to cover operation costs, but most of the BRT systems do not require subsidies and the fare revenue is enough to cover the operating costs, generating profits in some cases. The operation companies of LRT systems have more problems to self-subsist than the BRT operation companies (CEPAL, 2003) [20]. Normally the subsidies come from the municipalities' budget or taxes revenues, consuming funds needed for other development areas.

The rail vehicles use to be more expensive than the BRT vehicles (Table 3.5), especially in regions without own rail technologies production like South America, but at the same time, tram and metro vehicles use to have a longer lifetime (around 50 years) than the buses (around 20 years), so the difference tend to be lower.

Table 3.5 - Acquisition and maintenance cost of vehicles (adapted from CEPAL,2003) [20]

	LRT vehicle	Articulated bus (diesel)
Initial cost (Euros)	2 000 000	300 000
Annual maintenance cost (Euros)	19 000	7 400

Some of these operational costs are similar in the different systems because they have similar institutional organization and similar contracted staff (operational, maintenance, fare collection, administration and others). In some cases the LRT can reduce the operational costs in the number of drivers thanks to multiple rail vehicles that can be operated by one driver. This benefit tend to be more notorious in developed countries where the employees have higher salaries but even with this benefit some LRT still require subsidies, especially when they have low demand.

For a BRT system, the costs of road maintenance normally are covered with the budget destined to general maintenance of the road network of the city, while the rail maintenance costs are normally covered with subsidies.

3.4.3. Planning and implementation time

The time and the cost required for the design and planning of are shorter in BRT systems than in rail based systems, considering networks with similar size and complexity (Table 3.6). In a BRT system the time required for the design use to be from 12 to 18 months and the planning costs are between $1 million to $3 million; on the other hand a rail based system requires between 3 to 5 years of planning and design. About the implementation time, the BRT systems require less time than the other systems because this system is easier to implement from the different perspectives (financing, technology, flexibility).

Table 3.6 - Implementation time of different systems for a 10 km corridor (Videira S, 2013) [21]

System	Implementation time (years)
Metro	9
LRT	5
BRT	2.5
Conventional Bus Services	1

These differences use to be more notorious in countries or regions without too much experience with rail based systems or without own rail system technologies, for instance many cities in developing countries need external consultancy to design a rail based system and also need external technologies for the implementation of those especial vehicles.

The Transmilenio System in Bogotá is an interesting example because before the implementation of this BRT system, the city lost 40 years of planning in rail based options that never were implemented due to administration policies and low budget but just in the 3 first years of the governance period of Enrique Peñalosa, the first 40 km of the Transmilenio system were designed and implemented. Other important systems were also planned in little time like the Beijing BRT system that was designed in just 5 months.

3.4.4. Flexibility

The flexibility of the system is very important especially in complex projects because any transportation system could suffer unexpected situations during its implementation and operation. The BRT systems present a better flexibility due in part to the autonomy of its vehicles which could be used in any road for eventual modifications of the system.

A rail based system stay fixed to the rails, as a permanent infrastructure of the urban sprawl and that could suppose an important financial risk because in case of some failure the system cannot be removed or readapted. In this aspect the BRT projects present a considerable advantage over the other systems because the infrastructure of a not successful BRT system can be reconverted to a LRT system or other technology. For instance, the lanes could be destined for use of normal traffic.

Due to their autonomous wheel based vehicles and to their flexible infrastructure the BRT system can be modified with less time and less budget than a rail based system. This flexibility could be a very important factor for the success of the system and also could mean a lower financial risk.

3.4.5. Capacity

In order to do a objective analysis it is not possible to compare values like the daily demand or annual demand of the system because they depend exclusively of the length of the system. For this reason the capacities of the systems are measured in Passengers per hour per direction (pphpd) and this concept refers to the maximum quantity of passengers transported in some specific corridor of the system during the peak hour.

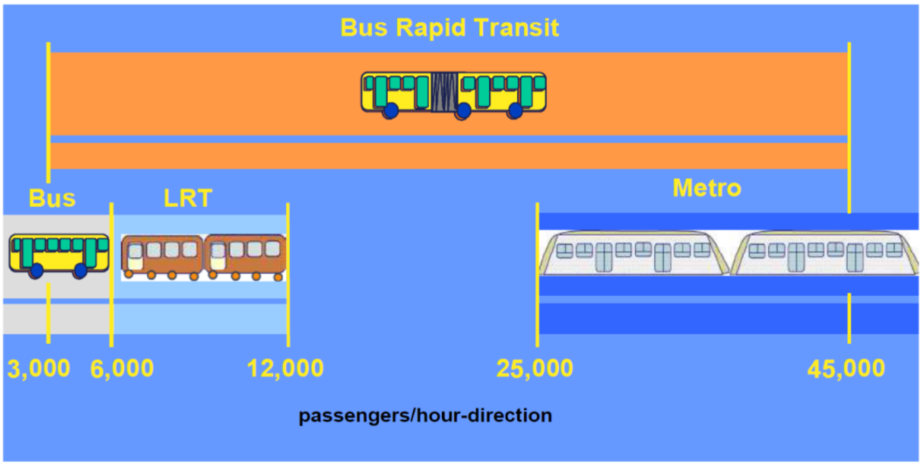


Fig.3.14 - Public transport capacity (BRT planning Guide, 2007) [7]

The Metro systems can transport higher loads of passengers than BRT and LRT systems, but some full BRT systems (high capacity vehicles and two lanes per direction) can also transport considerable quantities of passengers reaching values close to the best Metro systems in the world (Figure 3.14).

The capacities of the best BRT systems pass the capacity of the LRT systems and in some cases they reach the capacities offered by the metro systems.

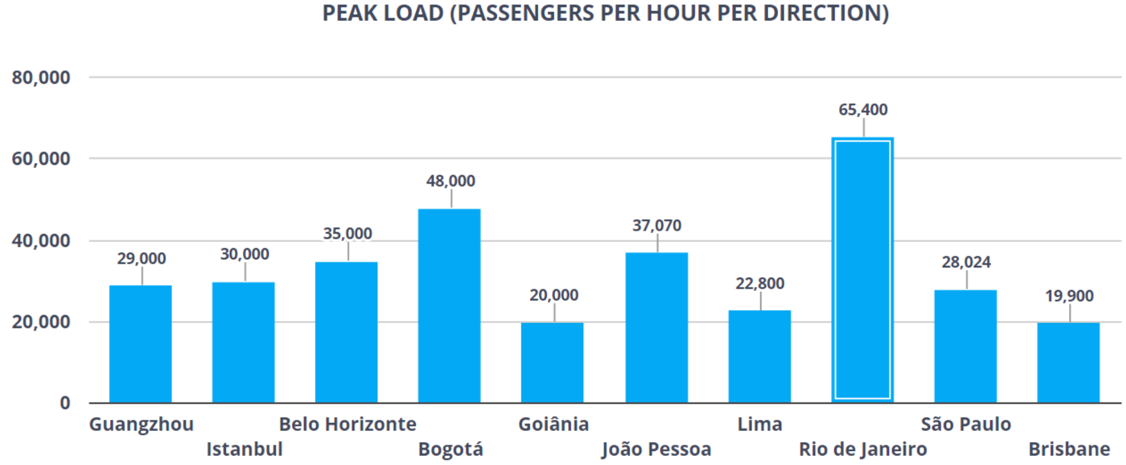


Fig.3.15 - The ten highest peak loads of the BRT systems (brtdata.org) [2]

The metro systems are the options with the highest capacities. Some metro systems can achieve incredible values of pphpd, for instance the systems in cities like Hong Kong, Tokyo, New York and Sao Paulo can transport more than 50000 pphpd, and to the date just the BRT in Rio Janeiro can reach such high levels (65400 pphpd)(Figure 3.15). The LRT systems can't transport as much passengers as the Full-BRT systems because in contrast to the BRT, the LRT systems can't offer express and normal services at the same time. It is possible to reach better pphpd values in a LRT when this system is elevated from the floor, but this also increases the cost of the system considerably.

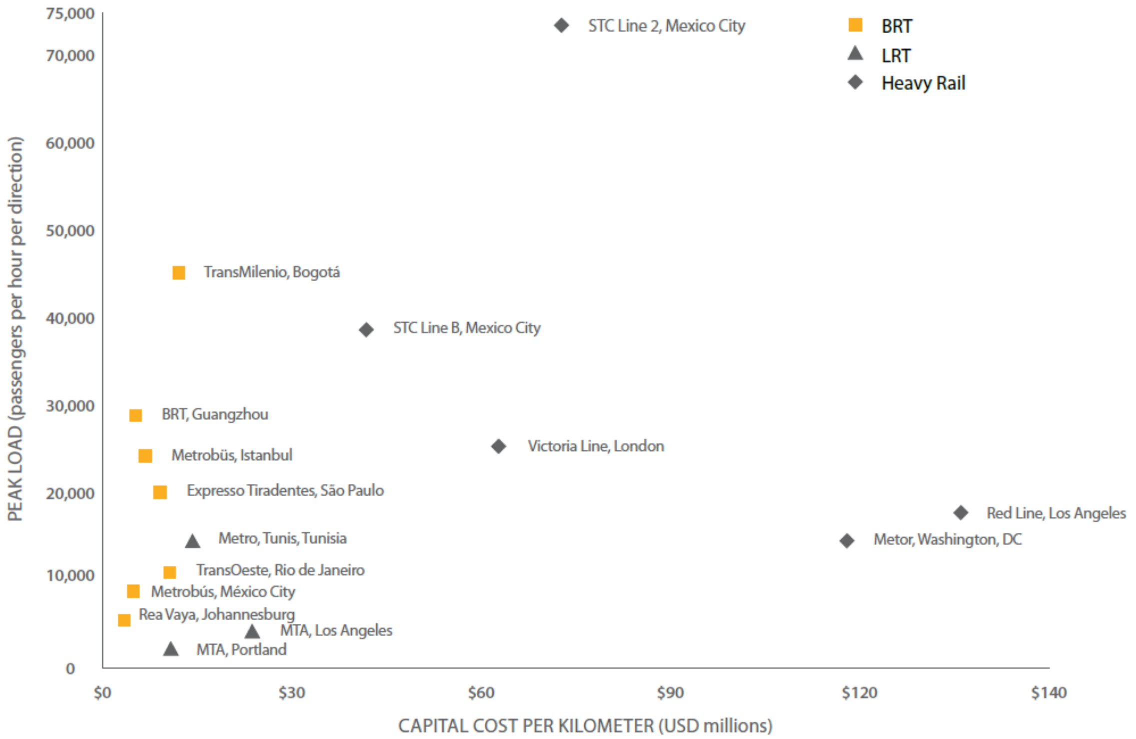


Fig.3.16 - Comparison of capital costs and peak loads of some transit systems (EMBARQ, 2013) [22]

In the Figure 3.16, the BRT alternatives stand out when are related the capacities with the capital costs of the system. The LRT systems don't reach the capacity that offer the full BRT system, so the only systems that reach higher values than the full BRT are the Metro and the elevated rail systems, but they are much more expensive.

3.4.6. Travel time / Speed

The travel time represents the total time that one person requires to go from door to door. Considering only the vehicle travel time from station to station, the Metro systems are the fastest but considering the total travel time the comparison is more balanced. For instance, the BRT and the LRT systems provide easier access and exit in their stations because they are located on the surface, but in the Metro systems, is required additional time to go to the platforms because they are one of two levels below the surface.

The speed is relevant also and it is more accurate to compare the commercial speed than the maximum speed. The commercial speed refers to the average speed from station A to station B including the time loss in the stations (waiting times and boarding times). The metro systems have the highest vehicle speeds but they can reach those velocities because their stations tend to be more separated than in a BRT or LRT system.

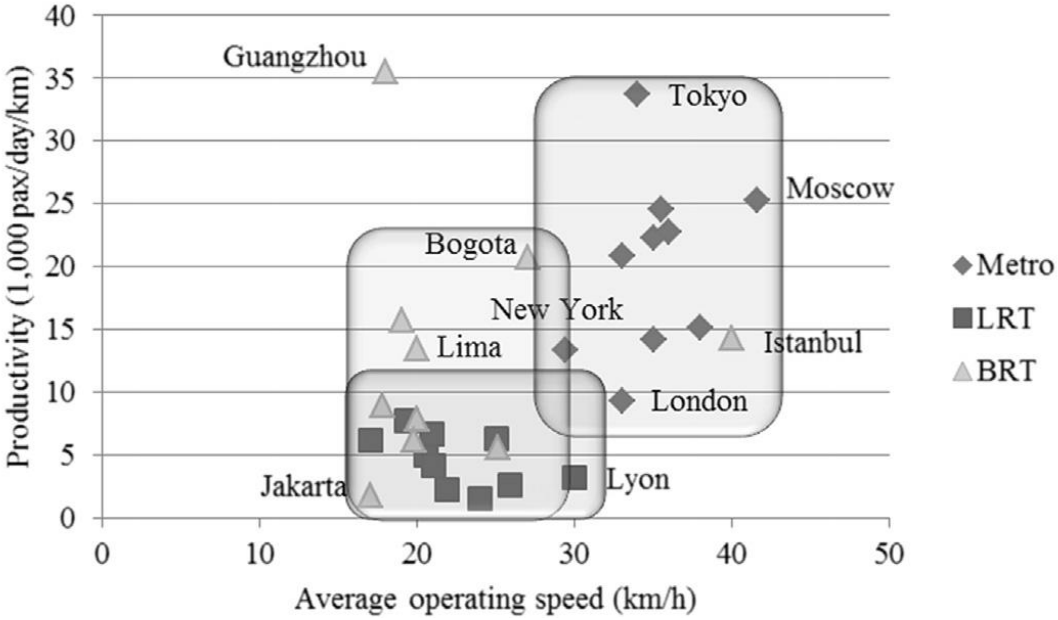


Fig.3.17 - Performance of the world's top ten transit systems (Lindau et al, 2014) [23]

The previous figure demonstrates that the Metro systems have the highest speeds and the LRT offers slightly higher speeds than the BRT system but productivity of the BRT is much higher than the productivity of the LRT.

3.4.7. Image and perception

Traditionally the Metro, LRT and elevated rail systems have been perceived as the most technological and aesthetical options for massive transportation and many cities around the world have implemented rail based systems as a symbol of progress and modernity. The BRT systems can also have a positive image but due these systems use buses, they have to deal with the negative stigma of the conventional bus services and sometimes this can affect the image and attractiveness of the BRT system.

Fig.3.18 – Civil Bus models produced by IVECO [24]

In the most of cases the BRT systems use wheel-base vehicles but there are some cities that have implemented buses with an appearance similar to the trams in order to overpass that existing negative image related with the bus services. For instance many French cities like Caen, Lyon, Nancy and Rouen use a specific bus model that looks like a tram vehicle. In North America some cities like Las Vegas also implemented this type of vehicle called Civis and manufactured by IVECO. This company produces these buses that use diesel engines, hybrid engines or even electric engines in the Civis buses and trolleybuses (Figure 3.18).

3.4.8. IMPACT OVER THE URBAN ENVIRONMENT

The massive systems produce positive impact on the quality of the urban environment reducing the air pollution and the congestion of the road infrastructure replacing a considerable quantity of private vehicles. Considering the built environment, the Metro systems are the systems with the lowest impact because they don’t require space on the surface.

The massive superficial systems (BRT and LRT) can produce positive but also negative impacts over the built environment, especially in historical centers which use to be composed by small roads but when the city is planned to grow with transit oriented development (TOD) policies these systems can generate investment and development along their corridors. Curitiba and Bogotá are interesting examples of densification and development along the different corridors of their BRT systems.

According to the BRT planning guide a simple BRT system corridor require around 3,5 meters of road width and some few corridors require even less space as the BRT in Quito that use roads of 3 meter of width in the corridors in the historical city center. Due to its fixed rails, the LRT corridors can be implemented in shorter widths producing less impact over the built environment.

3.4.9. COMPARATIVE TABLE OF THE SYSTEMS

The features compared in the previous points provide information to elaborate a comparative table of the systems in order to show in a simple way the advantages and disadvantages of each system:

Table 3.7 - Comparative table of the systems

Feature	Metro	LRT	BRT	Conventional Bus Service
Construction Costs	Very high	High	Medium-Low	Low
Operation costs and subsidies	High	Medium-High	Medium	Low
Planning costs	Medium-High	Medium-High	Medium-Low	Low
Implementation time	Long	Medium-Long	Short	Very short
Flexibility	Low	Low	High	Very High
Capacity	Very High	Medium	Medium-High	Low
Travel time/Speed	High	Medium-High	Medium-High	Low
Image and Perception	Good	Good	Medium	Bad
Impact over the urban environment	Low	High	High	Medium

In general the BRT systems have advantages about other massive transportation systems in terms of costs, implementation time and flexibility but considering the performance of the systems, the metro seems to be the best option. The rail based systems typically have a better image than the wheel based systems. A comparison between the superficial systems notice that a BRT system can provide the same benefits than a LRT option with a considerable lower investment.

4
STUDY AND ANALYSIS OF DIFFERENT BRT SYSTEMS IMPLEMENTED AROUND THE WORLD

4.1. INTRODUCTION

In order to find the applicability conditions for the implementation of a BRT system, a variety of BRT systems implemented in different countries will be analyzed. Not all the cities present the same conditions for the implementation of massive transportation systems and at the same time a specific transportation technology could not achieve the same results in different urban and mobility contexts, for those reasons studies in this chapter present cities with different values of size, population and density.

