AN ASSESSMENT OF THE PLANNING AND OPERATIONAL PERFORMANCE OF THE BUS RAPID TRANSIT IN ISTANBUL

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ABSTRACT

AN ASSESSMENT OF THE PLANNING AND OPERATIONAL PERFORMANCE OF THE BUS RAPID TRANSIT SYSTEM IN ISTANBUL

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In Turkey, the only city that currently operates BRT is İstanbul. There are researches that focus on different BRT systems in the world, yet there has not been a comprehensive, systematic and comparative evaluation of the BRT experience in İstanbul. There seems to be an urgent need to study this BRT investment, with a particular focus on planning, operation and ridership characteristics with a comparative approach.
This thesis analyses the BRT corridor in İstanbul and answers the question whether Metrobüs in İstanbul is a success or not. In order to understand the criteria for defining success, planning, operation and ridership characteristics are identified based on the previous literature and particularly the analysis of three best practice cases that currently operate BRT; these are Curitiba, Bogota and Mexico City. The study sets the criteria in planning, operation and ridership of BRT systems drawn by previous studies and answers by people who were involved in these projects. It compares the best practice cases and the Istanbul Metrobüs; focusing on planning and operation characteristics and using primary indicators of performance and ridership.
The study reveals strength and weaknesses of the Istanbul Metrobüs in comparison to best practice BRT cases in the world. The findings provide lessons both for the future extensions of the BRT in Istanbul and for other cities that may consider implementing this transit technology.

Key words: Bus Rapid Transit, İstanbul Metrobüs, public transport, transit planning, transit operation.

ÖZ

ISTANBUL METROBÜS'ÜN PLANLAMA VE İŞLETİM DEĞERLENDİRMESİ

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Yüksek Lisans, Şehir ve Bölge Planlama Bölümü, Şehir Planlama
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Otobüs sistemi kentlerin toplu taşıma yükünü taşıyan ana ulaşım omurgasıdır. Ancak, diğer taşıt trafiğiyle beraber işleyen otobüs sistemlerinde, hizmet kalitesi kaçınılmaz olarak düşmektedir. Bu nedenle otobüs sistemlerini daha etkin hale getirmeye ve hizmet kalitesini arttırmaya yönelik olarak yeni yaklaşımlar ve uygulamalar otaya çıkmış; otobüslerin kendilerine tahsis edilmiş öncelikli şerit veya koridorlarda işletilmesini sağlayan Hızlı Otobüs Taşımacılığı (HOT) dünyada 120'den fazla kentte ulaşım problemlerine ucuz ve hızlı bir çözüm sağlamak amacıyla uygulanmaya başlanmıştır.

Günümüzde, Türkiye'de ulaşım problemlerine çözüm olarak HOT uygulayan tek kent İstanbul'dur. Dünya'da bu tür sistemlerin performansını inceleyen çok sayıda araştırma olmasına rağmen, ülkemizde İstanbul Metrobüs sistemine ilişkin çalışmalar kısıtlıdır. Metrobüs'ü dünyadaki diğer sistemler ile karşılaştırarak, kapsamlı ve sistematik bir şekilde başarılı HOT deneyimleri kapsamında inceleyen çalışmalar bulunmamaktadır. Bu nedenle İstanbul'da yapılan Metrobüs yatırımının planlama, işletim ve yolcu sayısı özelliklerini karşılaştıran çalışmalara ivedilikle ihtiyaç vardır.

Bu çalışma İstanbul'daki Metrobüs koridorunu inceleyerek bunun başarılı bir uygulama olup olmadığını araştırmaktadır. Başarı kriterlerini belirlemek üzere yzın taraması yapılmış; ayrıca planlama, işletim ve yolcu sayısı özelliklerine bakılarak 3 başarılı HOT örneği olan Curitiba, Bogota ve Mexico City kentlerinde halihazırda işletilen HOT yatırımları incelenmiştir. Gerek daha önce bu sistemlere ilişkin olarak yapılmış çalışmalar incelenerek, gerekse bu projelere fiilen katılan kişiler ile yapılan görüşmelerde elde edilen cevaplar ile planlama, işletim ve yolcu sayılarına dayalı veriler toplanmıştır. Elde edilen sonuçlar Metrobüs ile karşılaştırılmıştır.

Yapılan karşılaştırmalı analiz, İstanbul Metrobüs uygulamasının güçlü ve zayıf yönlerini açıkça ortaua koymaktadır. Istanbul Metrobüs deneyimi hem bu sistemin gelecek hatlarının planlanması aşamasında hem de bu tür teknolojiyi uygulamayı planlayan diğer kentler için önemli dersler ve tavsiyeler sunmaktadır.

Anahtar kelimeler: Hızlı Otobüs Taşımacılığı, Istanbul Metrobüs, toplu taşıma, toplu taşıma planlaması, toplu taşıma işletimi

Dedicated to my family…

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CHAPTER 1

1. INTRODUCTION

Mobility in urban areas is rapidly increasing, and more importantly, becoming more and more automobile-oriented. In many urban areas passenger mobility is increasingly becoming dependent on private automobiles that cause air and noise pollution, emit greenhouse gases resulting in climate change, increase fossil fuel dependency, result in high time costs as well as accident costs, increase expenditures of local governments for road investments, and deteriorate street and community life while resulting in inequalities in accessibility for different users.

These trends are clearly unsustainable and hence urban transport in most cities in the world has to be planned with a view to create more sustainable transport systems, economically, environmentally and socially. This requires improvement of alternatives to the automobile and restrictions on automobile usage in cities, particularly in central areas that suffer from congestion. One of the most effective alternatives to the automobile is public transport. Many cities in the world have been investing in public transport to attract citizens and encourage them to use public transport. While urban rail systems, such as heavy rail, light rail and trams, received much investment, the past three decades also saw Bus Rapid Transit (BRT) being introduced as an innovative public transportation mode, offering significant advantages of service quality over conventional bus operations, and significant cost-savings and ease of implementation in comparison to rail alternatives. BRT is becoming more popular in cities both in developed and developing countries, with its cost-effective features, easy and quick implementation and high ridership potential.

Today there are more than 120 cities in the world that applied BRT in their public transportation network either as primary mode or as a feeder service to the rail transport system. BRT system is not a recently rising public transportation trend: especially in Latin American cities it has been implemented for decades. It has started to become more popular in other parts of the world in the past decades too.

In Turkey too, there is a BRT system that was recently built in Istanbul. In fact, in Turkey, both Ankara and Istanbul had implemented a busway system a few decades ago. In Ankara, the system was a 3,6 km, two lane median busway implemented on the main axle between Bahçelievler and Dikimevi. In the mid-1990s the system was removed since an underground LRT system was constructed on this corridor. In Istanbul too, in the 1980s the Public Transport Authority of the Greater Municipality aimed to increase the speed of buses and reduce the traffic congestion on Taksim-Zincirlikuyu corridor, and started to operate a segregated busway with 5 km route length. This busway is not in use today either (Üstündağ, 1994). These busway examples were segregated from other traffic with physical barriers; however, they were not fully segregated since there were at-grade intersections. Bus fare collection was also still on the buses; and hence while the systems enjoyed congestion-free running ways, they did not reach the high-speed levels expected from a rapid transit system typical to BRTs. As a result, it can be claimed that these were not advances BRT systems and that it was in the 2000s and with the introduction of the Metrobus in Istanbul that Turkey had its first example of a BRT system.

In Istanbul, which is the largest metropolitan area in the country, city officials introduced the system to combat traffic congestion and associated problems, as well as to respond to increasing mobility needs in a cost-effective and rapid way. The Metrobus in Istanbul remains to be the only BRT in Turkey.

Although the Istanbul Metrobus is the only BRT example in Turkey, a through performance analysis has not been made for this system. Since there are no other BRTs, it is not possible to compare it with other similar systems in the country. It can be compared with the urban rail systems in Istanbul; however, this may not be sufficient since the system should also be assessed in comparison to other systems similar to its own characteristics.

There are national and international articles that claim the BRT system in Istanbul to be a major success due to its high number of passengers; but there are also many negative publicity due to its crowded stations and vehicles resulting in poor travel conditions for its users. While operational aspects of the system appear to be good on paper, some experts criticize its planning stages and complain that it was too rushed in planning with poor integration into urban development plans and transportation master plan. There is a mixed understanding currently, as to whether this is a successful system or not. The main aim of the research is therefore to assess the planning and operational performance of the Metrobus system in Istanbul.

This study conducts a comparative analysis of different BRT operations in the world and Turkey. It aims to develop performance criteria by analyzing best practice cases, and assesses the planning approaches and implementation process of BRT Metrobus in Istanbul.

Four main research questions are formulated:

1. What makes a BRT operation/implementation “successful”?
2. How can “success” be defined in the context of BRT operations?
    - Planning approaches/criteria
    - Physical characteristics/criteria
    - Operating characteristics/criteria
    - Ridership performance/criteria
3. Is Istanbul Metrobüs a success with respect to these criteria?

In order to answer these questions, the study first reviews the literature on BRT ,n the next chapter, Chapter 2. This review indicates a number of criteria that are extremely important for a successful BRT operation. However, in order to attain a comprehensive list of criteria, best-practice BRT cases in the world are analyzed. This analysis, which is carried out in Chapter 3, focuses particularly on the three well-known and well-reported BRT cases in Latin America: Curitiba BRT in Brazil; Bogota BRT in Colombia, and Mexico City BRT in Mexico. The analysis reveals certain aspects with regards to the decision making, planning background, implementation and operation of BRT systems.

Using these criteria that are obtained from the literature review and the experience of well-known and well-reported cases of BRT, a large list of criteria are developed and presented in Chapter 4, which describes the methodology of the study. It is intended to analyze the Istanbul case, by comparing the same aspects, or criteria, across the three best-practice cases and Istanbul Metrobus. In addition, the performance analysis and comparison between the four cases (including Istanbul) comprises indicators for passenger statistics.

Chapter 5 presents the BRT system in Istanbul. Its planning background, physical characteristics, and operational features are described. This is followed by Chapter 6, which is the main analysis of the research. Istanbul is thoroughly assessed and compared with the three best-practice cases in terms of the criteria determined in the previous chapters of the study. In addition, where data is available, the operational characteristics and passengers' statistics of the urban rail systems in Istanbul are also compared and contrasted with the Istanbul Metrobus.

This main analysis of the research reveals areas where the Istanbul Metrobus has strength as well as areas where there is room for further improvement and development. Results of the analysis, more general conclusions and recommendations are provided in the last part of the study that is Chapter 7.

CHAPTER 2

2. BUS RAPID TRANSIT: DEFINITIONS, PLANNING AND DESIGN

2.1. The Increasing importance of public transport systems for sustainable development and urban planning

Spatial development of settlements is highly linked with the development of transportation. The state of urban transport infrastructure can have a significant impact on urban form, development, urban environment and air quality, and hence the quality of life in cities. Since sustainable development has become a major goal for many cities, the importance of attaining a sustainable urban transport system has also increased.

Sustainability and sustainable development have become major concerns after the discussions and declarations of a number of international conferences, such as the UN Earth Summit in Rio de Janeiro in 1992, the 1995 European Conference of Ministers of Transport, and 1997 Kyoto Convention of Climate Change, the 1996 HABITAT II Meeting in Istanbul, 1996 Vancouver Conference of OECD, named "Towards Sustainable Transportation", etc. The origins of the concept date back to the seventies, but the widely accepted definition of sustainability was made by the World Commission on Environment and Development, also known as the Brundtland Report as the "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (1987, p.54).

The definition made by the Brudtland Report was fairly broad and new definitions have been made since. The common features of these definitions are that they highlight the three dimensions of sustainability: economic growth or stability, societal development and environmental protection. Sustainable solutions should be economically viable, socially equitable and consistent with the long term ecological balance of the natural environment.

In one of the earliest international meetings that featured the sustainability concept, the Declaration of the United Nations Conference on the Human Environment in Stockholm Conference (1972), it was stated that "Planning must be applied to human settlements and urbanization with a view to avoiding adverse effects on the environment and obtaining maximum social, economic and environmental benefits for all."

The Earth Summit in Rio de Janeiro in 1992 also focused on promoting sustainable land-use planning and management, and promoting sustainable energy and transportation systems in human settlements. "The ability to access jobs, education and public services is a fundamental part of human development. An efficient and cost effective public transport essentially connects people to daily life." In many cities throughout the world public transportation services are not as well developed as they should be; and therefore, the movement of people is left to private vehicles and low quality paratransit operations, thus these cities face severe traffic congestion, air and noise pollution, accidents and loss of a sense of community. (Wright et. al, 2007)

In the HABITAT II Meeting in Istanbul in 1996, it was also stated that sustainability was essential for human settlements development, and that it gave full consideration to the needs and necessities of achieving economic growth, social development and environmental protection. The role of urban transport and accessibility was again highlighted as one of the important components of sustainable development.

The role of urban transport is considered significant for attaining sustainable development, mainly because it is one of the least sustainable sectors of urban development. The ever-increasing use of private automobiles and the decreasing use of public transportation and non-motorized modes create unsustainable growth in urban transport. This trend results in increasing dependency on petroleum, which is a scarce non-renewable source and a foreign resource that needs to be imported for many countries that do not have petroleum as their natural resources, in increasing greenhouse gas emissions leading to global warming and pollution of the environment, and in significant accidental costs and time losses in traffic as well as inequalities in accessibility.

The following table that is adopted from Newman and Kenworthy (2000) clearly shows the negativities associated with the increasing dependency on automobiles and hence the environmental, economic, and social consequences of this unsustainable growth in urban transport.