In some cases the BRT projects were planned as the main component of the public transport network, in other cases the BRT systems were implemented as a complement of a rail based system, or even in some places this technology was more oriented to regional transport rather than urban transport. The large variety of BRT systems around the world present different configurations and different complexities also. Some systems are composed just by one or few corridors but on the other hand other BRT systems comprehend a complex network of corridors. Between the cities selected for this analysis, some BRT projects are recognized as positive implementation examples but instead others have been remarked by their negative results.

4.1.1. THE BRT STANDARD

"The BRT Standard is an evaluation tool for world-class bus rapid transit (BRT) based on international best practices……….The BRT Standard functions as a means of achieving a common definition, as a scoring system, and as a planning tool" [16]. As the BRT concept became more important in the last decades, many organizations and institutions related with planning and mobility collaborated for the elaboration of this document. The BRT Standard qualification comprehends a table where the different aspects of a BRT system receive points and the maximum score that any system could reach is 100 points. The scores are given according to different concepts provided by this tool also.

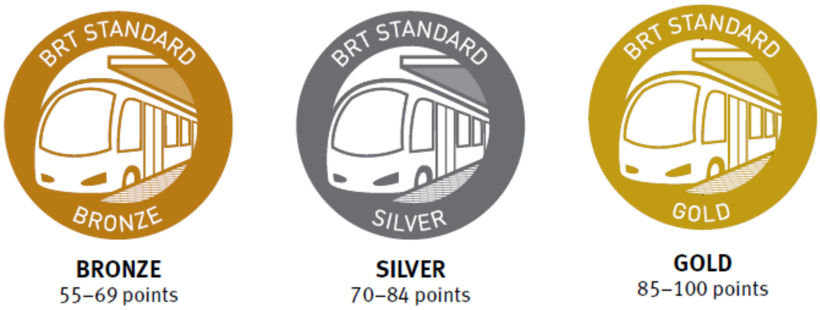


Fig.4.1 – BRT Standard categories [16]

According to the score achieved by the systems, they will receive a categorization that could go from basic BRT systems to Gold systems (Figure 4.1). The most relevant BRT systems in the world were already qualified by this tool. To analyze the technical performance achieved by any system, there will be used the scoring made by the BRT Standard 2014, the last edition currently available.

4.2. CASE STUDIES

4.2.1. ISTANBUL

4.2.1.1. Presentation of the case study

Table 4.1. – General information of the city and the BRT system implemented

Information of the city		
	City:	Istanbul
	Country:	Turkey
	Region:	Europe-Asia
	Population:	14,1 million
	Size:	5 343 km2
	Modal Division	36 % Public
		49 % Private
		15 % Not motorized
	Main transportation system:	Metro
	Other transportation systems:	LRT, Train, BRT, Bus
Information of the BRT system		
METROBÜS	Name:	TUYAP Metrobus
	Inauguration Year:	2007
	System Length:	52 km
	Corridors:	1
	Passengers per day:	750 000
	Peak Load:	30 000 pphpd
	Construction cost per km:	9,8 USD million per km

4.2.1.2. Urban and political context during implementation

Istanbul, the capital of Turkey is the largest city in this country and one of the largest cities in the world. From the planning point of view this city constitutes a very interesting case study due to its configuration because the city is divided by the Bosporus strait into two sides, the European side (West side) and the Asian Side (East Side). This strait contributes for the landscape and tourism of the city but also represents the main problem in the urban mobility of this metropolis.

There are two main bridges that cross the strait connecting both sides of the city and they are the Fatih Sultan Mehmet Bridge (a motorway) and the Bosporus Bridge (a multilane highway) which since its construction in the 1970s, uses to accommodate the public transportation of the city, that means the bus and minibuses services. Despite that Istanbul is experimenting an early stage of vehicle ownership, the rapid population growth and economic development since the 1950s have contributed to the fast motorization of the city. Between 1974 and 2009 the number of private vehicles crossing the bridge have increased around 12 times (Alpkokin P, Ergun M, 2012) [25].

Both sides are similarly urbanized but with different purposes, the European side presents more job opportunities because it contents the Central Business District (CBD) and on the other hand the Asian side is more oriented to residentially purposes. This produces that everyday millions of people have to move from one side to another and despite Istanbul have different transport means like rail, metro, LRT, bus and minibus services, it was the Metrobus BRT the first massive transportation system that connected both sides. Lately, the Marmaray Line, an urban rail system under the Bosporus strait opened its first phase in 2013 and the other stages of this new alternative still under construction.

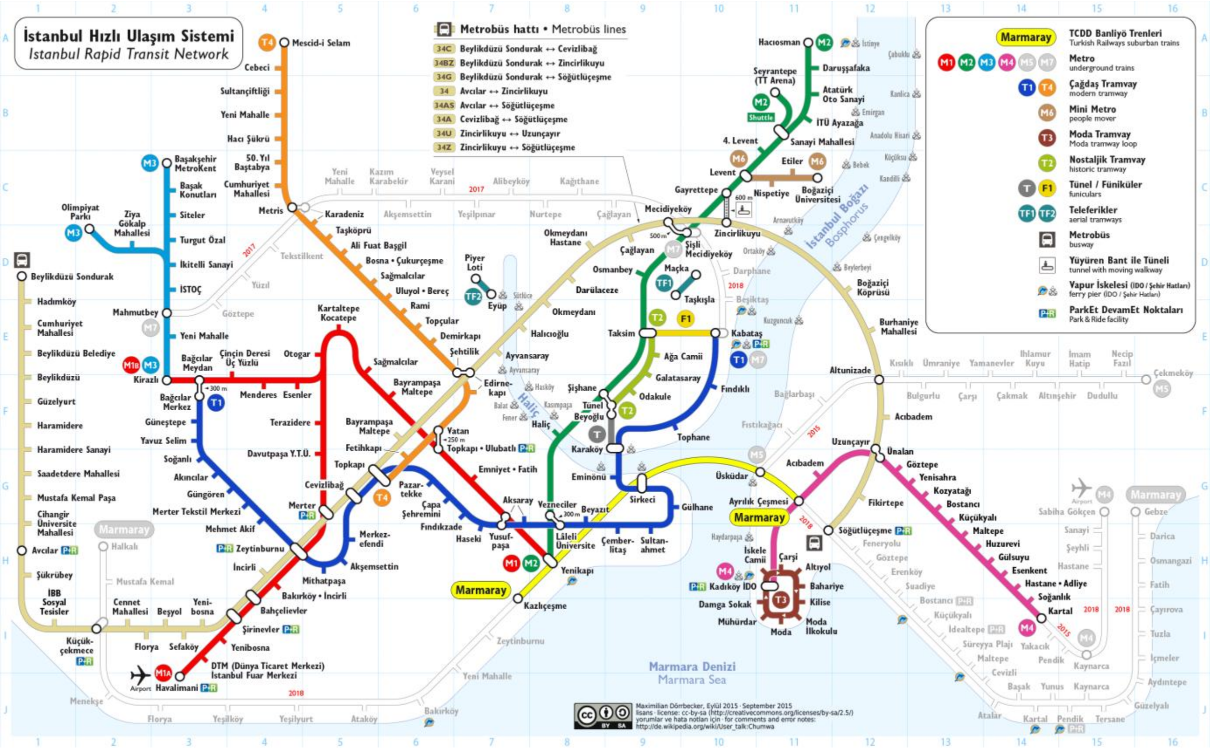


Fig.4.2 – Current transportation network of Istanbul [26]

Since the 1980s the local authorities were investing in rail based alternatives but the high construction costs and the delays in the excavation due the presence of archaeological objects in the soil, boosted the municipality to look for other surface alternatives like the BRT, although this system was not considered in the urban master plan of the city. In 2005 began the construction of the BRT, which was implemented in 4 phases in order to minimize the impact of the project over the city and also with the intention to attract ridership gradually.

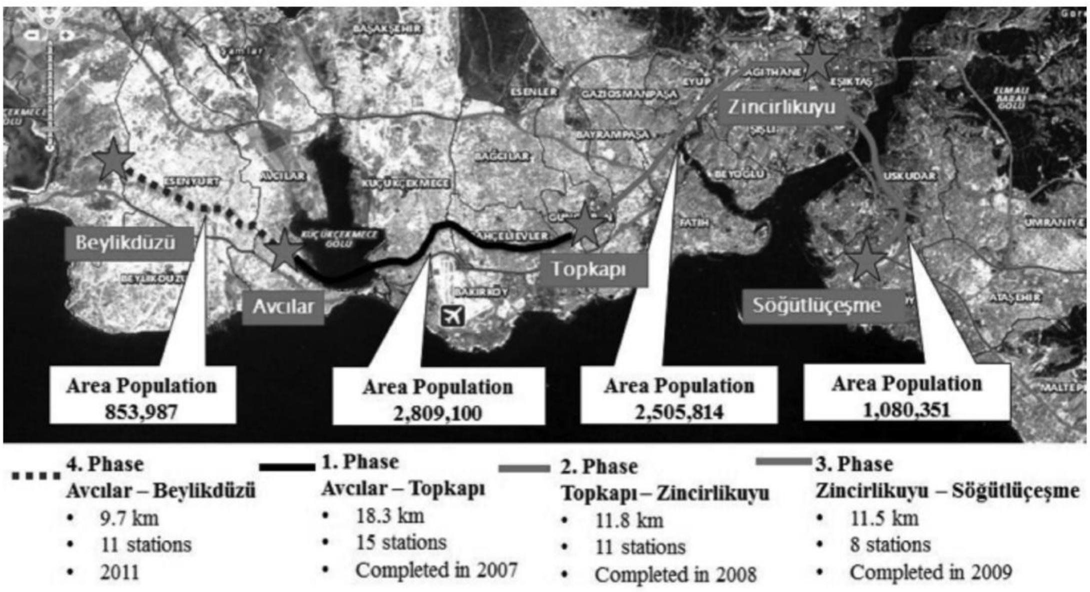


Fig.4.3 – Metrobus implmentation stage in Istanbul (Yazici M, et al 2013) [27]

During its implementation the BRT received some critics from planners who argued that the high demand of the corridor could only be reached by a rail based system. Other people criticized the use of the Bosporus Bridge as a part of the corridor, arguing that this could have a negative impact over the vehicles capacity of the bridge. Although this early critics, the BRT was implemented receiving the political and public acceptance since its opening, and similarly to other BRT cases, a political consistency from part of the municipality was determinant to overpass the initial critics to the system.

The BRT project was boosted and implemented by the Istanbul Metropolitan Municipality and the Istanbul Public Transportation Authority; these local authorities were the political strength behind the BRT system. It is possible to notice this political determination in specific circumstances during the implementation of the System, for instance when they decided to use the Bosporus Bridge as part of the corridor, the State Highway Department (the authority that manages the bridges) was not accepting the design of the corridor over the bridge, but eventually they have accepted it.

Fig.4.4 - The BRT corridor in Istanbul [2]

The entire BRT system has one dedicated line per direction except on the bridge where the buses are part of the mixed traffic. In order to reduce costs and implementation times, the buses run counter flow because the system uses conventional buses with the doors on their right side (Yazici M, et al 2013) [27]. All the stations are located in the middle of the corridor and the access it’s trough overhead pedestrian bridges. To reach the objectives of the system, 1536 vehicles of different means of public transportation were shifted to new feeder lines and also 250 conventional buses were re organized to operate in other parts of the city or in a feeder route. (Alpkokin P, Ergun M, 2012) [25]. The local authorities did not intend to use the new BRT as a transit oriented development (TOD) tool because they didn’t apply any measure to encourage the renewal and development along the corridor (Babalik E., Can E., 2015) [28].

4.2.1.3. Performance of the system from the technical point of view

Table 4.2 – Score obtained in the BRT standard edition 2014 [16]

Country	Turkey
City	Istanbul
System	***Metrobüs***
Corridor	***Avcılar - Söğütlüçeşme***
Corridor Length (km)	***52***
BRT Basics - Minimum score of 18 points needed	37
Service Planning	17
Infrastructure	10
Station Design and Station-bus Interface	5
Quality of Service & Passenger Information Systems	4,5
Integration and Access	4,5
TOTAL 100	78
BRT BASICS (MINIMUM NEEDED 18)	37
Point Deductions	-8
Total Score: (max = 100)	**70**
Classification:	**SILVER**

4.2.1.4. Positive results of the BRT system implemented (From the planning point of view)

The Metrobus can be considered a successful BRT project considering its ridership, performance and public acceptation (Babalik E., Can E., 2015) [28] (Yazici M, et al 2013) [27]. Studies based on surveys suggest that the Metrobus reached high levels of satisfaction between the inhabitants of the city, actually considering all the transportation modes on the surface, the BRT system has the best customer satisfaction level (Celik E. et all, 2013) [29].

Compared with other BRT systems, the Metrobus stands out in many aspects, for instance is the only system in the world that offers a 24/7 service during all the year and also provides a high speed service due to the large distance between stations and due also that the most part of the system was implemented on a freeway. The commercial speed of the system is 40km/hr, reaching higher speeds than LRT systems. The BRT system is carrying around 750 000 passengers per day this means that the Metrobus is also transporting more passengers than a LRT reaching numbers similar to the metro systems, in average.

The BRT success is also translated in the time and money savings for the customers, for instance before the Metrobus, it was needed to expend around 3 USD to do all the route in more than one mode of transportation but with the Metrobus all this route can be traveled for less than the half of the price (around 1.2 USD) and without vehicle transfers. Considering the bridge crossing, the time saving is around 26 min per travel and considering two travels each day that would mean a time saving of 52 min per passenger per day [28].

From the economical point of view the BRT is the system with best results in Istanbul, before and after its implementation. As opposed of the other rail based systems, the BRT was totally financed by the local government and did not require international cooperation. And also since its opening the Metrobus started to generate more money than its expenses that means that the system do not requires subsidies and contrary to the other public systems, is the only one that it's generating earnings for the local authorities. This is a strong point of a system implemented in a city like Istanbul, where all the public transportation means requires subsidies, including the conventional bus network.

Other important benefit is the social and urban integration that the system is generating, because according to studies the congestion over the bridges is predominantly from East to West during the morning and in the other sense during the evenings. And was the BRT the first massive system that offered to the people on the East side a faster and cheaper alternative to go to their destinies (work, university, business) in the West side.

4.2.1.5. Negative results of the BRT system implemented (From the planning point of view)

Nowadays the main problem of the system is the overcrowding of passengers in main stations during the peak hours, especially in the last stations before the bridge where the passengers charge use to be higher, and although the system has a high frequency service during the peak hours (one bus each 26 seconds) many passengers are unable to get on a bus. This problem seems to be very common in the most of the BRT systems around the world (Sorg, 2011) [30]. Part of the problem is because the system is transporting almost same quantity of people than a metro but with BRT stations, which are not enough large due to the limited available space on the surface. This a reason why some people argue that a rail based systems should be selected instead of the BRT, but when the BRT technology was selected the city was not able to wait many years until the construction of a rail based system. Some authors argue that with a better integration between the BRT and the other transport modes, this problem can be solved, and also the recently opened Marmaray train (Figure 4.2), will help to reduce the overcrowding because this new alternative also connects both sides crossing the strait under the water.

A notorious weak point of the system is the inefficient integration with other transport systems. The BRT was not part of a transport master plan, so the integration with the different transport modes is more improvised than planned. There was not a physical connection with the metro, for this reason many people had to walk surface to transfer to the other system. In 2013 and 2014 underground passages were constructed to solve this problem. The integration with some bus lines that work as feeder lines is poor also, and the integration is translated in the proximity of the stops and stations but there is not a real physical integration. The lack of bike stations or bike sharing in the stations seems insufficient. Some other deficiencies were noticed by the BRT standard, as the inefficient access for limited mobility or the considerable gaps between the bus and the boarding platform in the stations.

Even some authors say that the local authorities missed a good opportunity for Transit Oriented Development along the BRT corridor, there are other authors that argue that there were not so much opportunities to apply TOD policies because the corridor was already highly urbanized when the system was implemented.

4.2.2. Lima

4.2.2.1. Presentation of the case study

Table 4.3. – General information of the city and the BRT system implemented

Information of the city		
	City:	Lima
	Country:	Peru
	Region:	South America
	Population:	7,6 million
	Size:	2 672 km2
	Modal Division	62 % Public
		12 % Private
		26 % Not motorized
	Main transportation system:	BRT, Bus services.
	Other transportation systems:	First line of Metro
Information of the BRT system		
Metropolitano	Name:	Metropolitano
	Inauguration Year:	2010
	System Length:	26 km
	Corridors:	1
	Passengers per day:	350000
	Peak Load:	22 800 pphpd
	Construction cost per km:	No Data

4.2.2.2. Urban and political context during implementation

Lima had experienced an accelerated demographic growth during the last decades of the twentieth century but differing from the other important cities in the region, Lima experienced an even larger territorial expansion. The city got expanded producing suburbs in the peripheries of the city, and this urban expansion was marked by spatial and social segregation because the high incomes families occupied the South side and the lower income inhabitants were installed in the North and East sides of the city, in many cases in illegal settlements.

Both areas had the need of transportation to the city center, because the most part of the activities (works, studies, others) are located in this area. The high income families in the South part of the city were able to satisfy their mobility needs with the acquisition of private cars but on the other hand the low income areas had to look for other accessible way to move to the city center. In this scenario the informal public transport offered by buses, mini buses and taxis, appeared as an urgent solution for the low income neighborhoods. Then of few years a large quantity of cars from the private sector or from the informal public service, were entering the center generating an important congestion problem due to the overload of vehicles coming from the different suburbs in the periphery.

Since the beginnings of the 2000s, the local authorities understood that the city was requiring the introduction of a massive transportation system to improve the mobility in this metropolis. A city with no experience in massive systems required external cooperation from the Japanese agency (JICA) which impulse the elaboration of a transportation master plan for the city [31]. This plan was elaborated by two external consultants (Yachito and Pacific) and was published in 2005, subsequently it was accepted and adopted by the Municipality of Lima. This proposal identifies the need of massive systems, and also establishes that the city requires an investment in transport improvements of around 5 500 USD millions until 2025, that means 280 USD millions per year and the annual budget of the municipality is around of 300 USD millions. The municipality had not the financial capacity to invest in these transport solutions and for this reason it was forced to look for private investment.

Fig.4.5 – Current BRT corridor in Lima [2]

The BRT system, called "Metropolitano" was planned to be implemented through a congested area from North to South, reconverting the 7,5 km of the "Via Expressa", a main corridor that city implemented in the past for dedicate use of public bus services. The municipality required private cooperation for the implementation of the BRT system which was implemented in two stages: the design and construction of the infrastructure like the roads, stations, signs and deposits were covered by the municipality and the acquisition of the buses and equipment was financed by the private sector. Four private concessionaries were selected to manage the operation and fare collection of the system and they signed a 12 years contract with the municipality. In this agreement between private and public sector, around 75% of the system revenue goes for the bus operators, 13% for the private concessionaries and the last 12% for the municipality.

Fig.4.6 – BRT corridor and feeder lines in Lima [32]

Due in part to inexperience of the municipality in this type of projects, the BRT final cost was around 130% more than the expected cost. In 2010 the Municipality opened the first section of the BRT system. Nowadays the system has a total length of 26 km and 36 stations. This system constitutes the first massive system in this large metropolis and also represents the largest intervention of the local authorities over the public transport during the last decades (Vega P. Lafosse S, 2011) [33]. The BRT system is integrated with feeder networks with the intention to reach more people (Figure 4.6). One year later it was also opened the first line of the metro system. Only the first stages of both systems were implemented and for that reason nowadays they are carrying just a little percentage of the population. The BRT is being used by around 5.6% of the population and the metro is being used by only 2.5% (Lima Cómo Vamos, 2014) [34].

4.2.2.3. Performance of the system from the technical point of view

Table 4.4 – Score obtained in the BRT standard edition 2014 [16]

Country	Peru
City	Lima
System	***El Metropolitano***
Corridor	***(only 1 line)***
Corridor Length (km)	***16,8***
BRT Basics - Minimum score of 18 points needed	32
Service Planning	23
Infrastructure	14
Station Design and Station-bus Interface	10
Quality of Service & Passenger Information Systems	4
Integration and Access	6
TOTAL ABOUT 100	89
BRT BASICS (MINIMUM NEEDED 18)	32
Point Deductions	-1
Total Score: (max = 100)	**88**
Classification:	**Gold**

4.2.2.4. Positive results of the BRT system implemented (From the planning point of view)

From the technical point of view the system had achieved a positive performance since its opening, and it was qualified as a "Gold BRT", according to the BRT Standard 2014. The BRT presents all the components that a system requires to be considered as a massive transportation system and this is a reason why the system was well received by the users. In many aspects the "Metropolitano" provides a higher quality service than the informal public service, for instance according to the survey "Lima Cómo Vamos" (How are we going, Lima?) made in 2011, the passengers of the system highlighted the velocity of the system and the cleaner vehicles. Also the behavior and the attention of the BRT drivers to the transit norms are better in the BRT system than in the informal transport modes.

Nowadays the users of the BRT system have a better option to reach their daily destinies, because in the past they were forced to use the informal public transport, and consequently they accepted the prices and conditions that these private syndicates established. According to the "Lima Cómo Vamos" survey of 2014, both the Metro and the BRT were the transportation means that reached better acceptability for part of the population. In this survey, the 70% and the 57% of the population qualified as god or very good the service provided by the Metro and BRT respectively.

Even the BRT and the Metro are reaching a little percentage of the daily users of all the transport means; they are producing a good impact over the perception of the population about the massive systems. In an metropolis like Lima, without any experience with massive systems, these first stages of the BRT and Metro are generating a positive expectative over the population about the modernization of the public transport of the city (Vega P. Lafosse S, 2011) [33].

4.2.2.5. Negative results of the BRT system implemented (From the planning point of view)

The BRT system doesn't present problems in their performance but some planners argue that the accessibility to the stations must be improved. The implementation of the system showed some failures of the local authorities in the transport management of the city. The final cost of the BRT system was more than twice than the original planned cost and these extra costs was covered by the state but also it was required around 25 years to open just the first stage of the metro. Some planners argue that authorities have a more vehicle oriented focus of the transport instead than a pedestrian oriented focus. They criticized that the authorities gave more priority to the vehicle circulation than to a pedestrian circulation in any conflict between these sectors during the implementation of the BRT system as could be noticed in the access to some stations.

Fig.4.7 – Respective second lines planned for the BRT and for the Metro (Bonifaz J, 2013) [35]

A problem than can affect the performance of the system in the future is the similarity of routes that share the projected second lines of the BRT and the Metro (Figure 4.7). The problems come from the national and local authorities. The Metro is being controlled by the National Government and the BRT is managed by the Municipality and this produces a lack of integration in the transport planning. Both systems have more lines projected but this duplicity of planning criteria could represent an important barrier for the success of both systems in the future.

4.2.3. MEXICO CITY

4.2.3.1. Presentation of the case study

Table 4.5. – General information of the city and the BRT system implemented

Information of the city		
	City:	Mexico City
	Country:	Mexico
	Region:	North America
	Population:	8,85 million
	Size:	1 485 km2
	Modal Division	77,9 % Public
		20,7 % Private
		1,4 % Not motorized
	Main transportation system:	High quality Metro
	Other transportation systems:	Conventional bus
Information of the BRT system		
Metrobús	Name:	Metrobús
	Inauguration Year:	2005
	System Length:	105 km
	Corridors:	5
	Passengers per day:	900 000
	Peak Load:	12 000
	Construction cost per km:	2,9 USD million per km

4.2.3.2. Urban and political context during implementation

Mexico City, the capital of Mexico is a large city with 9 million of inhabitants and with a high population density of around 6000 inhabitants /km². This city constitutes an interesting case study because this city is the center of the most populated metropolitan area in the American continent with a population close to the 21 million people. The growth of the city during the last century also brought other problems in the urban daily life, so in the beginnings of the 2000s the city was suffering serious problems of congestion and pollution (The Greater Boston BRT Study Group, 2015) [36].

In those years there were important planners and public actors worried about the air pollution in the city and some of them, like the Mexican Nobel prize winner Mario Molina, were recommending to the government the improvement of the transportation to combat the air pollution. In this context, in 2002 it was published the Integral Road and Transport Program of Mexico City, an initiative that considered the implementation of BRT corridors as an important measure. This plan has as main objective the improvement and organization of the public transport in order to solve the problems of air pollution. Claudia Sheinbaum, the responsible of the environment department in the Federal district; she was the person behind the idea to use the BRT technology to combat the air pollution.

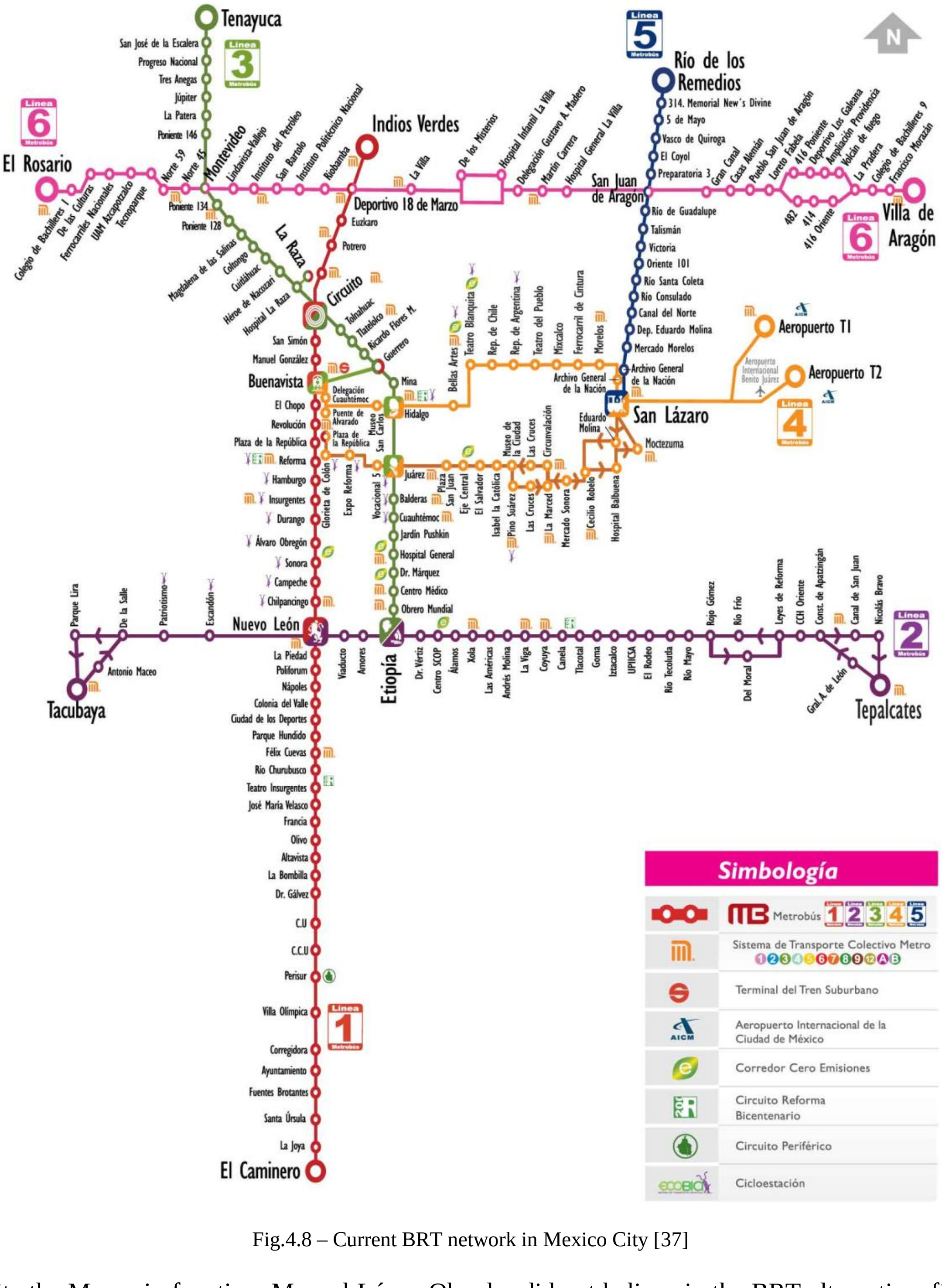


Fig.4.8 – Current BRT network in Mexico City [37]

Despite the Mayor in function, Manuel López Obrador did not believe in the BRT alternative, finally he had to accept and encourage this technology that was supported by national and international entities, especially Claudia Sheinbaum (Varela S, 2015) [38]. In this way in 2002 the national government, receiving international cooperation from EMBARQ (Wolrd Resources Institutes) started the design of the new BRT network and in 2004 they started the construction of the first BRT corridor.

In July of 2005 it was opened the Line 1, the first BRT corridor with a length of 20 km and three years later it was extended 9 km in south direction. The large ridership this first line was attracting during the first years boosted the implementation of the next corridor. The Line 2 opened in 2008 with a length of 20 km but going from East to West contrary to the Line 1 that was implemented in North - South direction. In 2009 the daily demand had increased almost twice, from 250 000 passengers in 2002 to 480 000 daily users in that year. Few years later the third corridor Line 3 was opened in 2011 with a length of 17 km and the Line 4 (28 km) was inaugurated just one year later. Lately the Line 5 was implemented in 2015 with a length of 10 km. Currently the BRT system has 5 corridor or Lines providing a total of 105 km of BRT corridors and reaching a considerable daily ridership of 900 000 passengers per day and a maximum peak load of 12 000 passengers per hour per direction [2].

Fig.4.9 – Metrobus corridor in the middle of the street [39]

It is important to notice some specific details during the implementation of this BRT project: the environmental purpose of this project and the large and complex metro network that the city already had before the implementation of the BRT system. Different to other BRT projects, this system was mainly intended to be a tool to combat the air pollution through the provision of better public transport, so this BRT project was conceived as a “environmental friendly measure” (Martínez A, 2010) [40] and was boosted mainly by the environmental department authorities rather than the correspondent public transport entities.

About the metro network it is important to notice that although Mexico City has the largest metro network (200 km) in Latin America, the system was just covering the half of the urban sprawl and was not really combating problems like the pollution or the congestion (EMBARQ, 2013) [22]. In 2000, from a total of 14,8 million daily trips only 9% percent was covered by the metro (NYC Global Partners, 2012) [41]. In this scenario the new BRT system was also intended to provide efficient public transport in the areas not covered by the metro network, integrating physically both transport modes in 15 stations.

4.2.3.3. Performance of the system from the technical point of view

Table 4.6 – Score obtained in the BRT standard edition 2014 [16]

Country	Mexico	Mexico	Mexico	Mexico
City	Mexico City	Mexico City	Mexico City	Mexico City
System	***Metrobus***	***Metrobus***	***Metrobus***	***Metrobus***
Corridor	***Line 1***	***Line 2***	***Line 3***	***Line 4***
Corridor Length (km)	***28,1***	***20***	***17***	***28***
BRT Basics - Minimum score of 18 points needed	32	29	31	20
Service Planning	20	20	20	15
Infrastructure	7	8	9	7
Station Design and Station-bus Interface	8	8	8	6
Quality of Service & Passenger Information Systems	4	4	4	4
Integration and Access	5	6	6	9
TOTAL 100	76	75	78	61
BRT BASICS (MINIMUM NEEDED 18)	32	29	31	20
Point Deductions	-3	0	0	-6
Total Score:	**73**	**75**	**78**	**55**
Classification:	**Silver**	**Silver**	**Silver**	**Bronze**

4.2.3.4. Positive results of the BRT system implemented (From the planning point of view)

The BRT system has produced important benefits for the city. The average travel time for the passengers has decreased to the half (The Greater Boston BRT Study Group, 2015) [36] due in part that the new vehicles can reach higher velocities than the previous bus and mini buses. In 2008 the system was saving annually 2 million hours in travel time equivalent to 1.3 USD million. This performance made the system more attractive for the people, even for those who already had an own car, they represent the 15% of the total ridership of the system. The BRT system is safer than the previous system for instance the Line 3 reduced the injuries and fatalities by 38% (EMBARQ, 2013)

[22] and lately studies says that the system is producing 54% less traffic accidents. The most part of the users come from low and middle income groups, and around 79% of the Metrobus passengers come from the previous minibus systems, as was intended since the opening of the system. Some areas close to the stations are more secure than before to the implementation of the BRT system. The non-motorized travels are promoted with the introduction of bike infrastructure, especially in the last corridor implemented.

The most remarkable benefit of the system is the positive impact over the environment. The emissions of the new BRT buses are lower than the previous conventional buses and minibuses, and this is producing a considerable reduction in the air pollution and in the emission of greenhouse gases (Martínez A, 2010) [40]. The BRT system reduced the pollution in 35% compared to the previous alternative and this benefit also represents economic income for the city, for instance until 2012 the Line 1 reduce a quantity of CO_2 emissions equivalent to 800 000 USD (NYC Global Partners, 2012) [41]. The combat against the air pollution is also improving the health of the inhabitants since the opening of the system. In 2008, the Line 1 was reducing annually 12 cases of chronic bronchitis and 3 deaths, saving around 3 USD million per year (EMBARQ, 2013) [22].

The Metrobus system has received national acceptance and international recognition. A survey made in 2009 showed that from 1 to 10 points, the BRT passengers had a satisfaction of 8.1. Other survey in 2010 gave the results that 65% of passengers considered the velocity of the BRT vehicles as fast, and 25% as very fast (Martínez A, 2010) [40]. In the international level, the Metrobus has seen recognized as a sustainable and environmental friendly measure and has received important awards. In 2006 was categorized as the Best Transport Project of the year by the World Leadership Forum and three years later the John F. Kennedy School of Government (Harvard University) awarded the Metrobus with the 2009 Roy Family Award for Environmental Partnership. Again in 2010 the Metrobus received the Mapfre Award for Best Environmental Performance (NYC Global Partners, 2012) [41].

4.2.3.5. Negative results of the BRT system implemented (From the planning point of view)

Although the positive impacts the system generates there are some weaknesses in the Metrobus's performance. A survey made in 2009 showed that the system had a good acceptance between the users but around 46% of them also noticed overcrowding in the buses. This is a normal problem that the BRT systems have to face when they are experiencing an accelerated ridership growth. The weak physical segregation in the corridors gave opportunity to the inappropriate invasion of some drivers. In 2010 a daily quantity of 20 drivers were fined for invasion of the BRT corridors (Martínez A, 2010) [40]. This specific deficiencies gave a worse image to BRT when is compared with the metro network. Another aspect criticized by some authors was the fact that for many years there was not fare integration between the metro and Metrobus although they were physically integrated in some stations. It was in 2012, seven years after th opening of the first BRT corridor, when the city implemented a common integrated card for both systems (metro.cdmx.gob.mx) [39].

In the economic aspect the system is not working as it was planned. The system is operating with a deficit that boosted the government to inject subsidies for the public operators of the system, like the Metrobus agency. The different lines of the system were not opened in the expected dates due some complications during the negotiation with the system operators and due also to delays in the construction of the infrastructure. These problems represented considerable economic losses for the local authorities. For instance in the implementation of the Line 3 the time lost during the construction represented a theoretical economic loss of 13.6 USD million (EMBARQ, 2013) [22].