Table 1: Environmental, economic, and social consequences of automobile dependency

Environmental	Economic	Social
▪ Greenhouse gas effect: ▪ Toxic emissions, air pollution ▪ Global warming ▪ Oil vulnerability – accidents ▪ Traffic noise ▪ Urban sprawl ▪ Loss of natural resources	▪ Petrol dependency ▪ External costs from accidents and pollution ▪ Congestion costs ▪ High infrastructure costs in dispersed sprawling areas ▪ Loss of productive agricultural land ▪ Loss of urban land reserves	▪ Loss of street life ▪ Loss of community ▪ Loss of public safety ▪ Isolation in remote suburbs ▪ Equity: access problems for carless people and those with disabilities

Source: Newman and Kenworthy (2000)

As stated by Drumheller et. al (2001), the uncontrolled increase of motor vehicle use is a major issue in urban areas, and among the most important problems induced by motor vehicles are the high amount of carbon monoxide (CO), Carbon dioxide (CO_2) and nitrogen oxide (NO_x) emissions into urban atmosphere. These gases are known as the greenhouse gases since they trap the energy coming from the sun in the atmosphere, creating a greenhouse effect and a climate that is warmer than it should be. Climate change caused by greenhouse gases, and especially the CO_2 emissions, is one of the major challenges of our day. According to the World Resource Institute (2005), the transport sector alone accounts for 24.1 % of CO_2 emissions worldwide. This ratio is higher (reaching 50 %) in developed and industrialized countries, such as those in Western Europe and North America: these countries managed to reduce energy usage and emissions in the industry sector, energy production and heating; however, the transport sector remains as the one sector where improvements are offset by the ever-increasing mobility and especially the ever-increasing automobile-usage.

The negative environmental effects of automobile-dependent growth include not only global warming and climate change, but also the depletion of the ozone layer, spread of toxic organic and inorganic substances, and depletion of the natural resources. In addition these toxic materials damage the landscape and soil (Kassens et. al, 2009). Furthermore, automobile-oriented growth results in urban sprawl and extensive road construction, that rapidly consume natural land transforming it into built environment and asphalt (Newman and Kenworthy, 2000).

Automobile-dependency also causes severe economic problems. In the world, the transportation sector is almost completely dependent on petroleum: 98% of fuels and energy used in the sector is dependent on petroleum (EU Transport White Paper, 2001). which is a non-renewable resource that is rapidly diminishing. In its definition of sustainable transport, OECD (1999) proposed a transportation system that does not endanger public health or ecosystems, and also emphasizes that this system should meet the mobility needs using renewable resources at a rate below their rates of regeneration, while using non-renewable resources, such as petroleum, at a rate below the rates of development of renewable substitutes. Hence this high dependence on petroleum is one of the aspects of urban transport that require a significant change.

From the social dimension too, automobile-dependence causes a number of problems that challenge sustainable development: Cities and their streets are occupied by either flowing or parked cars, and this kills street life as well as social interaction. Due to dispersed development that the automobile enables, sense of community diminishes. This is further reinforced with suburban lifestyles that isolate people in their distant suburbs and in their automobiles. Moreover, automobile-based transport infrastructure creates a system that favours car-users while deteriorate accessibility for those who cannot own or drive a car.(Newman and Kenworthy, 2000).

Considering the three dimensions of sustainability, which are environmental, economical and social dimensions, sustainable transport can be defined as follows: Environmentally sustainable transportation should decrease greenhouse gas emissions that affect the environment negatively; decrease the use of non-renewable energy resources; and minimize urban sprawl in order to decrease overconsumption of natural areas. In order to be economically sustainable, a transportation system should minimize use of energy, so that it decreases dependency on petroleum and imported energy; and also it should minimise time costs and traffic accident costs. Transportation can be sustainable in terms of social dimension if it is physically accessible by all and financially affordable by everyone. According to sustainable transportation concept, motor vehicles using renewable resources and clean energy resources should be introduced; and public transportation, pedestrian and bicycle transportation should be prior in policy setting, while private car usage is restricted and discouraged in urban areas. Considering all the negativities associated with extensive automobile-usage, it is crucial that automobile based transportation systems should be transformed to a more balanced, integrated and highly accessible transportation systems (Kentleşme Şurasi, 2009, Bayındırlık ve İskan Bakanlığı). Good public transport networks are generally considered to be the backbone of such accessible urban systems.

The need to reduce automobile-dependency creates a significant focus on public transportation for sustainable development. Other alternatives to the automobile include bicycle and pedestrian transport, also known as non-motorised modes; however, in particularly large metropolitan cities, these non-motorised systems cannot be as effective alternatives as public transport, due to higher distances of travel. Hence, for any sustainable transport plan and policy, it is crucial that public transport systems are improved: new systems, such as rail and bus transit, should be developed to increase accessibility; and existing systems should be improved to enhance service quality.

New urban planning approaches also create a new focus on public transport systems with their emphasis on building around public transport stations. These approaches comprise planning and design principles that decrease automobile dependency in urban areas while promoting more usage of public transport as well as biking and walking. These are Transit Villages, New Urbanism, Transit Oriented Development (TOD), and Smart Growth, which are briefly described below.

Transit Villages is a planning movement that tries to decrease the negative effects of transportation on environment by creating dense, walkable communities that have easy access to train lines with a view to reduce the need for driving and using fossil fuels. Transit Villages are dense urban areas well served by transit and high quality train systems. The approach aims to create active, attractive and strong neighborhood centers based on transit nodes, that is public transport stops and stations. (Bernick and Cervero, 1997).

New Urbanism aims to provide many choices for living in sustainable, convenient and enjoyable places to its residents, while trying to find solutions to global warming, climate change and peak oil. New Urbanism has many principles including walkability, locating most services and amenities in walking distance, creating pedestrian friendly streets, connectivity, interconnecting street grid networks to disperse traffic and facilitate walking, mixed-use and diversity of uses such as mixing shops, offices, apartments and houses in site (http://newurbanism.org/). This approach also centers on planning and development based on public transport accessibility.

Transit Oriented Development (TOD) can be defined as more compact spatial development in cities within walking distance of transit stations that connect mixed-uses such as housing, jobs, shops and entertainment facilities. TOD is about creating walkable, sustainable communities for people of all ages and income, providing more transportation and housing opportunities. According to Urban Land Institute TOD as an approach aims to struggle with traffic congestion and protect the environment in urban areas. Components of TOD can be listed as walkable design with pedestrian as the highest priority, train station as predominant feature of town centers and supported by other collectors such as trolleys, streetcars, light rail and busses, reduced and managed parking regulations in the downtown, mixed-use formation in close proximity containing housing, work and public uses, high density, high quality development around stations. (http://www.transitorienteddevelopment.org/)

Economic costs of abandoning previously built environment in urban areas are queried by communities. Urban sprawl requires rebuilding all infrastructures both ground and underground further from urban areas that already have existing urban infrastructure. Smart Growth is a more town centered approach: it is also transit and pedestrian oriented and has a greater mix of housing, commercial and retail uses. The aim of the approach is to preserve open space and other environmental assets. Same as the previous design and planning movements smart growth also aims to create walkable neighborhoods by providing mixed land uses and a compact city form, to provide a variety of transportation opportunities affordable and accessible for all. The movement has a significant focus on public transport, as a means to direct development in certain areas and corridors while preserving open spaces, environment and natural resources. (http://www.newurbanism.org/newurbanism/smartgrowth.html)

Benefits of these approaches are countless, and can be listed as follows: creating higher quality of life, better places to live, greater mobility with affordable and more accessible transportation, increased transit ridership and reduced traffic congestion, reduced car accidents and injuries, reduced pollution and environmental destruction as a result of green energy and decreased use of fossil fuels, reduced tendency to sprawl in spatial development and creating more compact urban forms. http://www.transitorienteddevelopment.org/

What is common in all these approaches is their emphasis on a good quality public transport system as the backbone of planning and development. While there is often a reference to “train” stations, the public transport backbone can be any form of public transport, buses or rail-based systems. The latter has been more commonly used; however, this is changing and bus-based TOD or transit village models are also becoming common. In the following section, main characteristics of public transport systems, including rail-based systems and buses, are introduced.

2.2. Public transport modes and the rise of Bus Rapid Transit

There are many different classifications among transit modes, and it is common to refer to Vuchic (1981) who made a number of different classifications, based on type of operation and usage; as well as on Right-of-Way category and technology.

Table 2 shows the classification for type of operation and usage, that point to private, for-hire and public or common carriers.

Private Transport: consists of privately owned vehicles run usually on publically provided or operated streets and conducted by owners for their own use. Private automobiles are common version, but also this mode includes motorcycle and non-motorized transportation such as cycling and walking.

For-Hire Urban Passenger Transport: is commonly called paratransit which is a transportation service provided by an operator and available to everybody who meets the conditions that is paying predetermined prices for carriage. This type of transportation includes taxi, dial-a-ride, and jitney which do not have a fixed schedule and route.

Common Carrier Urban Passenger Transport: this type of transportation is also known as transit, mass transit or mass transportation. They are operated according to fixed schedule and route and serve to all users who pay the established fares. Most common representatives are bus, light rail transit and rapid transit. In Table 2 the classification of transit modes by type of usage is shown in detail.

Figure 2 shows a more common classification by Vuchic (1981) that indicate the three Right-of-Way Categories and technologies. Category C refers to systems that operate on mixed traffic without an exclusive way or lane. Category B refers to a degree of separation, where the system has a technology that enables it to run in mixed traffic, i.e. no technical requirement for full-segregation and separation, but it operates fully or partially on its own dedicated lane. Category A refers to systems that are 100% separated and segregated from other traffic, including pedestrians. It is often their technology that enforces this requirement of full separation.

Table 2: Classification of public transport modes according to Right-of-Way Category and Technology

Usage Type / Characteristic	Private		For-hire		Public or Common Carrier
Common designation	Private transport		Paratransit		Transit
Service availability	Owner		Public		Public
Service supplier	User		Carrier		Carrier
Route determination	User (flexible)		User	User (carrier)	Carrier (fixed)
Time-schedule determination	User (Flexible)		User	User (carrier)	Carrier (fixed)
Cost-price	User absorbs		Fixed rate		Fixed fare
Carrier type	Individual			Group	
Modes	Automobile	Carpools	Taxi	Dial-a-ride	Street transit (bus, trolleybus, streetcar)
	Motorcycle	Vanpools	Rented car	(Jitney)	Semirapid transit (semirapid bus, light rail transit)
	Bicycle			Charter bus	Rapid transit (rail, rubber-tired, regional rail)
	Walking				Special and proposed modes
Optimum (but not exclusive) domain of operation:					
Area density	Low-medium	Origin: low Destination: high	Low		High-medium
Routing	Dispersed	Radial	Dispersed		Concentrated (radial)
Time	Off-peak	Peak only	All times		Peak
Trip purposes	Recreation, shopping, business	Work only	Business		Work, school, business

Source: Vuchic (1981)

The second classification brings a clear distinction between rail and bus systems. For the purpose of this study, which focuses on bus rapid transit systems, this distinction and relevant definitions are seen important. They are given below.

2.2.1. Urban Rail Transport:

Railways served as the main transportation mode for almost all mobility demand in the nineteenth century, including between and within urban areas. Urban rail systems are divided into different categories by different authors, but eventually they are defined with similar characteristics:

According to White (1998); U-Bahn, which is used in German terminology, is an underground railway; it generally serves within the built-up limits in the city, and has a good penetration in the city center with tunnels. Ownership of the system generally belongs to city transportation authority, and the network is generally self-sufficient. It has, on average, 1.000 meters station spacing, which is close enough to provide high proportion of passengers to reach on foot to the station.

Black (1995) used heavy rail instead of U-Bahn in his terminology. Heavy rail refers to either subway, i.e. underground systems, or elevated systems. That is because most tracks are located either underground or on elevated structures over streets or alleys. Similar with U-Bahn heavy rail systems provide within the city boundaries mainly in Central Business District (CBD), but with new lines they can also serve in suburbs. Stations are located close to each other; average station spacing is generally 1km to 1,6 kilometers. All heavy rail systems are electrically powered, and electricity usually comes from a third rail, and each truck has its own motor. Since they use electricity coming from a third rail, the roadbed have to be protected. This means full segregation from other forms of traffic, resulting in grade-separation, hence the underground or elevated structures.

According to Grava (2002), heavy rail mode which carries high amount of passenger fast and effectively at the city scale, can be a reasonable solution for private car usage, since it decreases travel time, particularly during peak hours in congested corridors.

S-Bahn term denotes the main-line surface railway which serves not only as long-distance transportation mode between cities but also in local traffic in the city according to White (1998). Station spacing within the inner city is approximately same with U-Bahn but distances of 2 to 3 km is more common. Despite having lower acceleration rates, average speeds are higher than U-Bahn as a result of the longer distance between stations. Although there are attempts to segregate inner city transportation from long-distance operations with provision of separate tracks and stations, peak service levels have often been limited by lack of track capacity.

Black (1995) used suburban railroad term instead of S-Bahn that White (1998) named. Suburban railroad is also called as commuter rail or regional rail that serves for commuters in intercity railroads. This system generally uses heavy equipments; it has high maximum speeds, and slow acceleration and deceleration rates. In general locomotives pull the passenger coach, but there are some self-propelled cars too. Routes are typically 40 to 80 kilometers long and reaches to sub-end terminal in Central Business District (CBD). Most of the stations in the route are in the suburbs and several kilometers apart. In peak hours ridership is high, and generally the service frequency is high during these times whereas the level of service provided is often decreased at off-peak. Suburban rail road systems provide high quality service, with trains running at speeds up to 128 km/hr and hence attracting private car users.

According to Grava (2002); commuter rail is the traditional rail mode which is still the most efficient way to move large volumes of people over many kilometers at a reasonable speed. This mode of transportation can work effectively in areas where movement demands are on a massive scale, since station spacing is relatively far apart, the volume of passenger is important to warrant stopping train. Most of the commuter rail systems create separate routes connecting the denser and older suburbs to the central core.

According to White (1998); Light Rail Transit (LRT) term is applied to electrically powered systems which have similar characteristics with U-Bahn, but generally block signaling, full-height station platforms or ticketing issue at all stations. System is operated by trains which are up to three or four single cars or one or two articulated cars. This transportation mode involves the many advantages which U-Bahn and S-Bahn have, but also combine it with better accessibility and lower cost of investment. However, but it has less capacity.

LRT is one of the most popular forms of rail transit being proposed for U.S. cities (Black, 1993). It is a modern version of the electric street car. They use electricity coming from an overhead wire, thus it is safer than heavy rail, and does not require protection of roadbed, hence can operate in streets. LRT offers more flexibility in location: in CBD where the land is expensive, they can operate on existing streets, thus right-of-way acquisition and construction cost is cheaper than heavy rail. It can be an alternative for medium-sized bus dependent cities.