4.2.4. BRISBANE

4.2.4.1. Presentation of the case study

Table 4.7. – General information of the city and the BRT system implemented

Information of the city	
City:	Brisbane
Country:	Australia
Region:	Oceania
Population:	2,15 million
Size:	5 950 km2
Modal Division	15,3 % Public
	78,5 % Private
	6,2 % Not motorized
Main transportation system:	Inter-urban train
Other transportation systems:	Coventional bus
Information of the BRT system	
Name:	Translink
Inauguration Year:	2000
System Length:	28 km
Corridors:	3
Passengers per day:	356 800
Peak Load:	19 900 pphpd
Construction cost per km:	No Data

4.2.4.2. Urban and political context during implementation

Brisbane, the capital of the State of Queensland, is the third largest city in Australia but is also the region that is experimenting the fastest growing in this country. Some authors find quite interesting that Brisbane had implemented a wheel based technology like the BRT because historically the massive transportation in the city was provided by a train network of more than 200 km (Tanko M and Burke M, 2014) [42]. In the 1900s the public transport was composed by the train network, managed by the government and by a conventional bus service managed, by the local authorities. The integration between these two independent modes was almost inexistent.

Local planners noticed that many areas between the train routes were not properly covered by the train network so the residents of these “excludes” areas had problems to access to the public transport and they had to walk considerable distances to reach the train stations. (Hoffman, 2008) [43]. In this context the local authorities searched for a solution that could be implemented in short time and influenced by the Ottawa BRT system, the idea to use busways emerged for first time in 1994. Even some authors like Hoffman (2008) [43] argue that the major Soorley was the man behind the idea of implementing a BRT system; in fact the real propeller of the system was Maureen Hayes, a local authority of the city council responsible of the Traffic and Transport department (Tanko M and Burke M, 2014) [42].

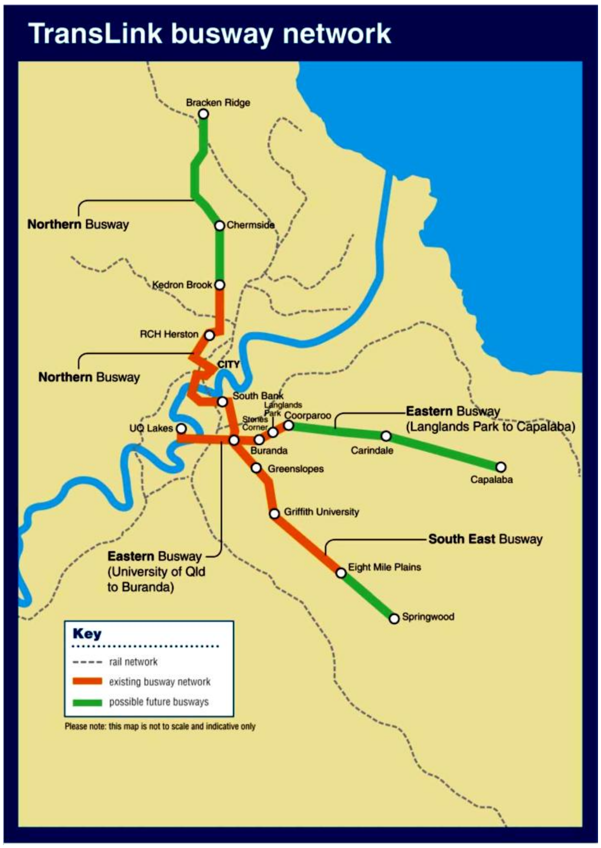


Fig.4.10 – Current BRT network in Brisbane (Tanko and Burke, 2015) [42]

Hayes made a visit to Ottawa to see the BRT system in that city and impressed by the performance of the system she ordered to a consultant company to elaborate a report about the viability of a BRT system in Brisbane. The report was presented in 1995 at the same time that the new Minister of transport commissioned the elaboration of a new plan to improve the transport in the region. The result was the Integrated Regional Transport Planning (IRTP) presented in 1997, and this new plan improved the BRT ideas presented in 1995, proposing the creation of a busway system in the region with the conventional buses integrated to this new network. The alternative to use LRT technology instead the busways was also considered but subsequently this technology was discharged due to the high cost and to the possible negative impact on the superficial traffic (Tanko M and Burke M, 2014) [42].

With the pressure to receive the 2000 Olympic Games, the first part of the Southeast Busway was opened at time for the inauguration of the event. This was the first line of the new BRT system and was completed in October of the same year, covering relevant areas of the city. Some years later, in 2006 it was opened the Nothern Busway, the second line of the system which cross the Brisbane River trough the Eleanor Schonell Bridge. The third and last line implemented is the Eastern Busway which started operations since 2009 (brtdata.org) [2]. The BRT system is composed by segregated busways with two lanes per direction, large stations, bridges and even underground tunnels. The system is designed to let the vehicles to reach velocities around of 80 km per hour between stations. The service in all the system is provided by conventional buses and not by articulated or bi-articulated vehicles.

The Brisbane's system has differences with the typical BRT systems because the system is externalized this means that even some routes only operate in the busways, the most of the routes operate out of the system but they use the busways just in specific sections (Hoffman A, 2008) [43].

The busways can also be used by special vehicles like police or ambulances because some stations are located close to some important buildings.

Fig.4.11 – BRT infrastructure in Brisbane (Bothwell B, 2010) [44]

The system have adopted some characteristic of underground systems specially in the central business district were the system has some stations constructed underground, similar to some metro stations. In this BRT system the stations are a key element and they are designed to support large capacities (Figure 4.11); normally the stations offer four boarding platforms and an extra lane for express services. Each station has notable architecture in order to provide a good image to the system.

4.2.4.3. Performance of the system from the technical point of view

Table 4.8 – Score obtained in the BRT standard edition 2014 [16]

Country	Australia
City	Brisbane
System	***(no BRT system name)***
Corridor	***South East Busway***
Corridor Length (km)	***16,5***
BRT Basics - Minimum score of 18 points needed	23
Service Planning	21
Infrastructure	13
Station Design and Station-bus Interface	6
Quality of Service & Passenger Information Systems	5
Integration and Access	12
TOTAL 100	80
BRT BASICS (MINIMUM NEEDED 18)	23
Point Deductions	-3
Total Score: (about of 100)	**77**
Classification:	**Silver**

4.2.4.4. Positive results of the BRT system implemented (From the planning point of view)

The large ridership attracted by the system is remarkable, especially in the Southeast busway where the ridership had growth a 124% since its opening. Actually this corridor had a considerable impact on the public transport of Brisbane, because the last year before its opening the ridership was decreasing in 800 000 fares per year and one year later the opening of this corridor the ridership was increasing in 866 566 fares annually (Hoffman A, 2008) [43]. In fact the South East busway is one of the busiest BRT corridors in the world (Currie G and Delbosc A, 2014) [45].

It also notable the high frequency levels the system reaches in peak hours. During peak periods the system provides 295 buses per hour, reaching a frequency of one bus each 12 seconds. On the other hand during off peak hours the systems offers 70 buses per hour with a frequency of one bus each 51 seconds (Currie G and Delbosc A, 2014) [45]. Comparing performance with a highway it was calculated that during peak hours one busway lane can transport as many people as nine lanes of highway (Institute for sustainable communities, 2011) [46]. The infrastructure like tunnels and segregated lanes let the system to produce time savings equivalent to more than 130 USD million per year (Tanko M and Burke M, 2014) [42].

Fig.4.12 - Station within Hospital permit easy access for ambulances (Bothwell B, 2010) [44]

The busiest routes are intended to subsidize other social services as school services and community routes. As it is possible to notice in the Figure 4.12, the stations were implemented close to important buildings like hospital facilitating emergency services (Hoffman A, 2008) [43]. Although the authorities did not implemented transit oriented development measures along the corridors, it is possible to notice development along the busways. The real estate market propelled this investment and for instance along Southeast busway the land value has increased around 20% (Institute for sustainable communities, 2011) [46].

4.2.4.5. Negative results of the BRT system implemented (From the planning point of view)

Even with a high frequency of one bus every 12 seconds, the overcrowding and queuing are visible in some stations of the Southeast busway (Currie G and Delbosc A, 2014) [45]. The system still permits the passengers to acquire their tickets inside vehicles, so this interaction with the drivers and the time required for this small payment is producing delays in the operation and consequently overcrowding. These problems are reducing in 10% the capacity of the stations (Institute for sustainable communities, 2011) [46]. With the infrastructure offered by the system it is possible to solve these problems with the introduction of higher capacity vehicles (articulated and biarticulated buses) and with measures to replace the on-board payment by Off-board payment.

Planners also notice that the lack of TOD measures represent a missed opportunity for controlled and organized land development along the corridors (Tanko M and Burke M, 2014) [42]. The unexpected development along the routes produced by the real estate market boosted the local authorities to look for specific actions in order to promote TOD.

4.2.5. CURITIBA

4.2.5.1. Presentation of the case study

Table 4.9. – General information of the city and the BRT system implemented

Information of the city		
 	City:	Curitiba
	Country:	Brazil
	Region:	South America
	Population:	1 864 416
	Size:	430 km2
	Modal Division	46 % Public
		26 % Private
		28 % Not motorized
	Main transportation system:	BRT
	Other transportation systems:	Regulated bus services
Information of the BRT system		
	Name:	Rede Integrada de Transporte
	Inauguration Year:	1974
	System Length:	84 km
	Corridors:	7
	Passengers per day:	561 000
	Peak Load:	12 500 pphpd
	Construction cost per km:	2,5 USD million per km

4.2.5.2. Urban and political context during implementation

The city of Curitiba was the first city that implemented a BRT system but also one of the best examples of BRT worldwide. Curitiba is the capital of Parana state and also the center of a metropolis composed by twenty-six municipalities. Nowadays the city is known by its efficient public transport and for its sustainable oriented urban planning. At present many authors and important institutions consider the Curitiba's BRT system as one of the best systems in world, but to understand this successful project it is required the analysis of the process around its implementation.

After the closure of the tram services in 1952 many private bus companies started to emerge providing transport for the inhabitants, taking advantage of the fast expansion of the city. In 1964 a consortium based in São Paulo elaborated a new master plan for Curitiba and one year later it was created the Institute of Planning and Urban Research of Curitiba (IPPUC), a municipality department that had the responsibility to implement the master plan. Some important guidelines consisted in decongesting the downtown trough the implementation of structural axis to reach linear urban expansion along the axis integrating land use and transportation. The plan established massive transportation along the two first axis (North-South and East-West) but the transportation technology was not defined yet.

Fig.4.13 – A BRT station in Curitiba [2]

The first studies made about the technology selection (1969) gave as a result that an LRT system should be implemented in the city but the municipality had to discharge this option due to the lack of funds. Alejandro Lerner, the Major of Curitiba in those days and his team had to look for a more affordable solution and taking the risk, they decided to provide a system with the same quality and capacity than the proposed LRT but using wheel based vehicles or buses implemented on high quality corridors.

The system was planned in 1972 and implemented in 1974 initially with 20 km in the North-South axis. The private bus companies signed contracts with the municipality to provide service for the new system in the different routes. In 1977 it was implemented the Boiquerão Corridor and three years later lines in the East-West axis were opened. Since 1980 a common fare was applied and few years later it was created the Integrated Transport Network of Curitiba (RIT) integrating the existing lines. In 1991 were made some improvements in all these corridors and since then, they started to operate as BRT systems [2]. In 1996 the RIT was expanded over the entire metropolitan region (Videira Martins, 2013) [21]. Most recently, in 2009 it was created the Green line connecting the South line with the Boiquerão and in 2014 it was implemented the last line called “Rua XV de Novembro”. The network also provides 150 km of bikeways (Vallicelli L, 2000) [47].

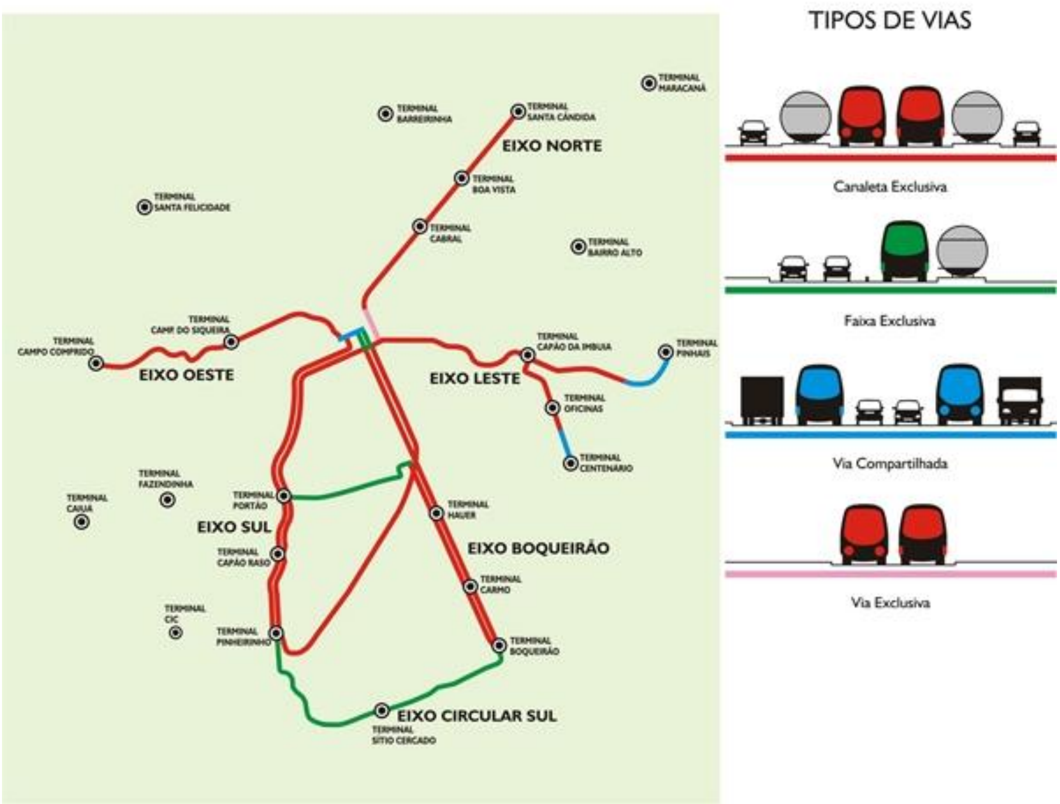


Fig.4.14 - Structural axis of the BRT network in Curitiba [48]

Nowadays the system has seven lines or corridors with 139 stations, 26 terminals and with an infrastructure of 84 km of segregated BRT corridors, 340 km of feeder routes and 185 km of inter-district roads (EMBARQ, 2010) [49]. Even now this project is considered as a “full BRT” system it is important to remark that initially in the 1970s there were provided many important components of a BRT system but some other important elements were introduced gradually years later (ITDP, 2007) [7]. Since the opening of the first stage of the BRT project many other proposals to use rail based systems have been elaborated. The study made by Duarte et al (2011) [50] demonstrates that the constant competition with the rail based proposals boosted the BRT system to introduce important improvements.

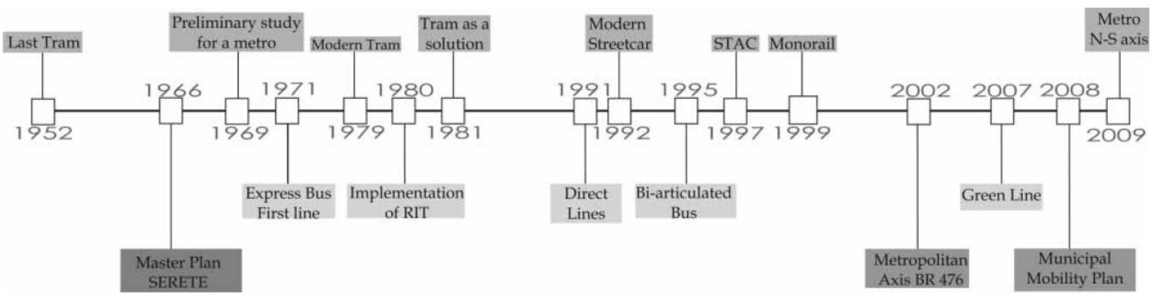


Fig.4.15 – BRT improvements versus rail based proposals (Duarte et al, 2011) [50]

It is important to notice that most part of the credit for the success of the BRT is given to the architect Jaime Lerner, the major of Curitiba in 1970s and to his team also, because they took the risk to develop and implement a system without precedents depending only to the low city budget. The good results obtained initially launched the political career of Jaime Lerner who was major of the city in three periods (ITDP, 2007) [7] and governor of Paraná state in two opportunities also. The success of the BRT and its improvements over the years is the result of this political strength supporting all the system stages. When some part of the population had doubts about the reliability of the system or when some groups were against its implementation, the clear political vision and the technical knowledge of the BRT concept were key factors to overpass any obstacle.

4.2.5.3. Performance of the system from the technical point of view

Table 4.10 – Score obtained in the BRT standard edition 2014 [16]

Country	Brazil	Brazil
City	Curitiba	Curitiba
System	***Rede Integrada de Transporte (RIT)***	***Rede Integrada de Transporte (RIT)***
Corridor	***Green Line***	***(All RIT corridors)***
Corridor Length (km)	***9,5***	***74***
BRT Basics - Minimum score of 18 points needed	33	33
Service Planning	24	24
Infrastructure	12	5
Station Design and Station-bus Interface	10	8
Quality of Service & Passenger Information Systems	4	4
Integration and Access	9	8
TOTAL 100	92	82
BRT BASICS (MINIMUM NEEDED 18)	33	33
Point Deductions	0	0
Total Score: (about of 100)	**92**	**82**
Classification:	**Gold**	**Silver**

4.2.5.4. Positive results of the BRT system implemented (From the planning point of view)

It is remarkable the good accessibility offered by the system to people with mobility constraints due to municipal policies. For instance it was introduced the Integrated Transport for Special Education (SITES), a free of charge line of the system for students with physical or mental deficiencies (Videira Martins, 2013) [21]. Are also notable the benefits generated by the Transit Oriented Development policies implemented along the corridors. The Figure 4.16 shows the urban recovering and the revitalization of the infrastructure along the trunk lines of the BRT system is (EMBARQ, 2010) [49]. The BRT corridors reached the initial objective of attracting development and also helped for the lineal and controlled expansion of the urban sprawl.

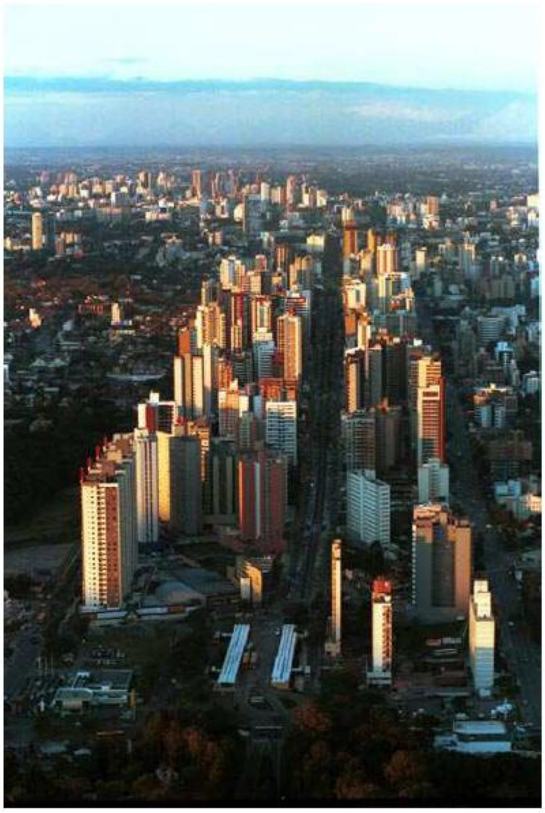


Fig.4.16 – Development along a BRT corridor in Curitiba (ITDP, 2007) [7]

From the economical point of view the Curitiba's BRT became a model for other systems. In this large and complex system the operational costs of the system are covered by the fare revenues, a benefit that the metro systems can't offer to the municipalities. The business model implemented in the system show to the world that is possible to implement a BRT system able to produce earnings for the operators, the local authorities, offering a reasonable and affordable cost for the users (ITDP, 2007) [7]. These economic benefits let the system to implemenet some measures as the reduction of the fares during the Sundays in order to impulse social activities during the weekends.

Many authors and planning institutes consider the Curitiba's transportation system as a referent of sustainable mobility, and due also to the sustainable policies that have been implemented in the system since its opening in 1974. Nowadays Curitiba is the only city in Brazil without informal transport service as result of an efficient transport management. The system also stands out in the environmental aspect implementing measures to protect the environment, for instance the gradually introduction of biodiesel buses during the last years. Many pedestrian streets with bicycle equipment also reveal the pedestrian oriented policies in some corridors. The sustainability of the system can also be measured with some methods as the index of Sustainable Mobility (I_SUM). In the study elaborated by De Freitas et al (2012) the authors applied this method in the Integrated Transport Network of Curitiba (RIT) to measure its grade of sustainability. The results of the study showed that the transport network of Curitiba reached and score of 0.747 out of 1, that means a 74,7% of the maximum value, showing that the city provides sustainable mobility although the system is not perfect.

4.2.5.5. Negative results of the BRT system implemented (From the planning point of view)

Although it was provided many kilometers of infrastructure for bicycles, in the transport network the non-motorized travels are conceived as recreation and not as a real alternative for transport. Even with an efficient public transport network, the rate of private car ownership is growing considerable in Curitiba. Any restriction to private car is not well received by the population and any measure represents a risk that local authorities don’t want to assume (De Freitas Miranda et al, 2012) [51].

The capacity of the system is a concern nowadays as it was since its opening. The system almost reaches its maximum capacity in some stations on trunk lines during the peak hours and on the other hand the service is excessive in the least transited hours (EMBARQ, 2010) [49]. It is important to understand that every time that the system was reaching its maximum capacity, a rail based proposal used to appear but in every case the authorities searched for some innovation in the BRT system to overpass its capacity, and in every case the measures were effective.

4.2.6. SANTIAGO

4.2.6.1. Presentation of the case study

Table 4.11. – General information of the city and the BRT system implemented

Information of the city	
City:	Santiago
Country:	Chile
Region:	South America
Population:	5,9 million
Size:	
Modal Division	35 % Public
	23 % Private
	42 % Not motorized
Main transportation system:	Metro
Other transportation systems:	Conventional bus
Information of the BRT system	
Name:	Transantiago
Inauguration Year:	2006
System Length:	92 km
Corridors:	14
Passengers per day:	340 800
Peak Load:	13 500 pphpd
Construction cost per km:	5,73 USD million per km

4.2.6.2. Urban and political context during implementation

The city of Santiago is the capital of Chile and also the most populated city in this country. Contrary to other South American case studies, this large metropolis had one of the largest Metro systems in the region operating efficiently since many years before the implementation of the BRT corridors. This metro system opened its first line in 1975 and although this system it was providing a high quality service, the other public transport modes (conventional bus or shared taxis) were generating mobility problems for the city due the low quality service they were offering.

The economic growth experienced by Chile since the end of the 1980s generated benefits like a considerable reduction of the poverty but also produced collateral effects over the urban mobility of the main cities, especially Santiago. Higher incomes for the inhabitants produced a considerable growth in the private car ownership, for instance the number of private cars trips increased around 250% from 1991 to 2001 (Muñoz J and Gschwender A, 2008) [52].

Since the beginning of 2000s there was a general consensus that the public transportation in Santiago should improve. The disorder, congestion, pollution, accidents, overloading of the road networks and the low quality service of the private bus services were the main problems in the transport provision. The local authorities were aware about these problems and the Ministry of Transports and Telecommunications elaborated the Urban Transport Plan for Santiago (PTUS), which had as main objectives the encourage of the public transport and the improvement of the service provided by the entire transport system (Holiugue C, 2011) [53]. This plan consisted in 11 programs, and the most notable of these programs was also the first one to be implemented titled as the Modernization of the Public Transport. In 2003 the name of this program was changed to Transantiago.

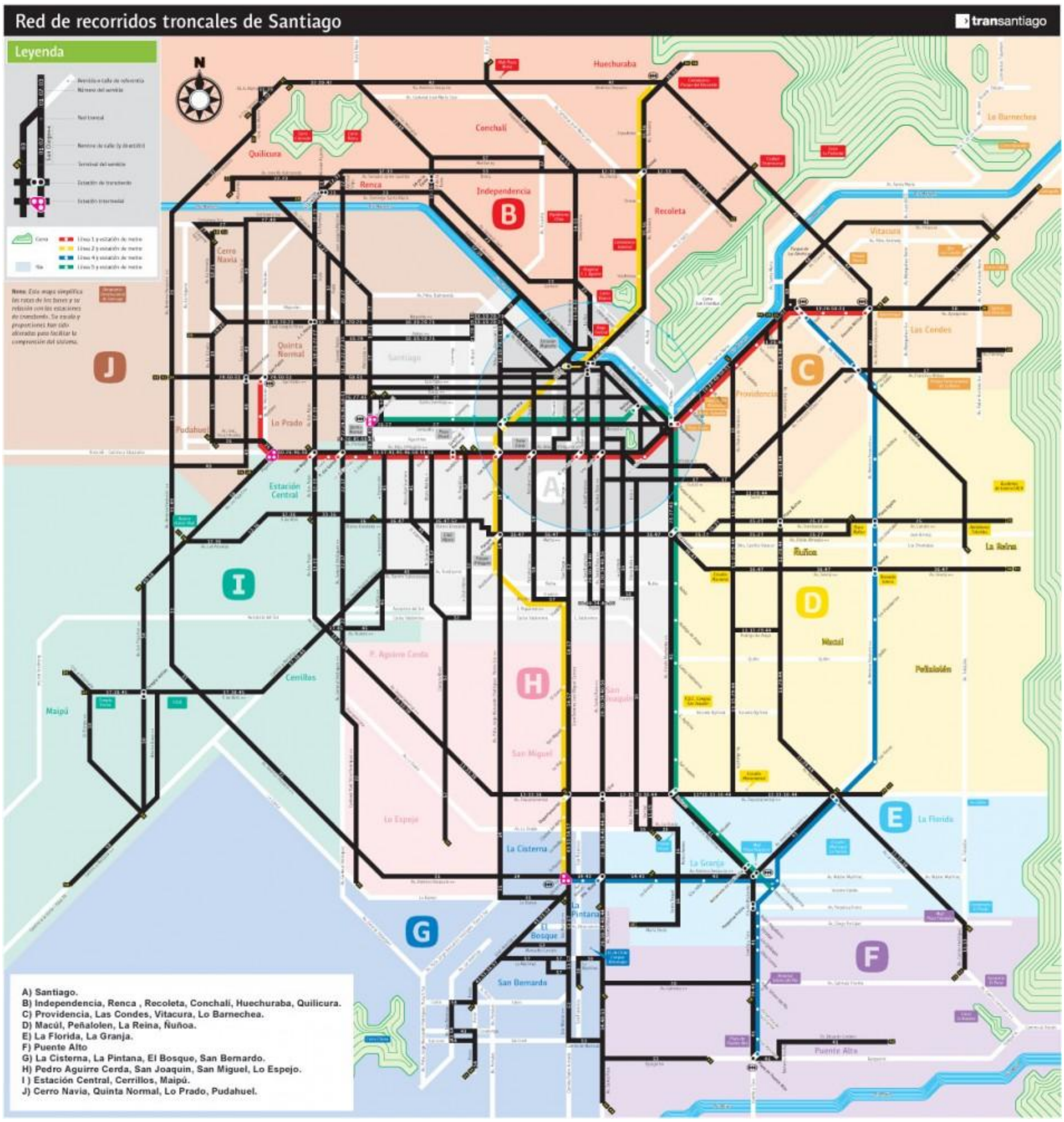


Fig.4.17 – Current Transatiago network [54]

The Transantiago program was an ambitious measure of reorganization of the entire public transport in the city (Metro, bus, shared taxis) integrating all the transport means into a new network. This new network was designed with a trunk feeder model in which the Metro and some new BRT corridors (that had to be already constructed to the inauguration of the new network) had to work as trunk lines and the private bus companies should provide service as feeder lines. The city was divided in 10 zones connected one another through the trunk services while the feeders had to provide service inside each zone.

The most ambitious approach of this whole transport transformation was the implementation stage referred by many authors as a “big bang” implementation because the new system should start operations from one day to another and not gradually like in other cases, producing a lot of confusion between the users since the opening of the Transantiago network. The transformation of the entire public transport in an important and large metropolis like Santiago is not an insignificant task (ITDP, 2007) [7].

At beginnings of 2007 there were not the adequate conditions to initiate the Transantiago program, the infrastructure like the stations and bus lanes were not finished, the number of buses were not enough for the initial demand, the fare payment system was not totally implemented and the educational campaign was not enough for the users (EMBARQ, 2010) [49]. Despite that many elements of the new network were not ready for the inauguration date, the Transantiago system started in February of 2007 and since its opening the system had to deal with serious operational problems and critics from the population.

Fig.4.18 – Transantiago articulated buses [2]

In fact, the implementation of the Transantiago is well known in the world due its difficulties since its inauguration (Pardo C, 2009) [19]. The national and international press had negative reviews of the system and the initial confusion resulted in the destitution of four ministers (ITDP, 2007) [7]. Since its opening the local and national authorities were forced to take measures to solve the problems in the Transantiago, for instance the contracts with the bus operators were renegotiated many times; the number of articulated buses also increased and new metro lines were also implemented.

4.2.6.3. Performance of the system from the technical point of view

Table 4.12 – Score obtained in the BRT standard edition 2014 [16]

Country	Chile	Chile
City	Santiago	Santiago
System	***Transantiago***	***Transantiago***
Corridor	***Avenida Grecia***	***Avenidas Las Industrias, Pedro Aguirre Cerda and Santa Rosa***
Corridor Length (km)	***10***	***15,2***
BRT Basics - Minimum score of 18 points needed	21	22
Service Planning	14	14
Infrastructure	7	7
Station Design and Station-bus Interface	7	7
Quality of Service & Passenger Information Systems	2	2
Integration and Access	5	5
TOTAL 100	56	57
BRT BASICS (MINIMUM NEEDED 18)	21	22
Point Deductions	0	0
Total Score: (about of 100)	**56**	**57**
Classification:	**BRONZE**	**BRONZE**

4.2.6.4. Positive results of the BRT system implemented (From the planning point of view)

Although the difficulties and problems that Transantiago had to deal since its opening it is also important to notice some achievements of this so criticized project. Even with some deficiencies, the new Transantiago network generated some indirect benefits for the city. The number of bus accidents decreased to the half (Muñoz J et al, 2014) [55]. The Transantiago is also helping to the environment and compared with the previous system, there is a considerable reduction of the noise and air pollution, due in part to the lower quantity of public transport vehicles. For instance in 2010 the pollutants emitted by the buses decreased from 50% to 15 % (Holuigue C, 2011) [53]. The improvement in the quality of the air in Santiago is also evident (EMBARQ, 2010) [49]. The Transantiago is also safer for the users considering than now the drivers receive a fixed salary so the competition for passengers have disappeared.

The accessibility and social equity have improved since the implementation of the Transantiago. The articulated buses introduced in the BRT corridors (around 80% of the fleet) are equipped with the correspondent elements for the transport of people with mobility restraints (Muñoz J et al, 2014) [55]. The old bus service could not provide the conditions to transport this sector of the population. Before the Transantiago the students use to be discriminated by the drivers due the reduced fare they had to pay, but with contracted drivers this problem already disappeared (Holuigue C, 2011) [53]. Many people that in past could not pay the metro fare, now they can use it due to the fare integration of the different modes.

Even the population still having a negative perception of the system, the Transantiago had stabilized with the improvements made to the system, the acceptance level has increased (Holuigue C, 2011) [53] and the service provided by the system nowadays is quite good (EMBARQ, 2013) [22]. The Transantiago started providing a lower quality of service than the previous conventional bus service but many performance indicators have improved in the next years, for instance the travel time offered in 2011 was better than in the previous system (Muñoz J et al, 2014) [55]. Even some authors criticized the bing bang implementation of the whole new network, other sources argue that although this approach can produce many problems in the beginning can also produce a solid and sustainable structure for the public transport in the future (EMBARQ, 2010) [49].

4.2.6.5. Negative results of the BRT system implemented (From the planning point of view)

This case study has been more studied due to its failures and subsequent problems rather than for its achievements. Since its opening the Transantiago (excluding the metro) produced a bad image for the users and for the authorities. Some planners consider the Transantiago as the worst public policy ever implemented in Chile (Muñoz J et al, 2014) [55].

Since its implementation the Transantiago faced many problems as consequence of an inadequate design of the system. Especially in the first years, the performance of the new system was not covering the requirements of the population in many aspects as the capacity, frequencies, travel times and comfort. The system started operations with a considerable less quantity of buses this means 4500 vehicles, around 2000 buses less than the initial projection of 6500 buses (Holuigue C, 2011) [53]. The new articulated buses could not reach high velocities due to the bad conditions of the pavement in some corridors.

Until 2010 the number of buses was insufficient, for that reason the commercial speed was not the expected yet (EMBARQ, 2010) [49]. Inside the vehicle and stations, the real time information provided to the users still insufficient. Although all the improvements the authorities implemented in the Transatiago, there is a need to adequate the service offered to the real demand patterns of the population. The Metro is offering a high quality service but the BRT and bus services need to improve to reach high standard levels also. It is needed to overpass the gap between the world class metro and the wheel based services (Muñoz J et al, 2014) [55].

The economic focus of the system before the implementation has led to many of the explained design problems. The starting point for the economic structure of the new system was the approach that the Transantiago had to offer the same fare than the older system, and also this fare should be able to self-finance the operational and extension costs of the system (Holuigue C, 2011) [53]. This economic approach was ambitious because the new system also carried new operational costs resulting from the integration of the different transport modes, and to cover them some budget was retired from other investment areas like the fleet acquisition.

Subsidies were not contemplated in the planning stage but in 2006 the government had to implement a permanent subsidy to the Transatiago in order to compensate some costs. This subsidy is more than 500 USD million per year (EMBARQ, 2013) [22]. A problem that has become common in the bus and BRT services is the fare evasion, produced due to the inefficient control and insufficient off-board payment equipment in many stations. There are loses of around 80 USD million per year because of this problem.

Many of the problems already explained could be avoided with a more efficient management from part of the authorities. In other successful projects like the Transmilenio the authorities created an agency to control and regulate the implementation and operation of the system. For the Transantiago it was just created a committee integrated by different national and local authorities. These staff from different agencies was not able to integrate and regulate a complex project as the Transantiago because they had other main functions to accomplish in their different posts. It would be more accurate to create an agency exclusively dedicated to the control and management of the Transantiago.