There are many comparisons showing that LRT has heavier and intensive characteristics than buses, but less severe and extensive features than heavy rail (Grava, 2002). Besides, LRT systems use electricity which can be produced at remote locations with a variety of energy sources. No matter how large the light rail vehicle, it is conducted by one person, thus provides labor productivity while moving large volumes of passengers. Good image of LRT has much greater acceptance by all social and economic groups, including not only low but also middle class.

Trams can also be considered as LRT systems since they use the same technology of overhead wires. The main distinction is that, LRTs refer to Category-B right of-way systems, where some degree of segregation is used in order to allow for a faster and higher-capacity transit service, while tram systems are Category-C systems that run with mixed traffic. The latter, therefore, is operated in slower speeds and with fewer number of cars (typically upto 2 cars per train; although technically 3 cars is possible, it is very uncommon in practice). Their carrying capacity, therefore, is comparable with that of buses.

2.2.2. Bus Systems

Grava (2002) describes buses as the workhorses of the transit world. There are many cities that offer only bus transit as public transportation and there is no city which does not have bus transit operation.

It is often argued that bus services tend to be slow and provide poor quality of service with uncomfortable vehicles. Nevertheless buses operate as the base service in public transportation with carrying considerable passenger loads. (Grava, 2002)

In recent years there is tendency to improve quality of buses by providing lower floors, wider doors, wheelchair lifts and other features to make them more accessible for elder and disabled people (Koski, 1979).

As reported by G. A. Giannopoulos (Avebury, 1989), urban areas below 200.000 population are likely to operate only buses for transit purposes, not any rail mode. As Koski (1979) mentioned, even largest cities that heavily and densely use rail transit need buses in order to supplement rail routes and feed the rail terminals.

A bus is a vehicle which transports people over streets, controlled by an individual driver, almost always utilized by diesel engine and rubber tires (Grava, 2002). When this type of vehicle is operated in mixed traffic, along a fixed route and schedule, admitting everybody who wants to enter with the payment of fare, it is called bus transit.

Buses provide a number of advantages as a transit mode. According to Grava (2002), buses do not depend on advanced technologies, they can be produced by many manufacturers. Purchasing of buses can be done according to experience records about buses. Technical and mechanical improvements about buses are slow in process, thus the vehicles already available are satisfying the basic requirements of the system. Basic technology that buses use is diesel engine which is very well known throughout world for decades, thus any truck mechanic who understands engines can take care of buses with little additional training. Anyone who has regular driving license with additional training and practice can run buses, thus buses do not require a special or skilled workforce. For creating transit channels and routes there is no additional construction expenses for bus transit, because they can operate on existing city streets. When their log use life, about 12-13 years are considered, the cost of vehicles are reasonable.

According to Black (1993), bus transit provides flexibility in operation, since vehicles can operate on any solid street surface, routes can be changed and shifted without any capital cost. Buses can easily cope with temporary obstacles that may appear on the streets and bypass the disabled bus in front. Rail transit vehicles get trapped when they come across such conditions, but buses are free to seek their own path.

Grava (2002) also gives some reasons to exercise cautions while operating bus transit systems. According to Grava (2002), bus services are labor-intensive operations, the ratio between operating stuff and the number of passenger carried is relatively high when compared to rail transit. In addition, since buses use fossil fuels, they have damages on environment. Despite having improvements on gas emissions of buses, it is not completely eliminated. Buses run in mixed traffic, which is an advantage for them, but they also get caught in street congestions that slows down the service and reduces the reliability. (Grava, 2002)

Black (1993) also stresses that traditionally buses operate in mixed traffic, thus they suffer from traffic congestion. In recent years by building special roadways or designating special lines for buses, it is aimed to raise their speeds. In conventional bus service the stop frequency is high (approximately 8 to 10 stops per 1.6 kilometers). Vuchic (1981) states that the distance between bus stops can be as low as 200 meters, and 500 meters at maximum. Buses stop only on demand, except for rush hours, thus they can skip the stop which increase their operating speeds. Another alternative to reduce travel time between destinations is limited-stop service with locating stops farther apart. The limited-stop buses provide 50 to 100 percent faster travel in light traffic, but they cannot make difference in heavy traffic.

According to Grava (2002), despite improvements, most of transit users tend to use rail transit instead of buses, since they provide a steady and stable ride. Buses wobble, shake and sometimes hit potholes which makes it difficult to walk in the bus and for standees to balance themselves.

With the increasing applications of LRT technology after the 1980s, there has been a major debate in transportation planning between those who support new rail systems (particularly LRTs) and those who favor all-bus transit, particularly buses with separate lanes.

According to Black (1993) Light Rail Transit (LRT) has emerged as a transport solution for large and medium size metropolitan areas. LRT satisfies most of the heavy rail transit's features, and it is easier and cheaper to build than heavy rail. Because LRT uses electricity generated from an over head wire, it can be constructed at ground level and even in the middle of the streets different from heavy rail trains using a third rail for electricity. Since third rail contains high electricity, heavy rail lines have to be designed to prevent people to walk through rails, thus LRT can be integrated with pedestrian traffic better.

According to Black (1993), most of the cities in the world have relied on bus transit systems which have a bad image as they are considered "uncomfortable, slow, dirty and smelly". Black argues that since buses run in mixed traffic they provide low-quality service whereas LRTs provide more utilized service with separate lines. LRT is an intermediate mode which can transport more passenger than buses and fewer than heavy rail.

According to Black (1993), one of the most important advantages of LRT over heavy rail is flexibility of location. Since land prices are high in central areas, LRT can be established in an existing street. Right-of-way acquisition and construction can be much cheaper than heavy rail which is generally constructed underground.

Cervero (1984) summarized the pros of the LRT systems too: it is a relatively quiet transportation option, since LRT propelled with electricity; it is less dependent on fossil fuels than busses, thus it is more environmental friendly; it can operate effectively along existing railroad right-of-way and streets, thus cheaper and easier to build than heavy rail.

According to Cevero (1984) light rail transit has more impacts on land use development than buses, but less than heavy rail.

There are also many counter arguments to the LRT proponents from bus system supporters. Gomez-Ibanez (1985) analyzed actual ridership and financial data of the new lines in San Diego, Calgary and Edmonton and argued that LRT proponents have overstated their cases.

Kain (1988) criticized constructing LRT lines in low-density cities. According to him, heavy rail is superior in handling high peak-hour volumes, and busses are superior in low volumes. He argues that LRT systems are nothing more than a slow and expensive bus service which cannot pass and unable to operate in the city streets.

According to Pickrell (1992), local officials use exaggerated forecast about passenger volumes to compete against their counterparts from other cities to obtain federal financing by constructing new LRT lines.

According to Moore (1994), construction cost of LRT is underestimated and ridership is generally overestimated in decision-making process.

According to U.S. Department of Transportation (1989), busses have flexibility advantage over LRT; they can share right-of-way with general traffic, this provides the opportunity to conserve scarce public resources where it is more productive than high cost of initiating light rail service.

According to Federal Transit Administration (2001), the ability to maneuver around temporary obstacles of busses offers the opportunity to maintain schedule dependency where it is not feasible to apply grade separation from general traffic.

These clear distinctions between rail and bus systems have been blurred to a certain extent with the increasing number of applications of Bus Rapid Transit systems. The public transit industry has struggled about mode and technology issues during last decades. As Levinson et. Al (2002) state, transportation agencies wanted to stimulate exclusive right-of-way in mixed traffic as well as combine line-haul efficiencies of rail transit with the distribution flexibility of bus service, thus Bus Rapid Transit (BRT) concept has emerged. Bus is a rubber-tired single-unit, enlonged vehicle conducted by a driver who also collects the fares, runs on concrete or asphalt pavement along a predetermined route and time schedule in mixed traffic. On the other hand rail is multiple train cars operated manually or mechanically on steel wheels. The combination of these features creates BRT service; it looks like a rail system, and provides carrying capacity as high as rail systems, but physically operates like a bus. (Levinson et. al, 2002)

As Wright et. al (2007) argue, “BRT is increasingly recognized as amongst the most effective solutions to providing high-quality transit services on a cost effective basis to urban areas, both in developing and developed countries.”

According to Levinson et. al (2003), “the objective is to develop a coordinated set of actions that achieves attractive and reliable BRT services, serves demonstrated demands, provides reserve capacity for the future, attract automobile drivers, relates to long-range development plans and has a reasonable cost”.

According to Arrillaga et. al (1998), BRT systems feature low-cost investments in infrastructure, equipment, operational improvements, and technology when compared to other public transportation modes such as heavy rail or LRT. In addition BRT can provide significantly faster operating speeds, greater service reliability and increased convenience, which are the same facilities that rail transit provides.

BRT includes an integrated system of facilities, amenities, operations and Intelligent Transportation System (ITS) improvements that are designed to increase performance, attractiveness for passengers, image, identity, and quality of service. BRT vehicles can operate in a wide range of environment without forcing transfers or requiring expensive running way construction (Levinson et. al, 2002). More detailed definition and characteristics of this technology is given in the following section.

2.3. What is BRT? Definitions and main characteristics of BRT

According to Federal Transit Administration, BRT is a rapid transit mode of transportation which combines the quality of rail transit and flexibility of buses.

According to Transit Cooperative Research Program (TCRP) A-23 Report; BRT is a flexible, rubber-tired transit mode combining stations, vehicles, services, running ways and ITS components into an integrated system with a strong positive image and identity. In other words, BRT is a permanently integrated system of facilities, services and amenities which collectively increase the speed, reliability and identity of bus transit. BRT can be seen as a rubber-tired rail system which provides flexibility in operation and implemented with lower investment and operating cost. (Levinson, H. et. al, 2002)

As Wright et. al (2007) stated “BRT is a high-quality bus-based transit system that delivers fast, comfortable and cost-effective urban mobility through the provision of segregated right-of-way infrastructure, rapid and frequent operations and excellence in marketing and customer service." BRT competes with modern rail-based transit system in terms of performance and amenity characteristics with lower implementation and operation costs. "A BRT system will typically cost 4 to 20 times less than a tram or LRT system and 10 to 100 times less than a metro system." (Wright et. al, 2007)

When BRT vehicles are operated on exclusive or protected right-of-ways, they provide similar level of service with heavy rail transit, when BRT vehicles are operated in combination of exclusive right-of-way, median reservation, bus lanes and street ways, they provide similar level of service with LRT, and when they run mainly in mixed traffic, they can provide the similar level of service with limited-stop tram/streetcar system. (Levinson et. al, 2002)

2.3.1. Development history of BRT

BRT concept is not new, but there has been a great emphasis in recent years. Plans and studies focusing on BRT system have been prepared since the 1930s. (Levinson et. al, 2002):

1937 Chicago Plan: the BRT concept was first suggested in 1937 Chicago Plan with a proposal to convert three rail lines to express bus operation on superhighways in central areas and downtown.

1955-1959 Washington DC Plan: as a part of 1956-1959 Transportation Survey for the National Capital Region (Mass Transportation Survey 1959) design studies for bus rapid transit were developed within freeway medians.

1959 St. Louise Plan: the 1959 Transportation Plan suggested 138 kilometers BRT system, 67 kilometers of which were to be grade-separated bus lane (W. L. Gilman and Co. 1959).

1970 Milwaukee Transit way Plans: the proposed Transit Way Plan suggested 172 kilometers of express bus routes over freeway system.

The first BRT system is accepted to be the system in Curitiba, Brazil. Started in 1972, the plan by the Mayor of Curitiba called for an above-ground subway system that would use buses instead of rail. The system is also often referred to as a major success story and was replicated around the world. Other Latin American cities adopted the model in the following years, while many other cities in North America, Europe and Asia started similar systems after the 1980s too.

2.3.2. System concepts:

In order to operate a successful BRT system the only thing is not building or reserving separated bus ways; the entire range of transit elements should be integrated including stations, fare collection and development of unique system image and identity.

BRT systems, like any other transit systems, should be designed as cost-effective as possible, but in order to decrease cost, key elements should not be eliminated. This will greatly reduce the potential benefits of the fully integrated BRT system.

It is important that BRT systems include all the elements of high quality, high performance rapid transit system. These elements should be integrated to the characteristics of BRT, especially service and implementation flexibility. It is essential to focus on service quality, stations, vehicles and other features of BRT system instead of cost saving. BRT has to be rapid which can be achieved by operating on exclusive traffic-free right-of-way, maintaining optimum station spacing and reducing time losses by minimizing dwell times at stops. (Levinson et. al, 2002)

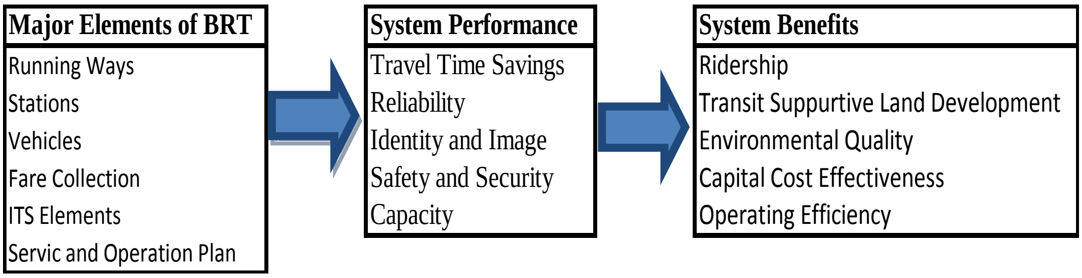

Figure 1: BRT elements

Table 3: BRT elements

Running Ways	BRT vehicles operate primarily fast and easily identifiable exclusive transitways or dedicated bus lanes. Vehicles may also operate in general traffic.
Stations	BRT stations, ranging from enhanced shelters to large transit centers are attractive and easily accessible. They are also conveniently located and integrated with the community they serve.
Vehicles	BRT uses rubber-tired vehicles that are easy to board and comfortable to ride. Quiet, high-capacity vehicles carry many people and use clean fuels to protect the local environment.
Services	BRT's high-frequency, all-day service means less waiting and no need to commit schedules. The integrations of local and express service can reduce long-distance travel times.
Route Structure	BRT uses single, often color-coded routes. they can be laid out to provide direct, no-transfer rides in multiple routes.
Fare Collection	Single BRT fare collection systems make it fast and easy to pay,often before you even get on the bus. They allow multiple door boarding, reducing time in stations.
Intelligent Transportation Systems (ITS)	BRT uses advanced digital technologies that improve customer convenience, speed, reliability, and operations safety.

Source: Journal of Public Transportation Volume 5, no. 2 (2002)

2.3.2.1. Running ways

Buses can operate successfully in mixed traffic, but bus ways and HOV lines increase their speed, reliability, safety and identity. It is essential to consider identity and image as well as speed and reliability while identifying and designing bus ways.

The positive aspect of curb bus lane is good pedestrian access and more manageable integration with turns in intersections. Negative features are delays caused by right turning vehicles and competing use of curbs by service and delivery vehicles. (Levinson et. Al, 2002)

The positive aspect of median BRT lines on arterial streets are identity, avoidance of interference with access to surrounding land uses. On the other hand, interference of left turning vehicles and poor pedestrian access are the negative aspects of median lines. (Levinson et. Al, 2002)

Running ways are the most critical elements while determining the speed and reliability of the system, and also most significant cost element in the entire system.

Figure 2: Running Way Examples, in Quito and Seoul

Source: Bus Rapid Transit Planning Guide, Wright et. al (2007)

Another issue about running ways is their characteristics, which are primarily three, as listed and described below:

Degree of Segregation: according to Diaz et. al (2004); the level of separation from other traffic is the primary planning parameter of running ways. BRT vehicles can run in mixed traffic without any separation from other vehicles on any arterial street or highway. Increasing level of separation with segregation through exclusive arterial lanes, grade separated lanes or exclusive transitways on separate right-of-way provides increasing level of time savings and reliability of the system. Fully grade-separated, segregated BRT lanes have higher implementation cost, but provides highest level of speed, increase safety and reliability as well.

Running Way Markings: treatments or markings to differentiate bus ways from regular traffic, can effectively inform the users where a BRT service operates. There are many types of markings including pavement markings, lane delineators, alternative pavement texture, alternating pavement color and separate right-of-ways. (Diaz et. al, 2004)

Guidance (Lateral): this feature controls the side-to-side movement of vehicles while operating. In conventional bus services and most BRT operations there is no lateral guidance, movement of vehicle rely on the skills of the conductor. Lateral guidance reduce right-of-way requirements, provides a smoother ride and precise docking in stations, allowing no-step boarding and exit. There are different technologies for lateral guidance including mechanical, electro-magnetic or optical. (Diaz et. al, 2004)

2.3.3. Stations

According to Diaz et.al (2004), stations are critical elements to connect users and other public transit services operating in the community with BRT system. They are also a distinguishing component for BRT service from other public transport services. Since BRT is operated on high demand corridors and has limited bus stops to increase the mobility, the number of passengers using stops is higher than conventional bus operations.

Stations are also critical for achieving system identity and image. For ridership objectives safe pedestrian and auto access to stations are essential. At major boarding points, off-vehicle fare collection and other passenger amenities are desirable. (Levinson et. Al, 2002)

Another important issue about stations is accessibility which describes the integration of surrounding communities with BRT system. According to Diaz et. al (2004); station access can be entirely focused on pedestrian access with proximity to major land uses or can provide large parking garages and lots to make the network more accessible for regional travels.

There are wide range of station types for BRT including, simple stops with basic shelters to complex intermodal terminals providing real time passenger information, newspaper kiosks, coffee bars, parking, pass/ticket sales and level boarding amenities.

Figure 3: Station Examples, Quito and Curitiba

Source: Bus Rapid Transit Planning Guide, Wright et. al, June 2007
In addition to stations, some bigger depots are needed at the end points or in the mode interchange areas. Depot areas should be big enough to accommodate buses on the queue and to allow maneuver easily.

Figure 4: Depot Examples in Bogota, TransMilenio

Source: Bus Rapid Transit Planning Guide, Wright et. al, June 2007

2.3.4. Vehicles

According to Diaz et. al (2004), vehicles of BRT have direct impact on speed, comfort and capacity of the operation and also shows the environmental friendliness of system.

Vehicles are important to reflect the system identity and image too (Levinson et. al, 2002). Vehicles should be designed according to specific BRT applications as to number and width of doors, internal layout etc. It is desirable to operate BRT system with buses of specifically designed BRT vehicles which focus on customer comfort, cleaner air and minimum noise emissions. (Levinson et. Al, 2002)

Like running ways, BRT vehicles are important elements for cost determination. While the basic features improved from standard bus to specialized BRT vehicles, price increases from $ 300.000 to $1.6 million per vehicle. (Diaz et. al, 2004)

Figure below show the external and internal layout, also the increasing accessibility features of the vehicle with platforms in the stations.

Figure 5: Vehicle Examples

Source: Bus Rapid Transit Planning Guide, Wright et. al, June 2007

2.3.5. System identity and image

Identity and image can increase ridership in competitive, consumer oriented societies, since they provide information to the customer with regards to where to access the system and routing. Identity and image should be emphasized in the design of all physical components of the BRT system, including vehicles, stations and running ways. (Levinson et. Al, 2002)

2.3.6. Service plan

According to Diaz et. al (2004), “BRT service needs to be frequent, direct, easy to understand, comfortable, reliable, operationally efficient, and above all, rapid. The flexibility of BRT elements and systems leads to significant flexibility in designing a service plan to respond to the customer base it will serve and physical and environmental surroundings in which it will operate.”

BRT service can be extended beyond the limits of dedicated guide ways where reliable, high-speed operations can be maintained. BRT service pattern works the best in all-stop ‘LRT type’ service in all times of a day, and completed by an overlaid integrated express service for specific locations in rush hours, such as express service between major park and ride stations and CBD. During peak-off periods express service is converted to regular BRT service, thus they can be more cost-effective. (Levinson et. Al, 2002)

2.3.7. ITS Applications

ITS helps transit agencies to increase safety, operational efficiency and quality of service. As stated by Diaz et. al (2004) “ITS technologies provide many performance improvements and benefits. The remote monitoring of transit vehicle location and status and passenger activity also improves passenger and facility safety and security."

As it is also stated by Hidalgo et. al (2010) that "ITS is a suit of technologies that allows for dynamic control and operation of a transit system, including automatic locators, centralized vehicle control, integrated traffic signal control, automatic fare collection and real time passenger information systems."

ITS elements can be used to deliver passenger information in a variety of places, monitor/control bus operations, provide priority at signalized intersection, enhance safety and security on board vehicles and at stations, and provide guidance for BRT vehicles. (Levinson et. Al, 2002)

As it is mentioned by Diaz et. al (2004), application of ITS elements increases the performance and provides benefits to many BRT systems, but integration of ITS technologies to the entire service is essential. A Control Centre is essential to integrate these.

The figure below shows the exact arrival time of the vehicles to the station which increases ridership with reliable information.

Figure 6: ITS applications, in Bogota and Singapore

Source: Bus Rapid Transit Planning Guide, Wright et. al, June 2007

2.3.8. Fare collection

Fare collection for BRT can be made electronically, mechanically or manually, but the basic aim should be to support efficient boarding in busy BRT corridors (Diaz et. al, 2004).

There are two types of fare collection systems. One is off-board which is more desirable for both the users and operators, since it permits multiple-door boarding, reducing station dwell times, passenger travel times and bus operating cost. The other one is on-board fare collection; this can be time consuming when the proper mechanism is not selected. With ITS and smart cards technology on-board ticketing can be easier without physical contact with driver. In addition, collecting fares after the bus moves is another solution to reduce dwell time for on-board ticketing. (Levinson et. Al, 2002)

Figure 7: Fare Collection Systems, on-board in Seoul and off-board in Bogota

Source: Bus Rapid Transit Planning Guide, Wright et. al, June 2007

2.3.9. Community participation in decision making

Public transportation planners, transit officials and users agree that traditional bus service should be improved and better vehicles, quicker stops, fewer delays, faster movement and most responsive service provided. When all these issues are considered jointly, BRT concept emerges as a viable option (Grava, 2002).

According to Levinson et. al (2003), community willingness can make BRT implementations easier, by supporting public transport, stimulating transit oriented development and fostering exclusive bus lanes, thus effective public participation becomes essential in the decision-making process.

BRT is a complex system including many improvements both in implementation and operation process, thus needing a continuous community and decision-maker support. Corporation between central, regional and local officials and transit planners, traffic engineers and urban planners is essential. (Levinson et. al, 2003)

2.4. Application Scenarios

Quick Passenger Exiting and Boarding: waiting times at bus stops slow the service and decrease the competitiveness of buses. Most of time loses appears while passengers are entering and exiting the bus. There are some actions to decrease dwelling time such as; having many doors along side of the bus, thereby losing some seats, but giving many channels for moving passengers in and out, collecting fares or checking passes inside the bus when the vehicle is already moving. If fares are to be paid on entry using smart cards which do not require physical contact with driver would also decrease the dwell time. Reserving one door for access by handicapped or elder people and using low-floor vehicles also provide rapid boarding and exiting. (Grava, S., 2002)

According to Wright et. al (2007), in most conventional bus operations, drivers are responsible for fare collection besides driving the vehicle, in this type of operation boarding can be done only front door, thus dwell time and waiting time of buses in stations increases. With off-board or pre-paid type of fare collection in BRT system decreases time spends on stations and prevents service delays. As Wright et. al (2007) stated; a pre-board fare collection and verification process will reduce boarding times from 3 seconds per passenger to 0.3 seconds per passenger. Also platform level boarding, which means stopping bay platform that has the same height with vehicle floor, provides fast boarding and exiting for passengers, allowing easier access for people in wheelchairs, parents with strollers, young children and the elderly.

Priority Treatments on Streets: a vehicle which carries many passengers should have priority to use public right-of-ways over private cars with only a few occupants. There are several means of priority actions such as; allowing only buses to make turns at critical junctions, giving buses right-of-way while they are changing lanes, reentering traffic flow or executing other traffic maneuvers. Installing signal devices is another priority option, in order not to make buses to wait in red light and designing exclusive bus lanes on existing streets. (Grava, S., 2002)

According to Wright et. al (2007), there are two form of signal priority operations which are active signal priority and passive signal priority for BRT vehicles. “Passive signal priority is the adjustment of normal traffic signals to give priority a corridor with a BRT system over a corridor without one and to give a priority to the BRT system over mixed traffic within that corridor” (Wright et. al, 2007). On the other hand active signal priority can be operated via ITS elements, with electronic equipments which detect the arrival of BRT vehicle at signal point and change the actual traffic signal passing for BRT vehicle.

Exclusive Channels (Bus Ways or HOV): This management includes improvements on city streets to provide free flow of bus traffic, which increase speed of the system. Use of HOV lines is restricted to vehicles which carry at least three (or two) passengers including buses and other public service vehicles. They may be separated from regular lines by pavement markings or barriers which permit entry and exit at controlled locations. Bypass lines or ramps can be provided at critical junction points, which allow buses and other priority vehicles to move around stacked automobiles in congested locations. (Grava, S., 2002)

Locating busways in the center median or in the center of two lanes is the most common option, which reduces right turning conflicts on right hand side flowing traffic (Wright et. al, 2007). It also can serve with single station in median which reduces infrastructure cost, instead of constructing separate stations both sides of the road.

Advanced Communication Systems: ITS system includes procedures and devices which can follow the exact location of vehicle continuously, monitor the performance of vehicle along the route, identify emergency situations immediately, provide up-to-the minute information to the operators; provide automated fare collection or pass check, and even position vehicles precisely at bus stop. (Grava, S., 2002)

System Integration: BRT system cannot be isolated from rest of the transportation systems in the community; either they provide easy access to the rail transit nodes or other bus operating systems, thus feeder lines to the core BRT system need to be tied into other modes of transportation by effective physical connections and schedule coordination. (Grava, S., 2002)

Wright et. al (2007) also emphasise that BRT systems should be integrated to rest of the city environment. BRT system can work effectively when it is an integral part of the other transport options, non-motorized traffic and pedestrian movement. As the authors state “the BRT system does not end at the entry and exit door of the station, but rather encompasses the entire client capture area. If customers cannot reach a station comfortably and safely, then they will cease to be a customer.”

2.5. Reasons to Support BRT

As discussed previously buses can have certain advantages over other transit modes. They can be implemented cheaper and quicker when compared to rail public transport. However, conventional bus services often suffer from poor public image, low speed, low level of reliability, comfort and safety issues.

In many cities, Central Business Districts (CBDs) continue to be the core of the urban area even where there is a dispersed development pattern. Thus this core requires more transportation services to make it more accessible. CBD has to be supported by public transportation, but land prices are relatively high in these districts, thus rail transit is not a cost-effective option, unless it uses a dedicated running way along existing roads or right-of-ways. For a given distance of dedicated running way, BRT is less costly to build than rail transit. Also it can be implemented quickly and incrementally. BRT can be a cost-effective mode while connecting suburban areas that are located separately. Building rail transit is not possible to connect suburban areas both to each other and to CBD, since density and passenger capacity is often low. (Levinson et. al, 2002)

The figure below shows the conceptual representation of a BRT system. According to this figure the core of the city is the main operation area of exclusive and grade separated bus ways. When the distance from CBD increases the right-of-way regulation is initiated to feed the high carrying volume of the system in CBD with exclusive bus ways. The city also uses freeways to support the system in low density areas and periphery.