4.2.7. BOGOTÁ

4.2.7.1. Presentation of the case study

Table 4.13. – General information of the city and the BRT system implemented

Information of the city		
City:	Bogotá	
Country:	Colombia	
Region:	South America	
Population:	7,76 million	
Size:	1 587 km2	
Modal Division	59 % Public	
	26 % Private	
	15 % Not motorized	
Main transportation system:	BRT	
Other transportation systems:	Conventional bus	
Information of the BRT system		
Name:	Transmilenio	
Inauguration Year:	2000	
System Length:	113 km	
Corridors:	11	
Passengers per day:	2 213 236	
Peak Load:	48 000 pphpd	
Construction cost per km:	12,5 USD million per km	

4.2.7.2. Urban and political context during implementation

Bogotá, the capital of Colombia is a large metropolis with a population near to 8 million inhabitants and with a high urban density of 15 058 inhabitants per square kilometer, a value higher than the most of the cities in South America. Transmilenio, the BRT system implemented in Bogotá it is recognized as one of the best systems implemented in the world and also is considered as the main pioneer of the system because it was the first BRT system implemented in a large metropolis. The success reached by the Transmilenio showed to the world that the BRT technology could be implemented in large and dense cities reaching a high performance comparable even with some metros (ITDP, 2007) [7].

Before the implementation of the BRT system in 2000, the city was suffering complex mobility problems. The public transport was covered by private bus and mini bus companies and similarly to other South American cities, the low quality service offered by these independent companies resulted in disorder, long travel times, pollution and high accident rates (Videira S, 2014) [21]. To solve the mobility problem, in 1997 the local authorities created a transportation master plan that included one metro line, busways and bicycle infrastructure (Filipe L. and Macário R, 2014) [56]. Enrique Peñalosa, the major of the city in that time rejected the plan mainly by its elevated cost. Considering that there were better conditions for a wheel based solution and inspired in the BRT system of Curitiba, the Major and his team decided to implement a BRT system instead than a metro. With a new transportation plan developed and with financial support from part of the national government and private sector the first stage of the Transmilenio system was designed and implemented in just three years. The idea was to "equate the TransMilenio system to the life-blood of the city with the BRT corridors representing the life-giving arteries" (ITDP, 2007) [7]. The BRT system was the main component of this new strategy, but this new plan had also other measures that gave more priority to the pedestrian and the non-motorized travels and at the same time trying to reduce the use of private vehicles. Some strategies included parking restrictions and higher fuel taxes (EMBARQ, 2013) [22].

Fig.4.19 – The Transmilenio system [2]

The first phase of the Transmilenio system was opened in December 2000 and simultaneously was constructed 300 km of new bikeways and traffic was retired from around of 120 km of roads (Videira S, 2014) [21]. Between 2005 and 2006 was implemented the Phase II of the project through the construction of three new corridors increasing the capacity of the system. Since its opening the new BRT system gained acceptance between the population, for instance the first years the number of users increased considerable, between 2007 and 2011 the total daily demand increased around 350 000 passengers without any extension of the system (Hidalgo D. et al, 2013) [57]. In 2012 were implemented another two new corridors which belong to the Phase III of the project.

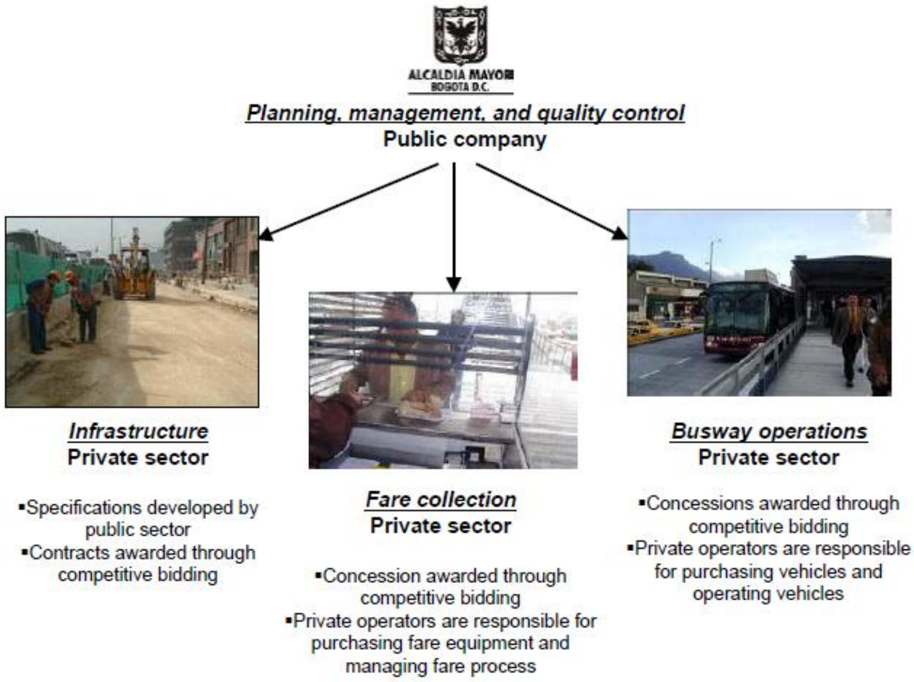


Fig.4.20 – Business structure of the Transmilenio system [7]

The structure of the TransMilenio system is composed by private entities that are in charge to provide the service and by the TransMilenio S.A., an entity created by local authorities for the control and regulation of the system, included the private operators (Figure 4.20). The trunk BRT corridors are fed by conventional bus service contracted by the local authorities. Before the implementation of the project, many bus private companies protested against the new system but now many of these private operators are providing service in the BRT system and thanks to the efficient business structure they are receiving considerable profits.

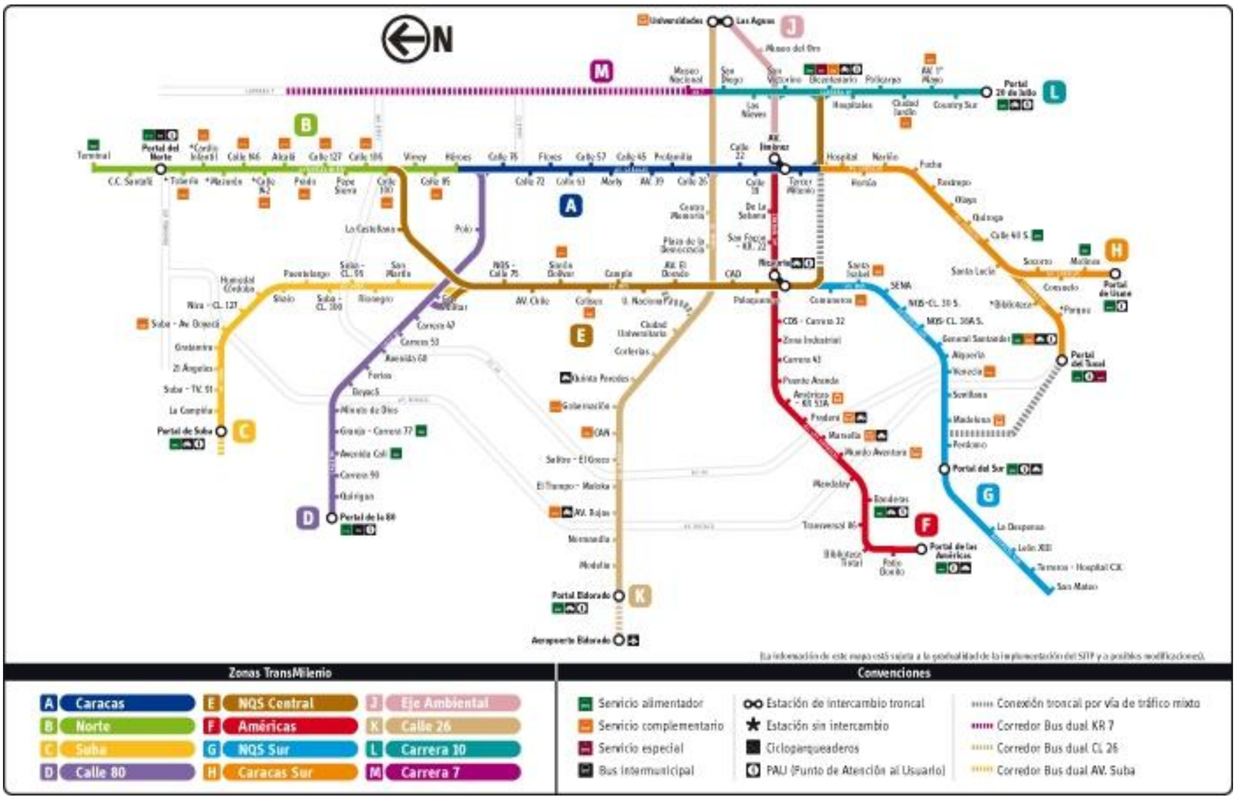


Fig.4.21 – Transmilenio network map [58]

The TransMilenio system has implemented three phases of a total of six phases and currently has 113 km of BRT corridors and 135 stations, reaching a high performance translated in around 2,2 million of daily passengers and achieving an incredible value of 48 000 passengers per hour per direction. At present the TransMilenio covers the 26% of the total public transport trips but the other 74% is covered by private bus companies which provide a deficient service (Hidalgo D. and King R, 2014) [59].

Since 2008 the authorities started a plan intended to convert the disorganized public transport into an organized and regulated service but this plan also contemplates the incorporation of new mass transit alternatives in the future, like the metro. Lately the debate about these new alternatives has been reducing the attention and the efforts in the progress of the BRT project.

4.2.7.3. Performance of the system from the technical point of view

Table 4.14 – Score obtained in the BRT standard edition 2014 [16]

Country	Colombia	Colombia	Colombia	Colombia	Colombia	Colombia	Colombia
City	Bogota	Bogota	Bogota	Bogota	Bogota	Bogota	Bogota
System	***TransMilenio***	***TransMilenio***	***TransMilenio***	***TransMilenio***	***TransMilenio***	***TransMilenio***	***TransMilenio***
Corridor	***Autonorte***	***Suba***	***Caracas***	***Calle 80***	***Americas***	***NQS***	***El Dorado***
Corridor Length (km)	***11,6***	***9,6***	***7,3***	***7,5***	***12,7***	***8,6***	***10,8***
BRT Basics - Minimum score of 18 points needed	32	33	32	33	32	33	33
Service Planning	24	24	24	24	24	24	21
Infrastructure	9	11	9	9	11	11	11
Station Design and Station-bus Interface	10	10	10	10	10	10	10
Quality of Service & Passenger Information Systems	5	5	5	5	5	5	5
Integration and Access	6	9	6	8	9	9	9
TOTAL 100	86	92	86	89	91	92	89
BRT BASICS (MINIMUM NEEDED 18)	32	33	32	33	32	33	33
Point Deductions	-3	-3	-3	-3	-3	-3	-3
Total Score: (Max = 100 points)	**83**	**89**	**83**	**86**	**88**	**89**	**86**
Classification:	**Silver**	**Gold**	**Silver**	**Gold**	**Gold**	**Gold**	**Gold**

4.2.7.4. Positive results of the BRT system implemented (From the planning point of view)

The success of the TransMilenio system in a large and crowded city like Bogotá showed to the world that an efficient-planned BRT system can provide high quality services reaching performances even comparable with high-quality metro systems, overpassing the capacity offered by LRT systems. The BRT planning guide briefs this impact in the next way: “It was not until the year 2000, when Bogotá’s TransMilenio was introduced, that an entire new level of capacity was possible” (ITDP, 2007) [7].

The TransMilenio system represented a fast and reliable solution for the mobility problem in Bogotá, a city that was looking for a rail based solution for around sixty years but without any success. The major Peñalosa and his team designed and implemented the Phase I of the system in just three years, and since its opening the system started to produce different kind of benefits.

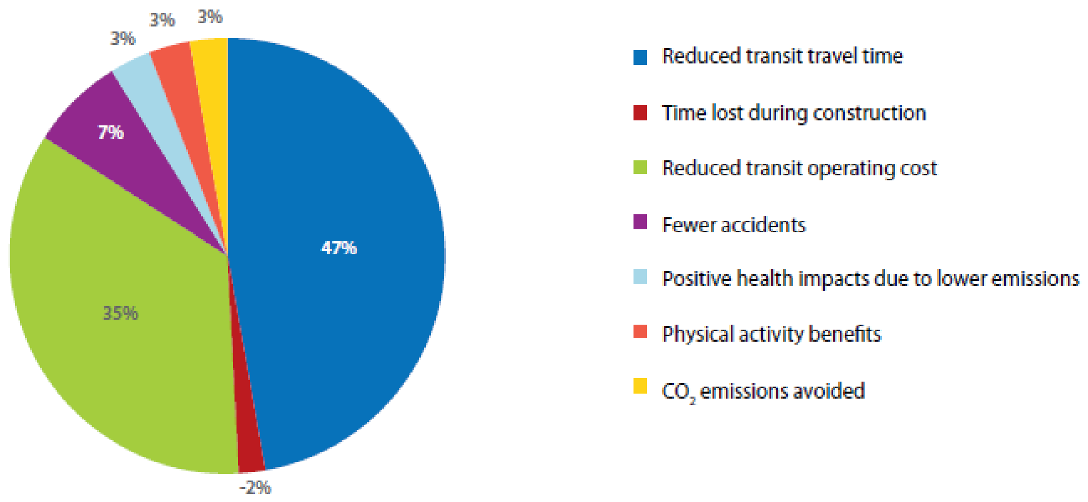


Fig.4.22 – Distribution of the benefits for the users produced by the TransMilenio (EMBARQ, 2013) [22]

Since its implementation the quantity of air pollutants decreased five times and the number of accidents in some corridors declined in 90% (Videira S, 2014) [21]. For instance, in the trunk BRT corridor “Caracas” there was a reduction of 39% in injuries and 48% in fatalities (EMBARQ, 2013) [22]. In the same corridor the criminal rates fell down around of 85% between 1999 and 2002 and with the implementation of the system have been produced more jobs than lost jobs (Hidalgo D. et al, 2013) [57]. Each year the Transmilenio’s users save around 134 USD in travel costs and around 325 hours in travel times (ITDP, 2007) [7].

The social impact is also notable because the most of the BRT users are from low and middle income groups of the society. The TransMilenio also provides jobs for vulnerable sectors of the society though re-insertion programs.

Similar to Curitiba the commercial and residential development along BRT corridors is remarkable. Due to the accessibility provided by the system, many schools and malls have opened near to the corridors. Studies also show that land prices close to the different BRT lines have increased during the last years.

Contrary to the rail based systems (LRT and Metro) an efficient BRT system could not require subsidies and the TransMilenio demostrated that a BRT system could be a profitable business for the private and public sector. A cost-benefit analyzes following the EMBARQ CBA methodology for the Phase I and II of the TransMilenio for the period 1998-2017 had as result a benefit-cost ratio of 1.6, showing that the system is producing profits (EMBARQ, 2013) [22].

4.2.7.5. Negative results of the BRT system implemented (From the planning point of view)

The system is reaching its maximum capacity because the ridership has been increasing considerably until 2012. Some trunk lines are working at 80% of its capacity during peak hours and at 70% of its capacity the rest of the time, and this is producing overcrowding in some stations (ITDP, 2007) [7]. This is affecting the quality of the service offered to the users especially to them with mobility restraints. The passenger overload could be noticed inside the vehicles and inside the stations also (EMBARQ, 2010) [49]. This problem is due in part to the planning of the service considering a value of six persons per square meter (Pardo C, 2009) [19].

The user’s satisfaction is declining during the last years. For instance according to surveys in 2001 the TransMilenio had a score of 4.8/5.0 but similar surveys made in 2010 showed that the satisfaction score decreased to 3.0/5.0 (EMBARQ, 2013) [22]. The system is not providing the same quality of service of the first years and the users complain about crowded vehicles, low frequencies in trunk and feeder lines, delayed services, insecurity and steeling inside the system (Hidalgo D. et al, 2013) [57]. Lately there is a modal share tendency oriented to the private vehicles. In 2012 the use of private vehicles increased from 15% to 18% and the use of public transport decreased from 71 to 63 % (Hidalgo D. and King R, 2014) [59]. There is a need to make some improvements in these aspects.

5
APPLICABILITY CONDITIONS FOR THE SUCCESSFUL IMPLEMENTATION OF BRT SYSTEMS

5.1. INTRODUCTION

Firstly it was studied the origin of the BRT concept, its evolution through the last decades and the importance that this alternative has achieved in the urban mobility perception around the world. Following the methodology adopted, then it was analyzed extensively the different types of BRT systems, their components and their characteristics. During that step it was comprehended the main advantages and disadvantages that the BRT presents compared with the rail based systems. Afterwards different BRT projects implemented in cities of different regions of the world were studied. In order to obtain independent criteria, we selected BRT projects of different urban contexts and with a wide range of results and impacts over their respective cities.

During all these previous steps important and interesting findings were obtained which provide solid criteria to establish important conditions and considerations to take into account during the different stages of any BRT project. The literature review provided also important concepts that were analyzed during the study of these different implementation cases. As it was established, the main objective of this work is to offer specific concepts that could help planners and authorities to analyze the viability of a BRT project in their specific contexts.

5.2. CONDITIONS FOR THE SUCCESSFUL IMPLEMENTATION OF BRT PROJECTS

To present the findings in a simple way, it was required to organize and separate them into the different planning areas they belong. Some authors and institutions provide recommendations for the implementation of BRT systems but they do not present those concepts following a systematic order, normally the recommendations are divided just by the stages of the different projects. In this work the results and considerations were organized in six areas or categories that represent the most important parts of any BRT project (Table 5.1). These six categories have a relationship between them and they are following a top-down order (Figure 5.1). This means that the considerations go from the decision-making levels until the public level (users) trying to show the impact that one category will produce over the next one.