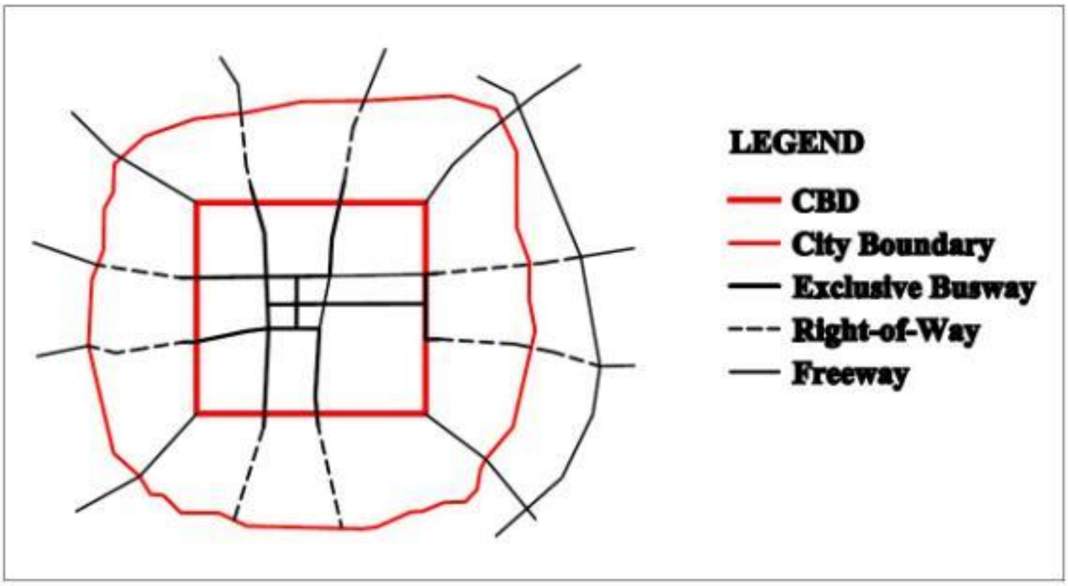

Figure 8: Conceptual representation of BRT System

Source: Journal of Public Transportation, Levinson et. al 2002

According to Grava (2002); the general perception is that every community should have bus system as their backbone of passenger mobility, but they seem to represent the last choice of transport by potential users. Most of the negative attitudes towards bus systems are originated from poor service quality, inefficient operation procedures and slow mobility because of being stuck in congested streets. As a new concept BRT intend to achieve:

- Reduced travel time by saving time at stops and while moving,
- Improved reliability by minimizing all factors that can interfere with vehicle flow and providing responsive management controls,
- Upgraded human amenities by providing attractive facilities and spaced both inside and outside the vehicle, and offering useful information to riders,
- Improved safety by providing monitoring systems, removing potentially dangerous features and bringing many riders on the system.

BRT systems can be implemented quickly and incrementally without preventing future rail investments, if needed. When compared to rail investment for a dedicated route BRT can be built cheaper. Also, they have low operating, marginal fixed and maintenance costs. Besides being cost-effective, passenger carrying capacity of BRT in some corridors can exceed the rail transit modes carrying capacity in peak hours with improvements on running ways and bus qualities. (Levinson B. et. al, 2003)

Figure below shows the construction cost of different public transportation modes including BRT, LRT, elevated rail and subway. Total infrastructure that can be constructed with $ 1 billion is 426 km for BRT, 40 km for LRT, 14 km and 7 km for elevated rail and subway respectively. The cost-effectiveness feature is clearly demonstrated in the figure.

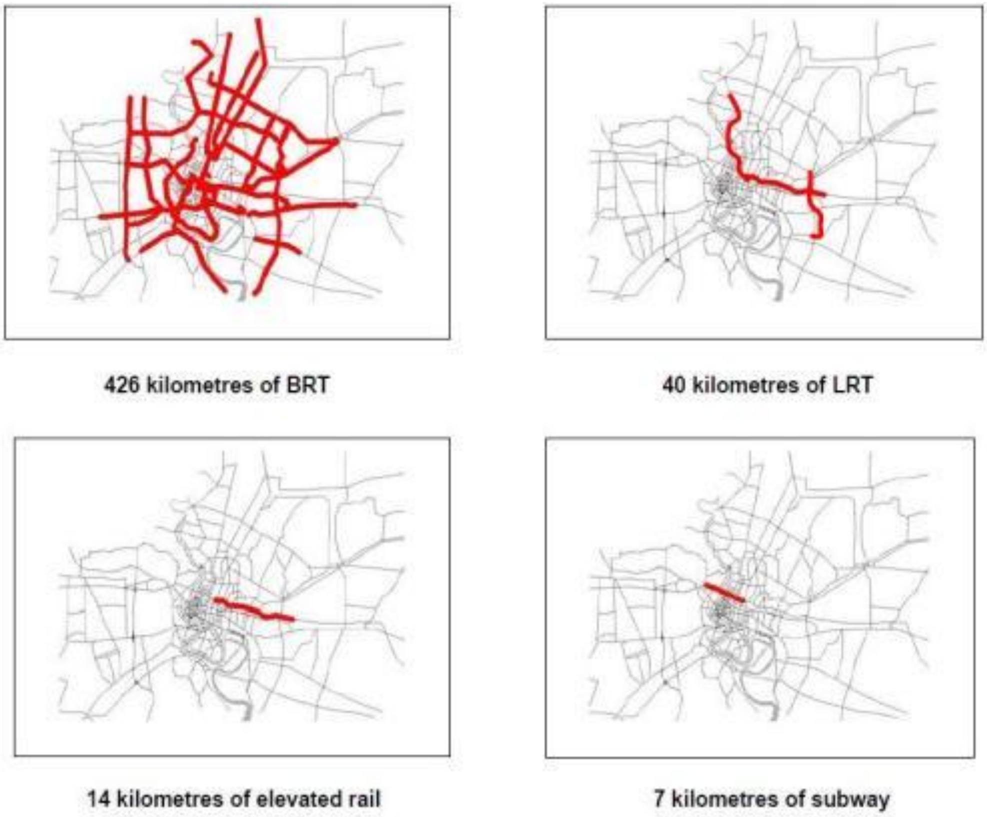

Figure 9: Comparison of Implementation Cost of Different Modes

Source: Bus Rapid Transit Planning Guide, Wright et. al, June 2007

As stated by Levinson, et. al (2003), “Benefits of BRT applications can be listed as faster journey times, higher frequency and better reliability, all these mean increased ridership, lower operating cost, less fuel consumption, greater safety and better land development.”

The aim of transit investmentsis to serve the travel demand effectively and attract a reasonable level of ridership. Higher ridership confirms the success of the transit mode and provides many benefits to the region including reduced congestion and travel time, increased accessibility and reduced pollution. Diaz et al (2004) state that “BRT systems have been successful in attracting all types of trips, including existing transit users and people that previously did not use transit at all such as non-motorized users.” However, it is the car users that most transit investments should aim to attract if they are to help attain objectives of sustainable transport. Levinson et. al (2003) state that BRT system, with its faster transit services, reduced travel times, high quality of service, good identity and image, high operating frequency and branding, can attract not only conventional bus and rail transit passengers but also private automobile users.

According to Wright et. al (2007) BRT system also provides fuel savings from public transport operations in cities, thus it reduces fuel expenditures of public transport operators, reduces fuel expenditures of other vehicles in mixed traffic and decreases dependency on imported fuel or reduces usage of domestic supply.

According to Levinson et. al (2003), “time savings range from 23 to 32% for city street operations and go up to 47% for operations on busways or reserved freeway lanes.” Time savings in BRT operations is greater than previously congested mixed traffic bus routes. On exclusive bus lanes time savings are 2-3 minutes per mile. It is claimed that when time saving exceeds 5 minutes per mile it affects mode choice of passengers.

All kinds of high capacity and high quality transit operations create different land use patterns along their route. BRT can support transit oriented development with creating greater accessibility and employment and economic opportunities. Also BRT stations with both pedestrian access and as an interchange node for other transit users lead formation of a mix of employment, retail and leisure activities. (Diaz R. et. al, 2004)

BRT system can also provide a more sustainable urban form, with densification on major corridors, decreasing cost of delivering services such as electricity, sanitation and water (Wright et. al, 2007).

According to Levinson et. al (2003), since BRT buses have priority on roads they reduce travel time and with high ridership they reduce the number or motor vehicles, and so they have beneficial effects on operating cost, safety and environmental benefits. Authors explain operating end environmental benefits of BRT by giving examples: Ottawa's Transitway saved $58 million from vehicles and $28 million from operating and maintenance cost by using 150 fewer buses than previously operating bus service and Curitiba uses 30% less fuel than other cities in Brazil, which is a result of the BRT system and indicates less gas emission to the city atmosphere.

Wright et. al (2007) also claim that BRT systems produces minimum gas emission to the air with improvement of vehicles, thus they preserve both built and natural environment. In addition, low emission of CO, NOx and SOx reduces negative effects of these gases on human health.

2.6. Reasons to Exercise Caution

According to Grava (2002), many of the BRT actions are not capital-intensive and they do not require large additional funds; however, since such efforts are beyond the regular procedures, in order to implement they require the expenditures of personal and institutional energy.

BRT implementations can be more successful than conventional bus services and rail transit systems, but all components should be implemented for better quality of service. As claimed by Levinson et. al (2003), BRT applications are complex systems so they need high coordination between institutions, officials and community members in decision-making process. Organizing all institutions and stakeholders all together is not an easy step both for implementation and organization and management process.

Since BRT implementation results in reallocation of road space, it can affect the capacity used by automobiles and other public transport operators. Wright et. al (2007) state that many officials are unwilling to implement BRT system in some cities, in order not to upset powerful special interest groups. Motorists and existing public transport operators may tend to reject BRT implantation, thus city officials should be careful about balancing all stakeholders interests.

Community willingness is another important determinant to ease the implementation of BRT system. When users of the public transportation systems are proponents of rail transit, since traditional bus services are not attracting passengers as a transit mode because of providing low quality service, it becomes difficult for the community to accept BRT as a transit mode.

Thus the advantages of BRT operations have to be explained clearly and carefully. (Levinson et. al, 2003)

When BRT is applied on existing urban areas, it encounters a space conflict. Its movement channels and facilities have to be implemented in areas that are already used for other purposes. In order to implement BRT components it is needed to take away lines from regular motor traffic or sometimes use of green space that is not exactly a part of, but nevertheless provides some visual relief. These may cause oppositions to BRT system. If motorists greatly outnumber bus riders, taking away established rights of use of the lanes cannot pass unnoticed in communities (Grava, 2002). It is claimed that the success in implementation is more likely when no existing circulation space is taken away and the success in continued operation depends on reasonably full use of system. If operation phase cannot be achieved the intrusion of motorists to bus and HOV lanes are inevitable when they see lanes very lightly used (Grava, 2002).

According to Levinson et. al (2003), despite being low cost and easy to build, implementation of BRT can still be time consuming, both in route determination based on community needs and land use and construction of bus lanes. In corridors where exclusive bus lanes are not possible, benefits gained from BRT operations become insufficient.

As stated by Levinson et. al (2003) creating exclusive bus lanes in corridors and application of ITS elements can be expensive and time consuming in all BRT cases. Since BRT systems use high quality, special vehicles, they increase the implementation cost of the system. Some authors like Black (1993) claim that LRT applications can be much cheaper in terms of vehicle cost.

2.7. Planning Considerations

2.7.1. Planning Context

Levinson et. al (2003) claim that BRT generally works more effective if the population of the city exceeds 750.000 and employment in central business district (CBD) is between 50.000 to 75.000 people.

Busway transit is likely to be suitable in a variety of locations according to Cornwell et. al (1993). Typical examples are as follows:

- In the main corridors of medium-sized cities, where travel demands are up to 20.000-25.000 passengers per hour per direction (p/h/d) for public transport,
- In secondary corridors of large cities, in order to feed rail mass transit routes,
- In outer city suburbs, to structure new developing areas,

While planning a system, it is essential to distinguish between a basic busway as a traffic management measure, in order to meet short-term traffic objectives and a bus-based mass transit system, which includes special operational measures, to meet medium-long term objectives. The physical infrastructure in each case might be similar, but the operational and organizational arrangements for busway transit are important components for the system and need careful planning (Cornwell et. al, 1993).

2.7.2. Allocation of Road Space

Hidalgo et. al (2010) argue that in order to reduce land acquisition and undesired displacement, there should be an effort to use existing right-of-way. However, as mentioned above, inserting a busway into an existing right-of-way creates difficulties about allocating road space between buses and conflicting road users. On the other hand, if there is a policy about restraining the use of private cars and promoting the use of public transportation, busways give the physical expression and commitment to this policy objective (Cornwell et. al, 1993).

In corridors where passenger demands are high, the number of passengers transported along bus lane or busway can be expected to be higher than those carried by private cars. As stated by Grava (2002), opposition from other road users is inevitable if the systems is not used reasonably. In other words, if the demand is low and busway is not used effectively, this may create a political pressure for reallocating busways to other users; and therefore, it may be necessary to permit the use of the busway by other vehicles, such as allowing its usage as an HOV lane (Cornwell et. al, 1993).

2.7.3. Running Way Segregation Types

Mixed Flow Lanes: according to Diaz et. al (2004) these are the most basic from of BRT running ways. Buses running in mixed traffic without any improvement suffer from delays in operation because of other vehicles using same street. BRT vehicles can cope with congested traffic with the improvement of queue jumpers providing buses to bypass crowded areas. Author state that “in most applications, queue jumper lines are used in conjunction with signal priority to allow vehicles to enter an intersection with a special signal ahead of other vehicles.”

Cost: Use of existing lane do not require modifications, thus has minimal cost.

$ 0,1- $ 0,29 million per queue jump line section per intersection

Reserved Arterial Lanes: a traffic lane in an arterial street is designated only for BRT operations, and entrance of other vehicles to this lane is restricted. Provision of reserved lane for only BRT vehicles increase reliability and reduce travel delays between stops. (Diaz et. al, 2004)

Cost: $ 1,5- $ 1,8 million per lane km

At-Grade Transit Ways: operation in these lanes has higher speed, reliability and is safer, since they are separated from general traffic physically, thus other vehicles cannot interfere the lane. The negative side of this type of segregation is intersection with other traffic at cross streets. (Diaz et. al, 2004)

Cost: $ 2,5- $ 4,8 million per lane km

Fully Grade-Separated Transit Ways: BRT service is operated in the grade-separated exclusive transit ways which have greatest level of separation from other traffic. Buses can run on former railroad right-of-way or on a major highway either along one side or median of a freeway or on separate elevated or underground viaducts. This type of lanes provides higher speed and reliability between BRT stations, but they are the most expensive investments. (Diaz et. al, 2004)

Cost: $ 4,8- $ 11,68 million per lane km

Figure 10: At-Grade Transit Way Examples, in Bogota and Sao Paulo

Source: Bus Rapid Transit Planning Guide, Wright et. al, June 2007

Figure 11: Fully Grade Separated Running Way in Eugene and Leeds

Source: Bus Rapid Transit Planning Guide, Wright et. al, June 2007

2.8. Feasibility and Warrants

In Figure 4, the trade-off between traffic flow density and bus flow is shown. According to the figure; there are four different scenarios: in Case 1 the passenger capacity is modest and road has enough empty space, thus bus priority arrangement is not needed. In Case2, although the road traffic nears the saturation level, the passenger volume is low, thus bus priorities would not be acceptable. In Case 3; bus priorities can be applied without creating significant disturbance to other vehicles, since road has enough carrying capacity. In Case 4; bus priority is most needed because of high passenger demand, but the disturbance to other traffic is greater because of high saturation of road. In order to implement bus priority, strong political will would be required in this latter case (Cornwell et. al, 1993).

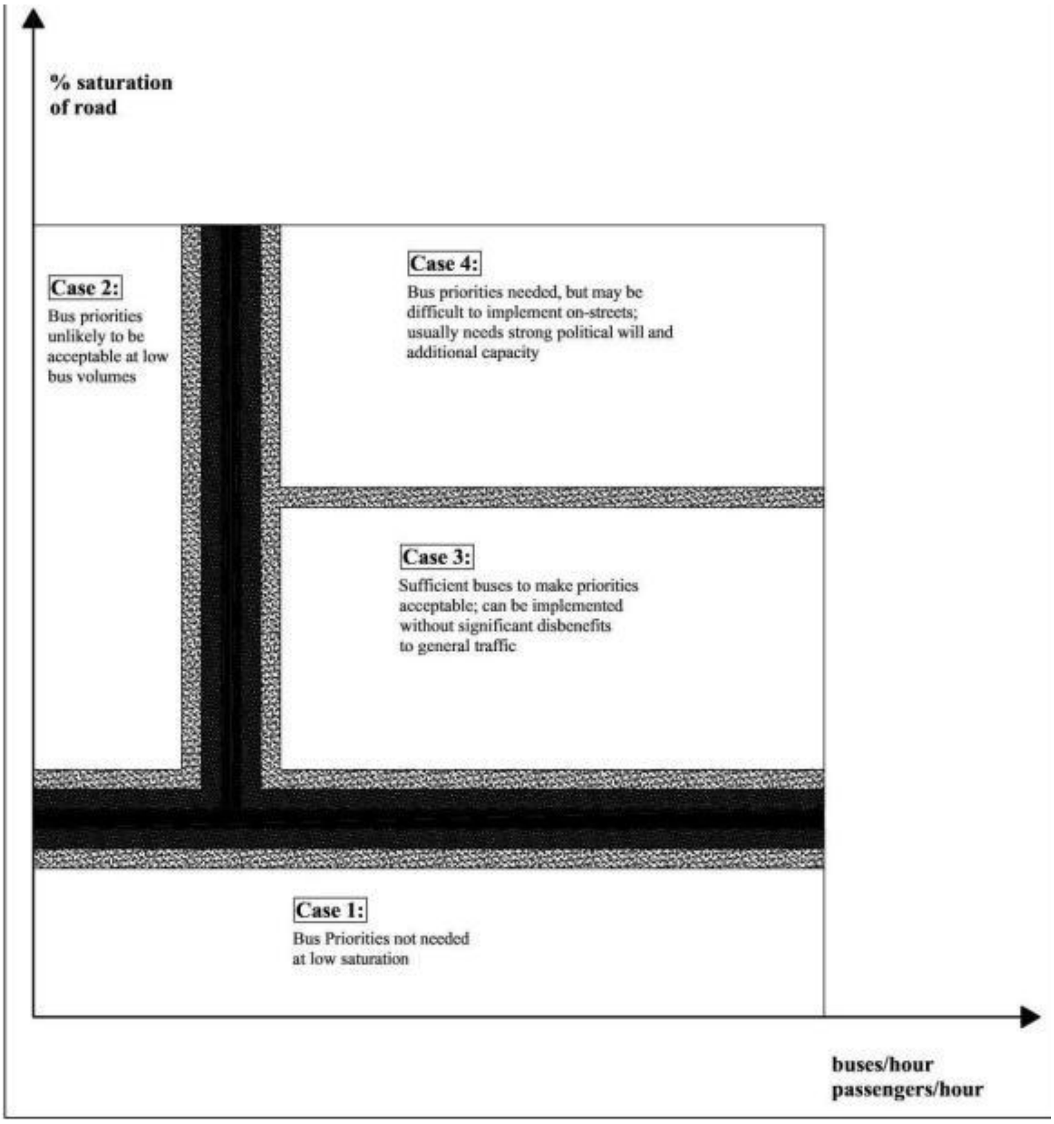

Figure 12: Feasibility of Busway along Existing Road

Source: Overseas Road Note 12, Design Guidelines for Busway Transit (1993)

When the existing road space is limited, the allocation of scarce road space to buses can be justified:

- Buses can transport more passengers when compared to private cars, around 20.000 people moved with buses (p/h/d), but only 2-3.000 people with private cars,
- It may be easier to divert cars to another route than constructing a new route for buses,
- It may be more cost-beneficial to allocate existing road space to buses and construct additional road for other vehicles, than to construct a new rail mass transit line.

2.9. Capacity Concepts

The capacity, which includes number of buses and number of passenger carried, of BRT system depends on all its components, that are the type of running way, the design of stations and stops, the size and height of vehicles, door arrangements on buses and fare collection technology (Levinson et. al, 2003).

Cornwell et.al (1993) argue that the technical literature defined the capacity of system usually with referring explicitly or implicitly to line-haul capacity; however passenger transport capacity is also important, because bus stop/station capacity is a limiting factor of a transit system. Maximum line-haul operation decreases when passenger transfer demand increases as shown in Figure 16. In practice it is impossible to fill the bus to full capacity, since there is an imbalance between empty spaces in the bus and the number of passenger boarding in each bus stop. In some cases; buses leave the stop empty, while in others the bus may be full and leave some of the passengers waiting at the stop. Without special operational policies it is difficult to achieve average load factor in excess of 70-80% without overcrowding on buses. (Cornwell et.al, 1993)

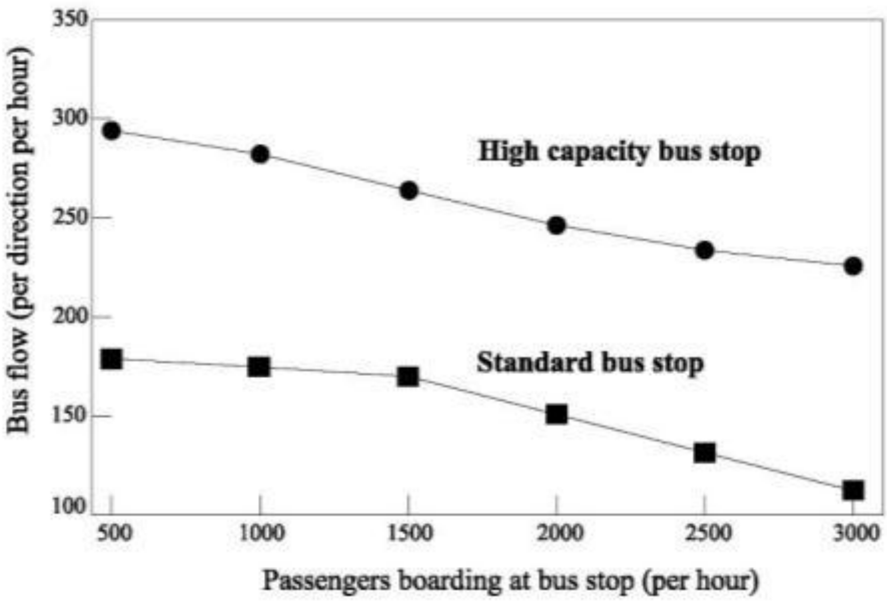

Figure 13: Relationship between Line-haul Throughput and Passenger Transfer Demand

Source: Overseas Road Note 12, Design Guidelines for Busway Transit (1993)

2.10. System Planning Parameters

In Figure 17 the main factors influencing the capacity of bus lane or busway are listed. These comprise the planning parameters of BRT systems since capacity plays an important role in planning and design of the system.

Table 4: Capacity Determinants

RIGHT OF WAY CHARACTERISTICS
• Road cross-section • Degree of physical segregation from other traffic • Junction design and control • Horizontal and vertical alignment • Road surface characteristics
BUS STOP CAHARACTERISTICS
• Overtaking facilities • Spacing • Number of loading positions(bays) • Platform storage area • Passenger information • Platform height
BUS CHARACTERISTICS
• Vehicle size and capacity • Existence and control of doors • Number, location, width and use of doorways • Number and height of steps • Floor height • Maximum speed • Acceleration and deceleration rates
OPERATING CHARACTERISTICS
• Route structure and scheduling • Driver behavior • Fare collection and ticketing • Trunk-and-feeder • Bus Ordering (or convoys)
PASSENGER CAHARACTERISTICS
• Passenger demand, by stop • Distribution, by time of day • Behavior
GENERAL TRAFFIC CHARACTERISTICS
• Volume and nature • Road user discipline • Encroachments (e.g. Hawkers)

Source: Overseas Road Note 12, Design Guidelines for Busway Transit (1993)

2.11. Organization, Management and Regulatory Framework

In order to implement an effectively operating busway transit that offers high performance, special operational and management arrangements are needed. According to Cornwell et. al (1993) these operational and management arrangements can be listed as follows:

- Maintenance of the bus track, bus stop facilities and traffic control devices,
- Fare collection and ticketing, possibly including off-board ticketing and management of season tickets or travel cards,
- Driver training for the particular conditions associated with high-intensity operations,
- Facilities and staff to undertake bus ordering, where appropriate,
- Provision of reliable and up-to-date passenger information,
- Supervision to limit dwell times at busy bus stops in order to avoid excessive delays and service disruptions.

According to Levinson et. al (2003); frequency of service is also an essential component of management and operation decision in BRT operations. Frequency of service in BRT lane should be at most 8-10 minutes in peak hours and should not exceed 12-15 minutes during peak-off periods to ease random passenger movement.

Hidalgo et. al (2010) state that careful attention should be paid to regulatory/institutional issues, and that the existing regulatory framework should be adapted if required. As mentioned previously BRT system should be an integral part of existing public transportation. According to Hidalgo et. al (2010) when BRT operation will be integrated to existing rail-based transit, officials should convince rail operators that the BRT is not a competitor, that it is a complementary operation.

Busways operate under a variety of regulatory arrangements, and according to Cornwell et. al (1993) currently there are no busways functioning in an entirely deregulated environment. In some cities bus service is provided entirely by publicly owned monopoly operators, while in some cities bus operations are carried out by privately owned companies. There are also cities where buses are operated by corporation of public and private sector as a part of integrated system, with color coding of vehicles according to function, and with a common fare. (Cornwell et.al, 1993)

2.12. SUMMARY

Mobility in urban areas is rapidly increasing and more importantly becoming more and more automobile-oriented. In many urban areas passenger mobility is increasingly becoming dependent on private automobiles that cause air and noise pollution, emit greenhouse gases resulting in climate change, increase fossil fuel dependency, result in high time costs as well as accident costs, increase expenditures of local governments for road investments, and deteriorate street and community life while resulting in inequalities in accessibility for different users.

These trends are clearly unsustainable and hence urban transport in most cities in the world has to be planned with a view to create more sustainable transport systems, economically, environmentally and socially. This requires improvement of alternatives to the automobile and restrictions on automobile usage in cities, particularly in central areas that suffer from congestion. One of the most effective alternatives to the automobile is public transport. Many cities in the world have been investing in public transport to attract citizens and encourage them to use public transport. While urban rail systems, such as heavy rail, light rail and trams, received much investment, the past three decades also saw Bus Rapid Transit (BRT) being introduced as an innovative public transportation mode, offering significant advantages of service quality overconventional bus operations, and significant cost-savings and ease of implementation in comparison to rail alternatives. BRT is becoming more popular in cities both in developed and developing countries, with its cost-effective features, easy and quick implementation and high ridership potential

BRT operations are composed of a package of elements such as special running ways, innovative station and vehicle design, effective fare collection systems, ITS elements and flexible service and operation plan, all of which help to provide high ridership while decreasing the negative effects of private automobile usage. The elements of BRT can be implemented partially as well, but in order to increase the benefit gained from the operation it is essential that the application comprises all features of the system.

The review provided above reveals a number of features or criteria that appear to be important for a successful BRT operation. Many of the discussions put forward by different authors overlap with each other and help to develop a list of criteria to help increase ridership and success of BRT systems. In order to be able to develop a comprehensive list of such criteria, the study continues with the next chapter to illustrate the implementation aspects of BRT by first providing an overview of BRT applications in the world, and then focusing on three well-known case studies of BRT: these are Curitiba from Brazil; Bogota from Colombia, and Mexico City from Mexico. In the literature these three cases, and particularly the first one from Brazil, are often referred to as the best-practice cases for BRT, and therefore, they are analysed in more detail, after which a list of criteria is offered to assess the performance of BRT systems.

CHAPTER 3

3. A REVIEW OF BRT IMPLEMENTATIONS IN THE WORLD AND ANALYSIS OF BEST-PRACTICE CASES

3.1. BRT Implementations in the World: An Overview

The popularity of BRT is growing throughout the world, because it includes passenger and developer attractiveness, it has high performance and quality, and it can be built quickly, incrementally, and economically. Even in largest cities, BRT provides sufficient transport capacities in many corridors. (Levinson et. al, 2002)

There are more than 120 cities operating BRT and bus corridors in North America, Latin America, Asia, Europe and Australia. Figure 18 and Figure 19 show the cities where BRT systems and busways are being operated as of year 2007.