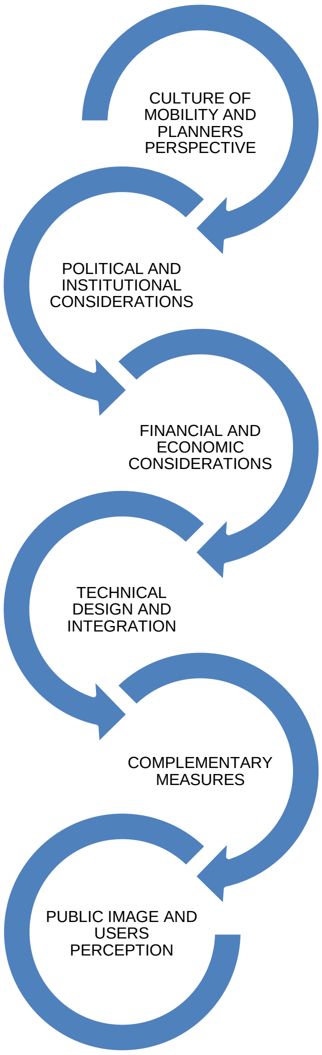


Fig.5.1 – Top-down perspective of the BRT implementation process

5.2.1. Culture of mobility and planners perspective

Firstly the city planners and authorities must define their mobility priorities between the pedestrians or the vehicles, between the public or the private transport because this perspective is going to influence the way they conceive and implement any massive transportion system, in this case the BRT system. A strong automobile culture in authorities and users is going to reduce the viability that a public transport project could have. The mobility perspective of the planners and local authorities is going to affect all the stages of any BRT project, even the perception of a BRT system as a valid alternative.

A pedestrian and public transport oriented focus instead of a private vehicle oriented focus is needed to establish the ideal initial scenario for the implementation of a BRT system. Experience shows that during the different stages of a BRT project there will be moments where the authorities will have to decide between the public or the private transport, and this will affect the final results of the project. In projects where the authorities gave priority to the private vehicles, the BRT presented problems in the infrastructure provision, accessibility, implementation times, extra costs and lack of NMT provision.

There is also important the acceptability that the BRT concept has according to the region where could be implemented. The election of a rail based alternative or a wheel based alternative is influenced by the cultural references. In general in the most developed regions like Europe or United States the LRT and Metro have a considerable favoritism over the BRT alternative nowadays but on the other hand in developing regions like South America the BRT have been adopted and boosted as a cheaper but valid alternative. There are many rail bases systems in large cities of developing countries but there are few examples of BRT systems implemented in developed countries. This cultural barrier can affect the election and subsequent development of a BRT project in a developed region like Europe, where the rail bases solutions are conceived as better alternative than the wheel based systems.

5.2.2. Political and institutional considerations

The political support from some relevant public leader is a common factor in the implementation of successful BRT projects. It is required some important authority who boost the system since the beginning. Both majors of Curitiba and Bogotá are recognized as the main promoters of the successful BRT systems in their respective cities but in other cases the support came from other authorities who convinced their majors to implement a BRT system. The most successful systems have been boosted by local authorities as a major, the responsible of the environment or transport department or by a project team. This political support is a key factor to overcome initial obstacles and criticism but also provide an easier coordination between all the institutions involved in the project. On the other hand some BRT systems had problems when there was not a political support from part of the local authorities.

This political commitment must be complemented by a technical knowledge about the BRT solution. The technical knowledge of the concept helps to answer any doubt that some sectors of the population could have. There must be some project team behind the political leader supporting the system. This team must provide the base of knowledge needed to make of this project a reality. Many authorities have not experience with BRT systems, so the team must be composed by local authorities and by external consultants. Nowadays there are many planning institutions and international organizations that promote this system and offer their cooperation for the implementation of BRT projects.

During the design stage it is needed the creation of some institution or agency dedicated exclusively to the management, control and coordination of the BRT project during the planning, implementation and operation stages. The technical project team must become part of this new agency but now has power to deal with different issues like the negotiation with the different actors involved in the implementation. Once the first implementation stage is finished, the agency must manage the operation of the system and also the subsequent stages that are going to be implemented. A BRT system is not an isolated project and the impact this system is going to produce over the rest of the transport is considerable, so this agency becomes so important to achieve the expected results. The best BRT systems have created this kind of exclusive entity but in the cases where the management and control of the entire BRT project was derived to different authorities of different departments, the result was a poor coordination and confusion translated in deficiencies and problems in the BRT system.

5.2.3. Funding and economic considerations

Compared with the rail based alternatives the BRT systems face less financial barriers due to its considerable lower cost. Normally the local or municipal budget can afford the design and implementation of a BRT system, even cities with small budgets can fund the first stages of a BRT project. The money can also come from the national government. In some cases where complex BRT systems are going to be implemented, external sources can participate in the funding of the system, like international development banks or the private sector. In many cases there was a public-private association where the local authorities implemented the infrastructure and the private sector provided the vehicles and some components. Once the final design of the system is done, must be avoided any cut in the budget during the implementation stage. These cuts will affect the quality of the system and consequently its performance, so in these situations it's better to search for extra funds from some source and implement the system with all the equipment and components that were planned in the design stage. The initial performance of the system is a key factor for the success or failure of the entire project.

With an efficient business model, a BRT system could produce earnings instead of deficit for the local authorities. In the best situations a BRT system should cover the operation, maintenance, improvements and extension costs with the profits generated by the fare revenues, offering an affordable ticket cost for the users. Due to different factors this ideal scenario is difficult achieve. The fare offered to the users must be the result of a technical study about the real cost of the services that the new system is going to offer. It is a wrong and unrealistic action to establish the business model of the new system with the idea that the fare must be the same that the previous conventional bus service.

During the planning and design stage must be considered every possible extra cost that the system could need to cover during and after the implementation. This must be done in order to avoid the introduction of any unexpected subsidy from part of the authorities. The most efficient BRT systems do not require subsidies because the fare revenues are covering all the expenses, even complex systems like Bogota and Curitiba do not require subsidies. A system without the need of subsidies can afford social measures like reduced fares for some sectors of the population or insertion programs.

5.2.4. TECHNICAL DESIGN AND INTEGRATION

The implementation of a BRT system is going to produce a large impact over the public and private transport, but also over the urban context. For this reason a new BRT system must be adapted and integrated with the current mobility network. Successful projects implemented the new corridors over the main avenues and highways that the city already had, this is an important consideration that must be contemplated during the feasibility study. The BRT cannot work independently from the rest of the public transport; the conventional bus service (public or private) must be reorganized in order to complement the new system. Normally the BRT corridors work as trunk lines while the conventional bus services work as feeder lines. In cities that already had another massive systems, the new BRT must be integrated with all the other alternatives and this integration must be visible for the user (physical and fare integration). With an efficient integration all the transport modes can get benefits and problems like overcrowding can be solved. The competition between the different modes must be avoided at any cost.

The initial operation of the system is the most critical stage of any BRT project. The success of the entire project depends mainly of the performance and public acceptation of the system when the first corridors start operations and for that reason all the components must be ready for this moment. There is a strong dependence between the different elements of the system so the failure or missing of one component will affect the other components and consequently it will influence negatively to the performance of the whole system. The gradual implementation of the components after starting operations is not a viable option for cities with high densities and with serious mobility problems. When a rail based system is going to be implemented, this receive such importance that is not conceivable the idea to start operations with inadequate components. In order to provide a high quality system, the new BRT system must receive the same level of importance that any other rail based system.

The experience demonstrated that the implementation of a BRT system must be made gradually. Firstly should be implemented one or two corridors with all their components prepared to provide an initial high performance and the next corridors will be implemented in the next stages of the project.

The initial stages must attract enough ridership to create a solid economic base to implement the next stages but also this approach will minimize the impact of the project over the urban context. Realistic deadlines for the implementation should be adopted and the implementation stage must not be rushed by the private interest of some politicians who wants the system finished inside their governance periods.

The implementation of a BRT system from one day to another with the respective reorganization of the rest of public transport is something so difficult to reach that this approach must be discharged. This bing-bang implementation approach can produce a considerable negative impact over the urban environment that can be so complicated to improve during many years.

In some regions like Latin America, the conventional bus services are provided by private companies or syndicates who have the monopoly of the public transport and this sector tends to oppose to the implementation of a BRT project. It is important to involve these operators in the operation of the new system in order to reduce the conflicts that they could produce. Through a competitive bidding process the best ones of these companies can be selected to provide part of the service in the new system. This requires a solid business model where these companies can receive considerable profits and better work conditions.

The overcrowding during peak hours is a problem that is becoming common in the most of the BRT systems, included the full systems like the Transmilenio in Bogotá. It seems that in large metropolis with high urban density and accelerated growth, there will be a moment where even a full BRT system could reach its maximum capacity. To delay as much as possible the overcrowding symptoms it required a high quality design like articulated and bi-articulated vehicles, normal and express services (two lanes per direction), large stations, high velocities and others.

5.2.5. Complementary measures

The study of different BRT projects showed that this system is going to produce urban development on the surface along the corridors, normally represented in the increase of the land value. This is expected in systems on the surface like the LRT or BRT, even in areas already highly urbanized. It is recommended the implementation of Transit Oriented Development (TOD) measures in order to manage and control the development that the corridors are going to produce. With TOD policies, the local authorities can use the BRT routes as a tool to organize the expansion of the urban sprawl and at the same time, they can boost the revitalization of some of these areas. Without this kind of measures, the result can be a disorganized development propelled by the private sector like the real estate market or the business sector. The TOD measures should be implemented since the beginning of the project to get better results.

With the use of TOD policies, should be also implemented Not-Motorized Travels (NMT) infrastructure integrated to the new BRT system. The bicycles must be promoted as a valid transport alternative and not just for recreational purposes. With bicycle infrastructure integrated to the system, the catchment area can be incremented considerably around the stations, for that reason should be provided bicycle parking in the different stations. The NMT represents a good opportunity for the planners because the provision of this kind of equipment is lower than the rest of the BRT infrastructure.

For a system on the surface like the BRT, the accessibility to the stations is an important factor for the users and for the image of the system. For the passengers the near areas around the stations should be attractive, safe and easy to access, that means areas where the pedestrian have the priority above the cars circulation. The private vehicles must be removed from these areas through measures like fines or restricted number of parking spaces.

5.2.6. PUBLIC IMAGE AND USERS PERCEPTION

The success of the entire project is related in part to the promotion of the system and the information campaign especially during implementation and during the initial operations. It should be destined funds for the communication of the new transport plan to the users, stakeholders and other actors affected by the project. In order to overcome the negative connotation of the buses, education campaigns and publicity must be used to explain to the new users that the new BRT system is a higher quality alternative than the conventional bus services. Also the future passengers must understand how to use the system, especially in cities without previous massive transportation systems. This information campaign has also the intention to avoid the opposition of some sectors. The authorities have to convince to the other transport operators that the new BRT is a complement for the whole transport system and that is not going to compete with them. The real estate market and the business owners can see the new BRT as a treat but with an adequate education campaign they can realize that the system will be an advantage and not a disadvantage for them. Without an adequate promotion strategy, even a system with an adequate design could not reach the expected results.

The public acceptance and user satisfaction during the first operations of the new BRT system is crucial for the future success of the project. With a high quality service and with an efficient education campaign, the new BRT system will attract the expected ridership. During the first stage the new system can receive the approbation of the users and this initial positive impact is going to create the adequate scenario for the subsequent implementation of new corridors. An initial negative image of the system will become a barrier difficult to overpass during the next years. Without the continuous improving of the system the initial user satisfaction could decrease during the years. After the implementation of the first stage of the project, funds must be destined to user satisfaction surveys and technical performance evaluations to identify the areas in which the system could be failing. Some part of the budget should be dedicated exclusively to the continuous implementation of improvements to the BRT system with the intention to keep a high satisfaction level and a good public image.

5.2.7. THE APPLICABILITY CONDITIONS

Table 5.1 – Matrix of the applicability conditions for the successful implementation of BRT projects

<table>
<tr><th></th><th>Conditions</th><th>Planning and design stage</th><th>Implementation and operation stage</th></tr>
<tr><td rowspan="2">CULTURE OF MOBILITY AND PLANNERS PERSPECTIVE</td><td>Pedestrian Oriented Perspective</td><td colspan="2">Authorities’ priority must be pedestrian over vehicles
The focus is to improve the public transport rather than the private car infrastructure (automobile culture)</td></tr>
<tr><td>Acceptation of the BRT concept</td><td colspan="2">The BRT should be conceived as a valid alternative like the rail based systems
Cultural and regional barriers against BRT systems must be overpassed in regions where this system has a negative perception</td></tr>
<tr><td rowspan="4">POLITICAL AND INSTITUTIONAL CONSIDERATIONS</td><td rowspan="2">Political support to the project</td><td>It is so important the political support from some relevant authority to the BRT project</td><td>Once the first stages are already working, the next authority in charge must keep the political support for the next stages of the project.</td></tr>
<tr><td colspan="2">This support can come from the major, head of transport department, responsible for environmental issues, some adviser or any local authority with relevant power</td></tr>
<tr><td>Technical knowledge of the system</td><td colspan="2">It is important the establishment of some technical project team behind the political leader supporting the system. This team must provide the base of knowledge needed to make of this project a reality.
Many authorities have not experience with BRT systems, so the team must be composed by local authorities and by external consultants.</td></tr>
<tr><td>Public entity for the control and management of the BRT system</td><td>It must be created a public agency dedicated exclusively to the BRT project
This new institution must have enough power to negotiate with the different actors and future operators during the design</td><td>The agency has to control the different issues of the implementation process and must have the capacity to deal with possible problems that could appear during the different stages</td></tr>
</table>

		stage	Also the agency is responsible for the management of the system and for the supervision of the different operators This entity is in charge of the maintenance of the system and the application of continuous improvements
		Since the election of the BRT alternative, the agency is responsible for the financial management in the different stages This entity must implement and respect the business model planned for the system	
FINANCIAL AND ECONOMIC CONSIDERATIONS	*Financing*	The design stage should have enough funds to cover salaries, technical studies or surveys required for the planning of the BRT system.	Must be avoided any cut in the budget during the implementation stage. In these situations it's better to search for extra funds from some external source in order to implement the system as it was planned initially
		Preferably the whole funding for the new BRT system should come from municipal or national budget With reduced local budgets the authorities can fund the project with a public-private association in which the municipality can provide the infrastructure and the private sector can provide the vehicles or some components	
	Efficient business model	Must be analyzed every possible extra cost that system could face during and after the implementation The business structure must be planned in order to avoid any subsidy for the new	The fare offered to the users must be the result of a technical study about the real cost of the services that the new system is going to offer Any subsequent change to the fare must be

		system	studied and justified with technical studies
		In the best scenario, a BRT system should cover the operation, maintenance, improvements and extension costs with the profits generated by the fare revenues, offering an affordable ticket cost for the users.	
TECHNICAL DESIGN AND INTEGRATION	*Integration, reorganization and mobility context*	The design must integrate the new system to the rest of transport modes Conventional bus services (private or public) should be reorganized in order to complement the new BRT system.	Possible extensions to the BRT system must not create obstacles in the operation of other transport modes. Physical and fare integration with the rest of the public transport is important for the performance of the BRT system
		Due to the large impact the system could produce over the public and private transport, the new BRT must be adapted to the current mobility context and should not be conceived as an isolated system. Successful projects implemented the new corridors over the main avenues and highways that the city already had. Normally the BRT corridors work as trunk lines while the conventional bus services work as feeder lines. The competition between the different transport alternatives must be avoided.	
	Components	The new BRT system must be planned with high quality components in order to achieve a high quality service	The system should not start operations without all the components implemented according to the design It is not recommendable a gradual implementation of the components after starting operations
		The success of the entire system depends mainly of the performance and public acceptation during the first stage of the project The lack or failure of one of the BRT elements is going to affect the operation of the	

		other components and consequently the system performance.	
	Gradual implementation	The BRT system must be planned to be implemented gradually in different stages. Studies should provide realistic implementation deadlines for the different corridors.	Firstly should be implemented just one or two corridors to minimize the impact of the project over the urban context The initial stage must attract enough ridership to create a solid economic base to implement the next corridors
	Involvement of stakeholders	In regions where the bus services are provided by private syndicates, it is important to involve these operators in the project to avoid opposition from this sector Through a competitive bidding process the best ones of these companies can be selected to provide part of the service in the BRT system.	
	System capacity (Overcrowding)	To avoid where possible the overcrowding problems, some improvements should be introduced to the system like bi-articualed vehicles, express services or higher frequencies during peak hours.	
COMPLEMENTARY MEASURES	*Transit Oriented Development (TOD)*	There must be applied TOD policies since the first operations of the system with the intention to manage and control the development along the BRT corridors TOD must be implemented even in areas already highly urbanized. These kind of policies can be used as a revitalization tool for forgotten areas	
	Not Motorized Travels (NMT)	NMT must be conceived as a valid transport and not just as a recreational mode. With bicycle infrastructure integrated to the system the catchment area can be increased considerably around the stations. Bike ways and parking infrastructure should be considered in the design.	
	Another policies	In order to attract users from the private transport, some measures must be implemented to discourage the use of the private vehicle. Measure like fines, restricted number of parking spaces or some kind of restriction for the circulation of private cars	

		These kinds of measures can produce opposition, especially in countries with a strong automobile culture. Informative and educational campaigns must help to implement these policies	
PUBLIC IMAGE AND USERS PERCEPTION	*Promotion and information campaign*	Must be planned informative strategies for the communication of the new transport configuration to the users, stakeholders and other actors affected by the new BRT system. A strong education campaign will teach to the future users how to use the system, especially in cities without previous massive transportation systems. The marketing strategy must promote the system as a higher quality alternative than the conventional bus services	The education to the new users must not be overestimated. The lack of information campaigns to the future users is going to affect negatively the initial ridership attracted by the system Any future change or improvement made to the BRT system in the future should have also an informative strategy for the users
	Public acceptability	The public acceptation and user satisfaction during the first operations of the new BRT system is a key factor for the future success of the entire project. This is possible to achieve with a high quality service and with an efficient education campaign. An initial positive impact is going to create the adequate scenario for the future implementation of new corridors. An initial negative image of the system will become a barrier difficult to overpass during the next years	
	Continuous improvements	During the design stage, should be considered a budget source for the future introduction of improvements to the system. With an efficient business model this funds can come from the fare revenues	The user’s satisfaction and the technical performance of the BRT corridors must be monitored continuously through surveys and studies to identify areas in which the system could require improvements.