According to 2010 data, there were 120 cities operating BRT and bus corridors which correspond to 280 corridors, 4.335 km route length, 6.683 stations and 30.000 buses (Hidalgo et. al, 2010). Around 26,8 million passengers are using these systems in their weekday transportation activities. The rapid growth of these systems also continued after 2010: 16 cities have started to operate BRT and bus corridors. This indicates 13% growth in total world BRT system numbers, including cities in China, Indonesia, Colombia, India, Thailand, Brazil, Mexico, Peru, UK and Canada. These cities implemented 21 corridors with 396 route length, 464 stations and 2.047 buses. 1,4 million passengers have started to use these systems in weekday (Hidalgo et. al, 2010). In addition, in year 2010, 7 cities expanded their BRT and bus corridors with a further 125 km in total (Hidalgo et. al, 2010). This may be considered as an indication that these cities are satisfied by their previous implementations and continue to finance BRT operations. Figure 3.1 shows the BRT and Bus Corridor applications in the world and its growing popularity.

BRT applications are likely to continue in both developed and developing countries. There are 49 new cities where BRT corridors are under construction. 16 cities that are currently operating BRT system are carrying out construction to expand their corridors. Furthermore, there are 31 new cities where BRT systems are in planning stage. (Hidalgo et. al, 2010)

Table 5: Cities running a BRT system (as of March 2007)

Continent	Country	Cities with BRT systems
Asia	China	Beijing, Hangzhou, Kunming
	India	Pune
	Indonesia	Jakarta (TransJakarta)
	Japan	Nagoya (Yutorito Line)
	South Korea	Seoul
	Taiwan	Taipei
Europe	France	Caen (Twisto), Clermont Ferrand (Léo 2000), Lyon, Nancy (TVR line 1), Nantes (Line 4), Nice (Busway), Paris (RN305 busway, Mobilien, and Val de Marne busway), Rouen (TEOR), Toulouse (RN88)
	Netherlands	Amsterdam (Zuidtangent), Eindhoven, Utrecht
	UK	Bradford (Quality Bus), Crawley (Fastway), Edinburgh (Fastlink), Leeds (Superbus and Elite)
	Germany	Essen (O-Bahn)
Latin America and Caribbean	Brazil	Curitiba (Rede Integrada), Goiânia (METROBUS), Porto Alegre (EPTC), São Paulo (Interligado)
	Chile	Santiago (Transantiago)
	Colombia	Bogotá (TransMilenio), Pereira (Megabus)
	Ecuador	Quito (Trolé, Ecovía, Central Norte), Guayaquil (Metrovía)
	Guatemala	Guatemala City (Transmetro)
	Mexico	León (Optibus SIT), Mexico City (Metrobús)
North America	Canada	Ottawa (Transitway)
	United States	Boston (Silver Line Waterfront), Eugene (EmX), Los Angeles (Orange Line), Miami (South Miami-Dade Busway), Orlando (Lynx Lymmo), Pittsburgh (Busway)
Oceania	Australia	Adelaide (O-Bahn), Brisbane (Busway), Sydney (T-Ways)

Source: Bus Rapid Transit Planning Guide, Wright et. al, June 2007

Table 6: Cities running a BRT system (as of March 2007)

Continent	Country	Cities with basic busways
Africa	Ivory Coast	Abidjan (Boulevard de la Republique)
	South Africa	Johannesburg (Soweto Highway)
Asia	China	Beijing (Qinghua Dong Road), Shejiazhuang, Shenyang
	Japan	Nagoya ("Key" Routes)
	Turkey	Ankara (Besevler-dikimevi), Istanbul (Taksim-Zincirlikuyu)
Europe	Belgium	Liege, Evry
	Italy	Genoa
	Spain	Madrid (Paseo de la Castellana)
	UK	Ipswich (Superoute 66), Runcorn
Latin America and Caribbean	Brazil	Belo Horizonte (Avenida Cristiano Machado), Campinas (Amoreiras), Manaus, Recife (Avenidas Caxangá, Joaquim Nabuco, Sul, and Herculano Bandeira), Rio de Janeiro (Avenida Brasil)
	Chile	Santiago (Avenida Grecia)
	Peru	Lima (Paseo de la República or "Via Expresa", Avenida Abancay, and Avenida Brasil)
	Trinidad and Tobago	Port of Spain
North America	United States	Los Angeles (San Bernardino Freeway, Harbor Freeway), New York City (Lincoln Tunnel), Philadelphia (Ardmore busway), Providence (East Side bus tunnel)
Oceania	Australia	Perth (Kwinana Freeway)

Source: Bus Rapid Transit Planning Guide, Wright et. al, June 2007

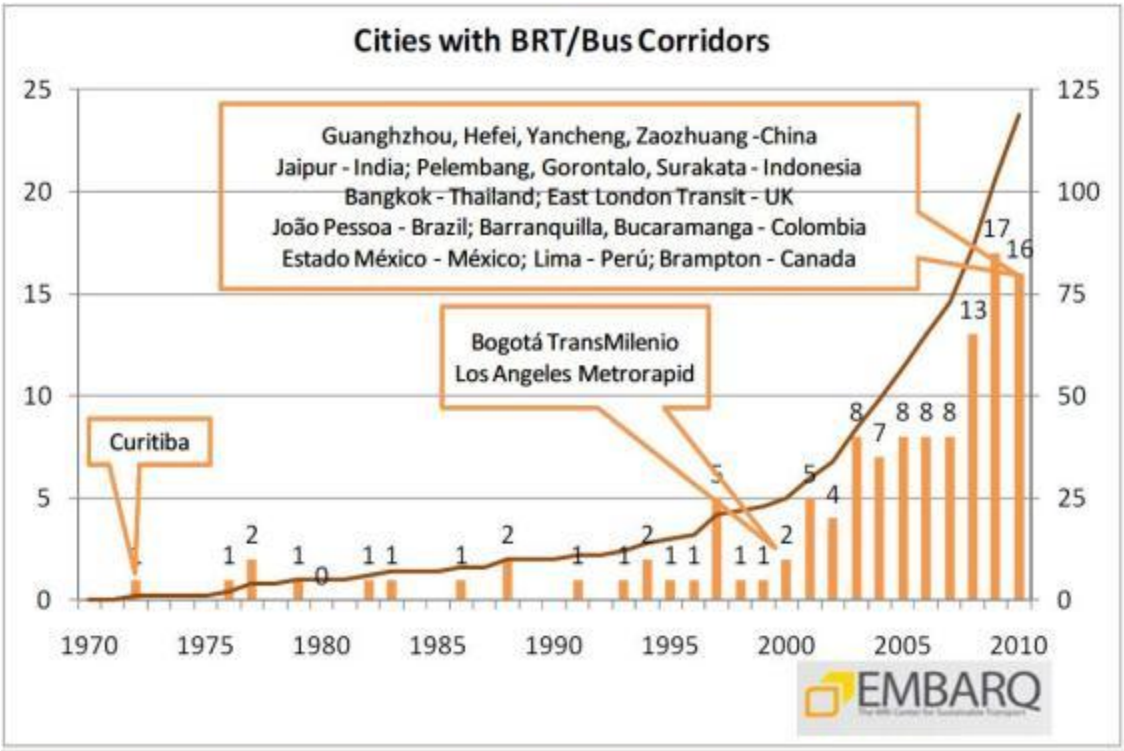

Figure 14: Cities with BRT/Bus Corridors

Source: EMBARQ BRT/Bus Corridors Database, January, 2010

It is stated by Levinson et. al (2002) that there are about 20 cities in US and Canada operating, constructing or planning BRT services. These systems vary in length, extent, components, design,operating features, ridership, cost and benefits. Among cities in Canada and US, Ottawa and Pittsburgh have the most extensive and heavily utilized busway operations providing both express and all-stop services, and both stimulating significant land development along their BRT corridors (Levinson et. al, 2002). They are briefly described below.

According to 2007 statistics total urban area of Ottawa was 413 km^2 with 778.207 residents. Ottawa was growing rapidly, thus the need for a rapid transit operation was obvious. In 1983 the first transitway in Ottawa opened, and then in 1984 and 2007 additional transitway and bus lane sections started to be operated. The length of exclusive roadway is 30,2 km, the length of bus lanes are 16 km, including 38 stations, and 11 park-and-ride lots with 5.340 spaces. Ridership of Ottawa transitway is 240.000 passengers/day and 60 million passengers/year. The system carries 10.200 passengers per hour in peak periods. There are 180 buses operating in the system, some of which are articulated and double-decker buses in order to meet high demands. Transitway is fully integrated with O-Train and Diesel LRT. In addition, these systems are integrated in terms of fares. (Mercier, Alan, 2008)

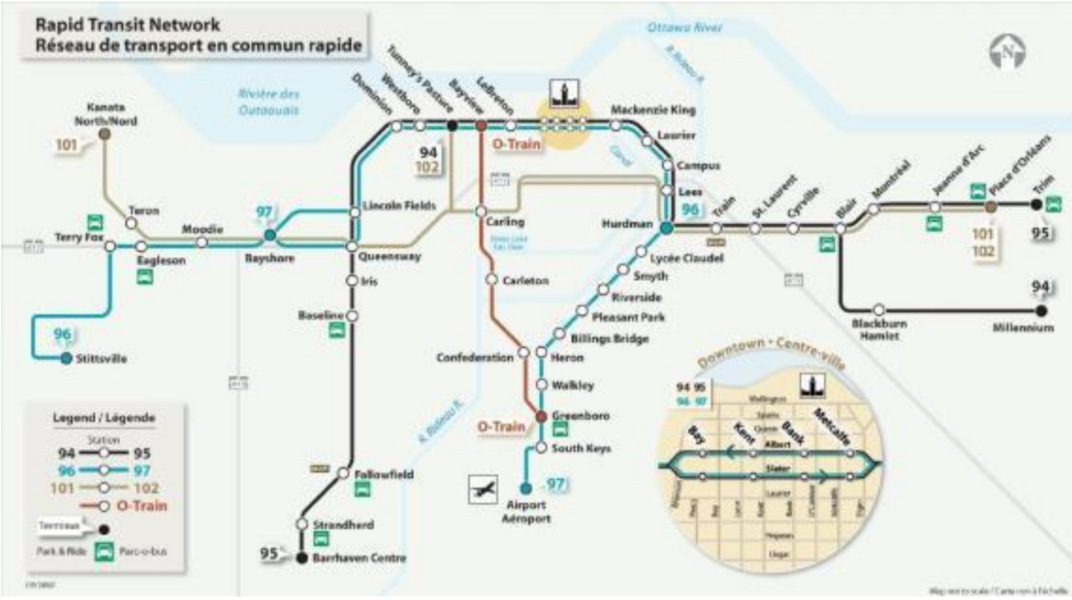

Figure 15: Ottawa Transitway Network

Source: Rapid Transit in Ottawa BRT Today and Tomorrow, Mercier, Alan, 2008

Pittsburgh has three corridors in operation. Its first busway started to be operated in 1977, the second in 1983 and the third one in 2000. Weekday ridership is approximately 51.600 passengers in three corridors.

North American cities generally have lower public transport usage due to their automobile-dependent development. Therefore, ridership in other parts of the world, and particularly in Latin America and Asia are much higher than the figures given above for Ottawa and Pittsburgh. As stated by Hidalgo et. al (2010) “the mega cities of Latin America and Asia rely on public transport to keep their citizens moving and economies working while mitigating the negative environmental impacts of rapid motorization.” Many cities are upgrading or transforming their public transportation systems in order to meet high mobility demands. BRT is becoming important services with considerable ridership levels in these cities. Figure 22 shows the key features of cities operating BRT in Latin America and Asia.

As seen in Figure 22, the population of cities and their density (population/km^2) varies. Among the thirteen cities given in the Figure, the most populated one is Mexico City with 19.240.000 people, the least populated is Pereira in Colombia with 443.000 people. According to their total urban area, the densities also vary. Among these cities Bogota has the highest density with 150 people/ha; Pereira is in the last row with 631 people per km^2. It is clear that BRT can be implemented in medium-sized or large mega cities.

Hidalgo et. al (2010) also gives detailed information about cities operating BRT in Latin America and Asia (Figure 22.). Information about systems includes corridor length and characteristics; such as operation in median busways or bus lanes, number of stations, terminals and transfer stations. As a supply aspect the number of vehicles and their characteristics are mentioned; and as a demand aspect passenger volumes are given. This information will be discussed later in the chapter in moredetail. As previously mentioned BRT operations need cooperation between many institutions, and in the comments part of Figure 23 and Figure 24 the status of operating companies and their ownership are given.
Table 7: Key Statistics of Cities that operate BRT in Latin America and Asia

CITY	COUNTRY	METRO AREA POPULATION 2006	METRO AREA POPULATION DENSITY (POP/KM2)	2009 HUMAN DEVELOPMENT INDEX VALUE (RANK)[a]
Critiba	Brazil	2.960.000	4.568	0,813 (75)
Sao Paulo		18.610.000	9.456	
Santiago	Chile	5.700.000	2.896	0,878 (44)
Bejing	China	10.850.000	14.505	0,772 (92)
Bogota	Colombia	7.800.000	15.058	0,807 (77)
Pereira		443.000	631	
Quito	Equador	1.550.000	3.236	0,806 (80)
Guayaquil		2.460.000	7.130	
Ahmedabad	India	5.340.000	11.459	0,612 (134)
Jakarta	Indonesia	13.670.000	10.051	0,734 (111)
Leon	Mexico	1.470.000	1.205	0,854 (53)
Mexico City		19.240.000	9.286	
Guadalajara		3.950.000	6.628	