6
THE CASE OF COIMBRA: IS A BRT SYSTEM A VIABLE SOLUTION FOR THIS CITY?

6.1. INTRODUCTION

Although nowadays the BRT systems are conceived as a valid alternative to transport people massively, the experience showed that in the most of the cases the BRT systems have been implemented in developing countries with low funding capacity. That doesn't mean that the BRT concept has not been implemented in developed regions but as it was noticed before, the number of implementation examples in regions like United States or Europe is relatively lower than in regions like Latin America or Asia.

Historically European cities have shown a preference for the rail based systems. With "normal" funding conditions the most of these developed cities could afford the implementation of a LRT or Metro system in their transport networks but with the financial crisis that is affecting some European countries during the last years, many cities now don't have enough budgets to afford one of the rail based alternatives. Coimbra is a good example that illustrates this situation.

Coimbra is a relatively small city with a population just over 100 000 inhabitants but is one of the most relevant cities in Portugal. From the planning point of view this city constitutes an interesting case to analyze the viability of a BRT system because the authorities of Coimbra were implementing a LRT system but due to economic reasons they had to stop this project. The LRT system received the name of "Sistema de Mobilidade do Mondego" or SMM. The project is stooped since 2010 and nowadays many sectors of this city are considering if a BRT alternative could be a viable solution. The local authorities and city planners are dealing with the next dilemma: Is it better to wait (maybe for several years) for funds for the SMM project or is more favorable to adopt a cheaper alternative like a BRT system? In this chapter will be analyzed this problem with the criteria obtained previously.

6.2. THE SMM PROJE CT (SISTEMA DE MOBILIDADE DO MONDEGO)

The SMM is a project about the implementation of an LRT system or Tram-train in order to provide public transport to the urban area of Coimbra but at the same to connect this municipality with other towns outside the city, in the suburban area (Figure 6.1). The network is composed by two lines: The Lousã Line that is the main and longest line and this covers urban and suburban areas. This line goes from Coimbra-B station until Serpins station. With this line is intended to reactivate the public transport offered by a train line that was interrupted more than 30 years ago. The second and shortest line is the Hospital Line which should provide service just in the urban area.

Fig.6.1 – The SMM project [60]

The implementation of the SMM project was planned in two main stages: first stage comprehended the implementation of the Lousã Line and the acquisition of the vehicles. Subsequently the Hospital line should be implemented in the second stage of the project.

In 1996 it was created the “Metro do Mondego” agency, an entity funded with public budget. This agency was in charge initially of the design and implementation of the SMM project and subsequently this entity should also manage the system after starting operations. All the studies and the final design of the project were made by this agency and according to the plans the system had to start operations in 2014. The technical details of the system are summarized in the next table:

Table 6.1 – Technical specifications of the SMM project [60]

2	Number of Lines
10,7 km	Length of the Lousã Line (Urban service)
26,9 Km	Length of the Lousã Line (Suburban service)
4 km	Length of the Hospital Line
20	Number of stations in the Lousã Line (Urban service)
13	Number of stations in the Lousã Line (Suburban service)
10	Number of stations in the Hospital Line
1	Underground station (in Celas)
2	Number of tunnels in the urban area of Coimbra
6	Number of tunnels in the Sururban area
535 m	Average distance between stations in the urban service of Lousã Line
1 921 m	Average distance between stations in the suburban service of Lousã Line
364 m	Average distance between stations in the Hospital Line
3	Number of municpality united by the system
80 – 90 km/h	Maximum speed expected
1,435 m	Distance between rails (European gauge)
2,65 m	Approximate width of the vehicles
42 m	Maximum length of the vehicles
170	Minimum number of places for passengers in the suburban service
90 - 110	Minimum number of seats for passengers in the urban service
12	Number of pontoons
9	Number of bridges
5	Number of underpasses
11	Number of overpasses

The system was planned to provide service in the urban and suburban areas. The urban service was covered by the Hospital Line and by the Lousã Line from the station Coimbra-b until the station Sobral de Ceira. On the other hand, the suburban service comprehends only the Lousã Line from the station of Sobral de Ceira until Serpins station. All the urban service was designed to have two parallel rail lines (one rail per direction) except the last four stations because since the station of Alto de São João, the two rail lines joint in just one rail line. This is justified because in the suburban area the demand is considerable lower than in the urban area.

6.3. THE HISTORY OF THE PROJECT AND THE CURRENT SITUATION

The agency Metro do Mondego, that was elaborating studies about the project since 1997, started the implementation in 2008. Around the city many areas in the urban sectors where the LRT lines were intended to pass were expropriated. Some important interface stations were also finished in December of that year. In 2010 it was removed an old train line that connected Coimbra with Lousã because the SMM was supposed to use this route with the new Lousã Line. In their place it was provided a temporary bus service connecting Coimbra with Lousã until the first stage of the SMM project were completed.

In the same year, the agency started the processes of leveling and preparation of the channel space between the stations Carvalhosas and Serpins, in the suburban area. Ten months later the works were stopped due the lack of funds as a result of austerity policies adopted by the national government. In

2010 Portugal was feeling the problems generated by economic crisis that started in 2009 and this affected the funding of the SMM project. In 2011 the national authorities tried to extinguish the agency Metro do Mondego because this entity had an operational cost of 700 000 Euros per year, but finally the agency was not dissolved. To that point were invested around of 100 million Euros. There were made many expropriations, were constructed many stations and the soil of 27 km of the Lousã Line was prepared for the subsequent implementation of the rails.

Fig.6.2 – Works made in the Lousã Line [60]

Nowadays the SMM project is waiting to be reactivated and the economic situation in Portugal still being not favorable. It doesn’t seem that the SMM is going to be reactivated in the near future and many important voices in Coimbra and Portugal are aware of that. During the last years many urban planners started to look for a solution to this problem and in this context the BRT started to emerge as a valid alternative to be analyzed. As an article titled “Why not a Busway in the Lousã Line” of “Transportes em revista” (a Portuguese magazine about urban mobility) noticed in 2014: “Despite that the economic and financial situation of the country does not allow, for now, the implementation of a light rail system, it could be possible to guarantee the mobility of the population of the municipalities of Coimbra, Miranda do Corvo and Lousã, using the same space-channel and with a much lower investment. One solution may be to adopt a road transport system with dedicated lanes, usually called BRT, BHLS or Busway, and later, depending on demand needs, could be reconverted to a light rail system” (Moura Carlos, 2014) [61].

Fig.6.3 – Conference about a Busway Alternative for Coimbra (2016) [62]

More recently, in 2016 the same magazine organized a conference in Coimbra about the viability of a possible BRT solution (Figure 6.3). Local authorities, transport planners, and other sectors from the population assisted to that conference [62]. During the conference many voices agreed with the fact that a BRT could be a solution for the system but the main opposition that the BRT concept received was the performance of the system in the suburban areas were the LRT system was intended to achieve high velocities in sections with high slopes and with the presence of tunnels.

6.4. DOES COIMBRA ACCOMPLISH THE CONDITIONS FOR THE IMPLEMENTATION OF A BRT ALTERNATIVE?

In order to answer this question in the most appropriate way, it is important to remark the next considerations obtained in the previous points of this chapter:

- Is not being compared both alternatives (LRT or BRT) to see which one is the best for Coimbra. The SMM project is the result of years of planning and this solution seems to respond adequately to the transport requirements and transport planners argue that with favorable economic conditions the SMM project should be implemented according to the initial planning.
- The question must be answered considering the works already done, the current economic situation and urban reality of Coimbra. In the current situation, could a BRT be implemented in Coimbra successfully? Could a BRT system be adapted to the initial design of the SMM project?
- Finally it is important to notice that any solution adopted must satisfy the actual transport requirements of the regions covered by the SMM project.

With the criteria obtained in the previous chapters of this work (Table 5.1), it was elaborated the next table:

Table 6.2 – Applicability conditions for a BRT alternative in Coimbra

	Conditions	In the current situation, does a BRT alternative accomplish the conditions?	Observations
CULTURE OF MOBILITY AND PLANNERS PERSPECTIVE	*Pedestrian Oriented Perspective*	Accomplish	The authorities and planners already have a pedestrian oriented perspective. They give priority to the public transport above of the private transport
	Acceptation of the BRT concept	Not - Accomplish	The most influent persons to the project do not conceive the BRT as a viable solution in this specific case because they consider that a BRT will not reach the high performance that the SMM project is expected to achieve
POLITICAL AND INSTITUTIONAL CONSIDERATIONS	*Political support to the project*	Not - Accomplish	There is not a strong political figure supporting a BRT alternative. The national and local authorities are waiting for enough funds to continue with the implementation of the SMM project. The authorities rely on the agency Metro do Mondego to take any decision related to the problem.
	Technical knowledge of the system	Not - Accomplish	The local authorities and planners have basic knowledge of the BRT concept. No city in Portugal has implemented a BRT before. This alternative is been promoted mainly by private sector and by the press.
	Public entity for the control and management for the BRT system	Accomplish with some changes	Metro do Mondego could manage the BRT system. There are some differences between the operation of an LRT and a BRT system, so to achieve this it is required training programs for this agency.
FINANCIAL AND ECONOMIC CONSIDERATIONS	*Financing*	Accomplish	The budget required for a BRT solution is easier to get because the cost of this solution is considerable lower. The private sector could participate in the funding of a BRT alternative.
	Efficient business model	Accomplish	With some changes a more efficient business model could be applied to the BRT. The SMM project had an estimated operational cost of 13 million Euro per year and with a BRT alternative the subsidies could be reduced considerably.
TECHNICAL DESIGN AND INTEGRATION	*Integration, reorganization and mobility context*	In the urban area -Accomplish with some changes	The BRT could be inserted in the urban context, adopting the geometrical design of the SMM project. To ensure the same safety

			than a LRT, some changes must be introduced like protection barriers between the parallel lanes in the urban service.
		In the suburban area – Not accomplish	A BRT alternative should have an optical guide system to ensure safety and this could produce a final performance relatively lower than the LRT system in the suburban areas where the SMM project was intended to reach high velocities in sloped sections with the presence of some tunnels.
	Components	Accomplish with some changes	A BRT is going to require almost the same components that the SMM project. The difference will be in two elements: The BRT uses wheel based vehicles instead of the rail based vehicles. For the type of geometrical design and for the complex relief (high slopes, many curves) a BRT alternative will need an optical guide system in the vehicles to ensure high performance and safety for the users because in a BRT the vehicles are not fixed to the floor like in a LRT option.
	Gradual implementation	Accomplish	The same implementation stages than the SMM project but with the advantage of shorter implementation times. A BRT system could be implemented in just one or two years.
	Involvement of stakeholders	Accomplish	The same actors are involved except the providers of the vehicles.
	System capacity	Accomplish	The BRT could reach the same demand requirements. Actually the BRT offers a high operational flexibility that could be beneficial for the areas and periods with lower demand.
COMPLEMENTARY MEASURES	*TOD, NMT and another policies*	Accomplish	The same complementary measures should be applied.
PUBLIC IMAGE AND USERS PERCEPTION	*Promotion and information campaign*	Accomplish with some changes	It is required better educational campaigns for the users in order to avoid the negative image of the buses. A BRT system should be promoted as high quality system and not as a cheaper solution.

	Public acceptability	Accomplish with some changes	In the context, for a BRT system is more difficult to achieve the public acceptation than for a LRT system. It’s recommended the use of BRT vehicles with similar design to the LRT vehicles. This strategy was applied in other European cities
	Continuous improvements	Accomplish	The lower operational cost of the BRT alternative can provide a better economic base for the implementation of improvements

6.5. Conclusion about the case of Coimbra

A BRT alternative presents favorable economic conditions. The main advantage that a possible BRT solution offers is the lower investment cost required for implementation. The economic reality does not ensure the reactivation of the SMM project in the near future. With some changes in the business model, a BRT alternative could offer better economic conditions to attract private investment to the project. Also the implementation time for a BRT solution is considerable lower, so this solution could be implemented in less than two years.

From technical point of view a BRT system could be implemented following the geometrical design and urban insertion of the previous SMM project but it is important to notice that a BRT alternative should have an optical guide system to ensure safety and this could produce a final performance relatively lower to the LRT system in the suburban areas where the SMM project was intended to reach high velocities in sloped sections with the presence of some tunnels.

As can be noticed in the previous table, the most unfavorable conditions for a BRT solution come from the decision makers. The lack of strong political support to a possible BRT solution is going to affect negatively all the stages of a BRT project, if finally this alternative is adopted. Without a project team supporting a possible BRT alternative with technical knowledge, the local authorities could deal with several problems and due the lack of experience in this kind of systems, the final result could be a system that doesn't accomplish the expected results.

The authorities must be convinced about the viability of a possible BRT solution. With a strong commitment of planners and local authorities a BRT system could be implemented and with external cooperation of expert institutions in the BRT concept, the final result could be a system that could accomplish the demand requirements. But without these ideal conditions in the high spheres of the transport planning, the result could be an inefficient BRT system that consequently would be rejected by the users.

7

CONCLUSIONS

7.1. MAIN CONCLUSIONS

In this work it was carried on an exhaustive study of the main aspects related to the implementation of BRT projects and the results were presented in a table that summarizes the different findings and concepts obtained during the elaboration of the different chapters. The intention of the “Applicability Conditions” presented is to provide clear and specific parameters to planners and local authorities that are considering the possibility of implementing a BRT system in their respective cities. This work must be used as a tool to understand under what circumstances a BRT system could represent a viable solution that could achieve positive results. As it was established before, the main objective of this work was not to create a scoring methodology for the BRT systems.

The literature review showed the acceptation and recognition that the BRT concept has gained worldwide in the last years. The analysis of different BRT systems demonstrated the efficacy and efficiency that this type of systems can achieve but on the other hand the study also noticed the failures in some projects highlighting the need of a previous evaluation of the feasibility of the BRT project before its implementation. The considerable lower cost of the BRT alternative does not automatically convert it in the best option when is compared with the rail based solutions. Every city or metropolis presents different conditions and it is important to analyze if these conditions accomplish the requirements for a successful implementation of a BRT system.

The study only of the best implementation cases will provide concepts and ideas that are not suitable to the urban reality of many cities. The study of a wide range of systems showed the weaknesses and problems that BRT systems can face during the different stages of any project. At the same time, to understand the success or failure of any BRT project it is required the study of the different aspects related to the project, that means that should not only be studied the technical performance but also must be analyzed the impacts (positive and negative) the system produced over the urban environment and mobility context where the system was implemented.

In this work it was presented a Top-Down structure to understand the different aspects related with any BRT project, because the whole study realized showed that this perspective fits better to the reality of the different case studies. The different actors and decision levels are related with the other spheres in this structure, so any decision in any level it will affect the effectiveness of the measures adopted in the subsequent steps. The experience showed that the most successful BRT systems had a strong political support since the beginning of the project and this commitment from part of the authorities had influenced positively the decision and measures adopted in subsequent stages of the system. This doesn’t mean that just this political support is enough for the success of any BRT project;

in fact this condition must be followed by a detailed implementation plan that comprehends a technical design adequate for the urban context. On the other hand, a BRT project with a correct and suitable design could not achieve success without this political commitment supporting it constantly.

Finally it is important to remark that the results obtained with a BRT system seem to be more positive when this system constitutes the only massive transportation system presented in the city. In cities that already had other massive options like the Metro or LRT, the public acceptation and the performance of the BRT system tends to be lower than the rail based systems. The BRT system can achieve large numbers with favorable conditions but as any other system this option has also a capacity that could be overpassed even in the best scenarios. The BRT alternative should be considered as an intermediate solution or a as a complement of a transport network, especially in large metropolis with high urban densities where a BRT system would not be able to support the entire transport network in a long term. As the only massive system in a metropolis, a BRT system could satisfy the transport demand for some years but then the overcrowding problems will appear and there will be the need of implementing another massive system to complement the public network.

7.2. STUDIES IN THE FUTURE

Many studies were made about the evolution of the concept or about the results obtained in different case studies but little investigation was realized about the conditions required to achieve positive results with the implementation of a BRT system. The findings of this work, summarized in the table of the applicability conditions, could be established as a base for further studies like the creation of a systematic evaluation tool that could consider into a smaller scale every relevant detail related with the implementation of BRT systems.

Based on the concepts presented in this work, a detailed methodology could be elaborated. A methodology that could give a numerical score to every aspect of a BRT project in order to obtain a final score that could represent numerically the level of feasibility that a BRT system has according to the urban reality where is intended to be implemented.

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