[a] HDI (Human Development Index) rank is out of 182 countries

Source: Modernizing Public Transport, Hidalgo et. al, 2010

Table 8: Overview of Bus Systems in Latin America and Asia

CITY/PROJECT (INITIAL YEAR)	GENERAL DISCRIPTION	SUPPLY/ DEMAND	COMMENTS
Curitiba RIT (1973)	Citywide integrated bus system with five BRT corridors (65 km of median bus ways), 139 stations, 26 terminals, 340 km of feeder routes, 185 km of inter-district circular routes, 250 km of "rapid bus" routes; total 340 bus lines and 1.100 km of bus routes.	2.200 vehicles, including 114 bi-articulated diesels as well as articulated, conventional, small buses, special service buses; electronic fare collection system. 2.26 million passengers/day.	7 private operators under agreements with a public authority. New 22 km BRT corridor under construction
Quito Metrobus-Q (1995)	Three BRT corridors (37 km, mostly median busways); 68 stations, 9 terminals; integrated feeder services; centralized control (seperately for each corrior)	189 articulated buses (113 trolley buses), 185 feeder buses, coin-based fare collection. 560.000 passengers/day.	Public operator/owner (Trolebus and Ecovia corridors), private operator (North corridor), no fare integration among corridors. Discussion to replace Trolebus with LRT.
Bogota TransMileno (2000)	High-capacity BRT system with 84 km median busways, 104 stations, 10 integration points, integrated feeder services and advanced centralized control.	1.900 articulated buses, 10 bi-articulated buses, 448 feeder buses, electronic fare collection system. 1.6 million passengers/day.	Five private groups, partially formed by traditional operators, hold concession contracts for 7 trunk and 6 feeder zones. Two new corridors (22 km) under development as wellas a citywide reform of traditional bus services. Metro system under study.
Sao Paulo Integrated System (2002)	Integrated system under single fare with partial BRT treatments in some corridors (e.g. Passa-Rapido corridor). 104 km median busways, preferential bus lanes, 327 transfer stations, 24 terminals.	13.711 buses: 1.073 articulated, 5.599 padron (90-passenger), 2.423 conventional, 3.063 microbus (21-passenger), 1.553 minibus (42-passenger), integrated electronic fare collection system. 6 million passengers/day.	Private operators under concession contracts with the municipal public agency SPTrans. Integration has been expanded to regional rail and several municipal services within the metropolitan area.
Leon SIT-Optibus (2003)	3 BRT trunk corridors with 25 km median busways (60% segregated), 3 terminals, 51 stations, integrated feeder services, centralized control.	55 articulated buses; 500 auxiliary and feeder buses; electronic fare collection system. 220.000 passenger/day	Thirteen existing private concessionaries formed 4 new operators for trunk-ways and continue feeder service operation. System under expansion (Phase II) including reorganization of citywide services.
Jakarta Transjakarta (2004)	Three BRT trunk corridors with 37 km median busway, 4 terminals, 63 stations, poor integrated feeder, centralized control.	162 conventinal buses (12 m), electronic fare collection system. 260.000 passenger/day	Two private operators, physical integration with commuter train and local buses
Mexico City Metrobus Insurgentes (2005)	Two BRT corridors, 50 km median busway, 77 stations, four terminals, centralized control using ITS	209 articulated buses, 12 bi*articulated buses, electronic fare collection system. 450.000 passengers/day	Eight bus operators, (one public), two fare collection contractors, physical integration with regional buses, regional rail and Metro.

Source: Modernizing Public Transport, Hidalgo et. al, 2010

Table 8: Overview of Bus Systems in Latin America and Asia (continued)

CITY/PROJECT (INITIAL YEAR)	GENERAL DISCRIPTION	SUPPLY/ DEMAND	COMMENTS
Beijing Beijing BRT (2005)	One BRT trunk corridor with 16 km median busway, one terminal, 19 stations, centralized control.	60 articulated low-floor buses, manual fare collection system. 120.000 passenger/day	One private operator, and physical integration with Metro.
Pereira Megabus (2006)	16 km exclusive busways (50 % in median on left side on one-way streets in downtown), plus 800 m in mixed traffic on a major bridge, 37 stations, two terminals, centralized control.	52 articulated buses, 82 small feeder buses, electronic fare collection and control system. 115.000 passengers/day.	Two private operators of buses, one fare collection concessionaire.
Guayaquil Metrovia (2006)	35 km exclusive bus lanes on the median or left side on one way streets, 60 stations, 3 terminals, centralized control.	92 articulated buses, 80 feeder buses, electronic fare collection system. 300.000 passengers/day	One private concessionaire for bus operations, one fare collection and technology provider. System expansion in 2007
Santiago Transantiago (2007)	18,8 km of segregated corridors, 4,6 km of new road connections, 62,7 km of improvements in road geometry and pavements (in 7 corridors), 70 large bus shelters along the main corridors, and 3 intermodel stations.	1.200 new low-floor articulated buses, 1.500 conventional trunk buses (to be gradually replced by low-floor buses), and 2.300 feeder buses. Integrated electronic fare collection system. 5,7 million passengers/day.	Buses privately operated through 14 concession contracts: one private operator for finacial management, one private operator for systems integration (control and user information) and one public operator (Metro).
Guadalajara Macrobus (2009)	16 km of median busways, 27 stations, integrated feeders, centralized control.	41 articulated buses, 103 feeder buses, electronic fare collection. 127.000 passenger/day	Good integration with light rail system and feeder routes, one private concessionaire for bus operation.
Ahmedabad Janmarg (2009)	18 km of exclusive median busways, 26 stations, centralized control.	25 conventional trunk buses, manual fare collection. 35.000 passengers/day.	One public bus operator, one private fare collection contract and one ITS contract.

Source: Modernizing Public Transport, Hidalgo et. al, 2010

BRT operations in medium-sized cities and along corridors in large cities can carry same levels of, and even more passengers than many of the LRT lines. Since BRT provides faster transit services, reduced travel times and high quality of service with good identity and image, it increases ridership. Provision of high speed and high quality service with exclusive busways and better vehicles increases demand for bus transit.

Figure 3.3 shows the total passenger numbers, i.e. ridership, in 2009 in the Latin American and Asian cities that operate a BRT.

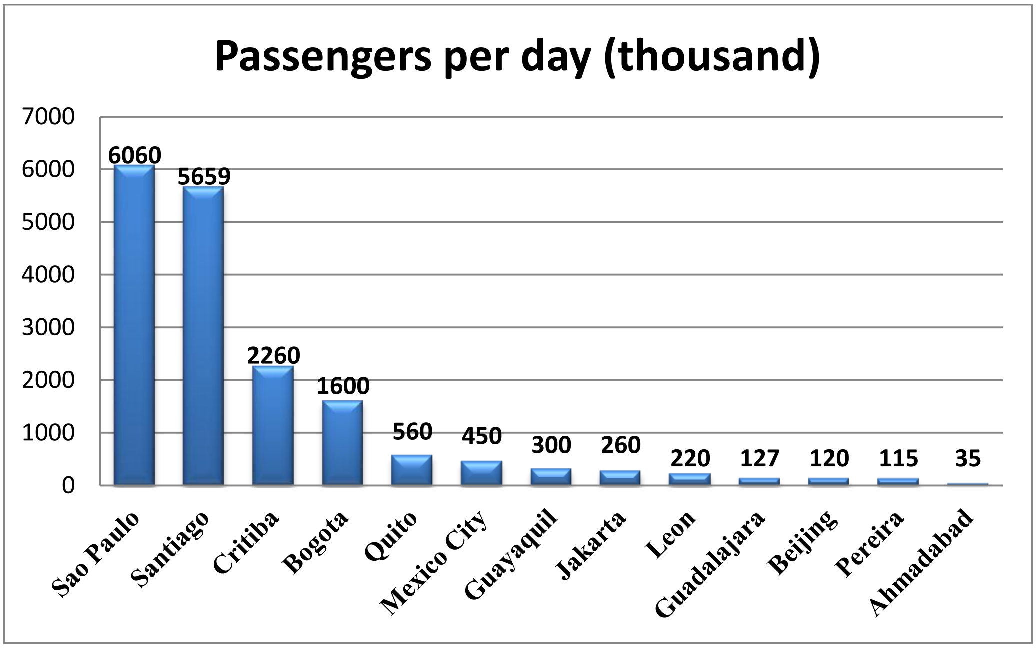

Figure 16: Total Passenger Numbers (2009)

Source: Modernizing Public Transport, Hidalgo et. al, 2010

As mentioned previously BRT systems can carry high amount of passenger volumes. Among thirteen Latin American and Asian cities the highest passenger volume is in Sao Paulo's integrated system with 6 million passengers per day. Sao Paulo has a good integrated system under single fare system. BRT system in Sao Paulo is operated with 1.073 articulated, 5.599 padron (90-passenger), 2.423 conventional, 3.063 microbus (21 passenger), 1.553 minibus (42-passengers) in total 13.711 buses. They use integrated electronic fare collection system. The figure shows that the least passenger volume is in Ahmadabad with 35.000 passengers per day. In 18 exclusive median busways they operate 25 conventional trunk buses.

As well as total daily passenger volume, peak hour passenger volume is also important for BRT operations. In Figure 26 the peak loads are shown in thirteen Latin American and Asian cities.

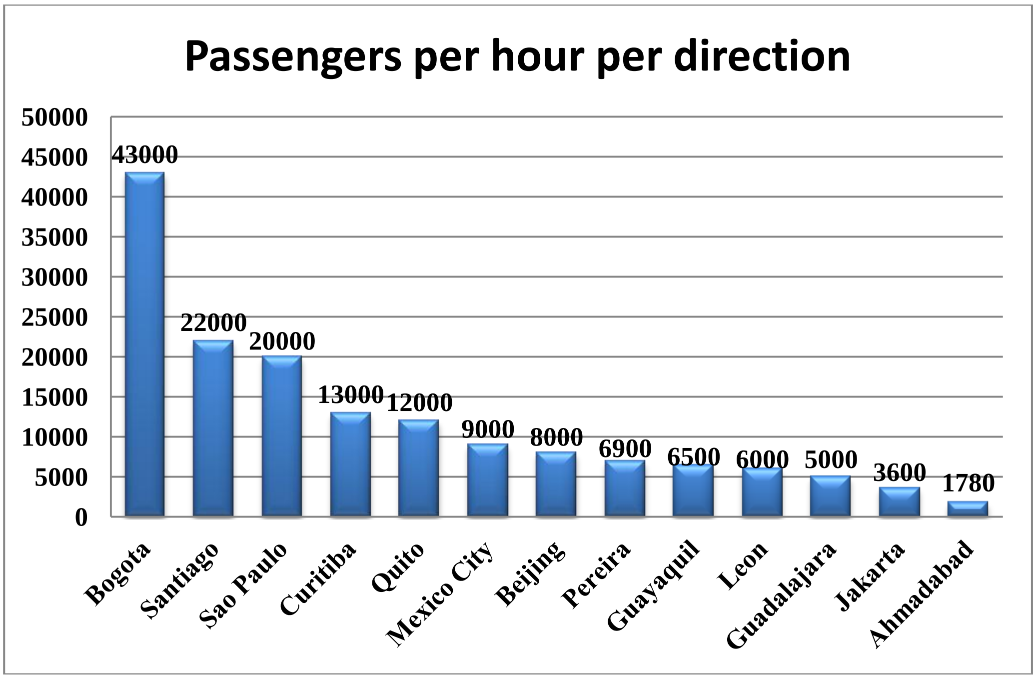

Figure 17: Peak Loads (2009)

Source: Modernizing Public Transport, Hidalgo et. al, 2010

In peak hours the best performing system is TransMilenio in Bogota with 43.000 passengers per hour in each direction. TransMilenio is a high-capacity BRT system with 84 km median busway including 104 stations, 10 integration points and integrated feeder services. The system is operated with 1.190 articulated, 10 bi-articulated buses and 448 feeder buses; total passenger volume is 1,6 million passenger per day. Among thirteen operations Janmarg in Ahmadabad has the least passenger volume with 1780 passengers per hour in each direction in peak hours.

Total passengers carried by a BRT line is an important indicator to define its success and attractiveness among other transportation modes; however, major variations can take place in these figures with respect to the differences in the length, extensiveness and coverage of systems. Therefore, to make the ridership data more comparable, the number of passenger carried per km of route should also be analyzed (Figure 27).

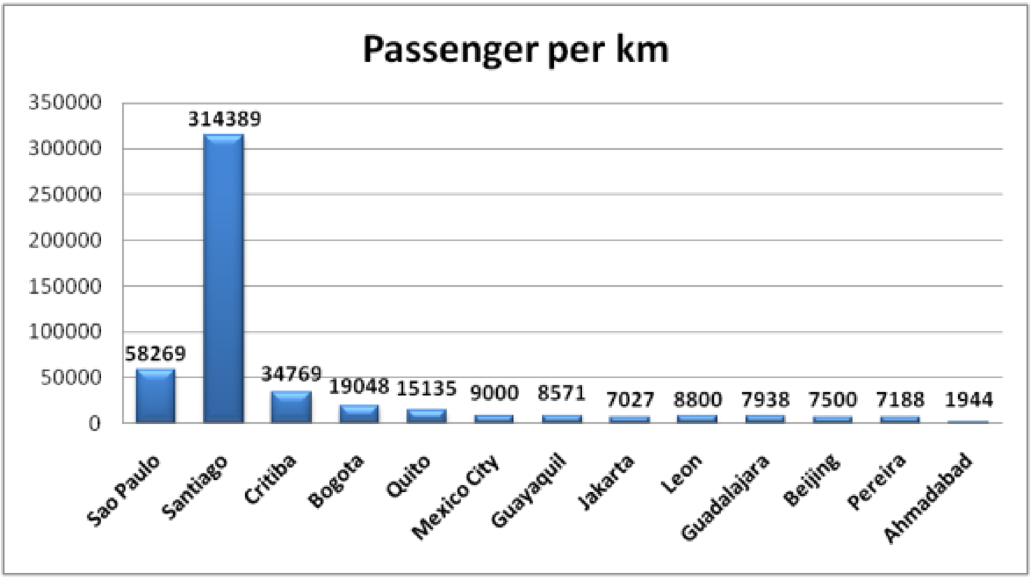

Figure 18: Number of passengers carried per km of route (2009)

Source: Modernizing Public Transport, Hidalgo et. al, 2010

The chart above shows the passenger load per km in Latin American BRT operations. As it is indicated in the chart that the highest passenger volume is in Santiago BRT line, despite Sao Paulo has the highest total passenger number, which was more than 6 million per day. Its total route length is 104 km, and thus the passenger carried per km is lower than Santiago. The highest rate is observed in Santiago that has around 5,6 million total passengers carried in 18 km BRT line. The passenger demand in Ahmadabad is again relatively low among other operations, since the route length is the same with Santiago, which is 18 km.

BRT implementations are easy to build and more cost-effective when compared to other rapid transit operations. Figure 28 shows the total cost of BRT implementation in Latin America and Asia including both infrastructure and equipment costs.

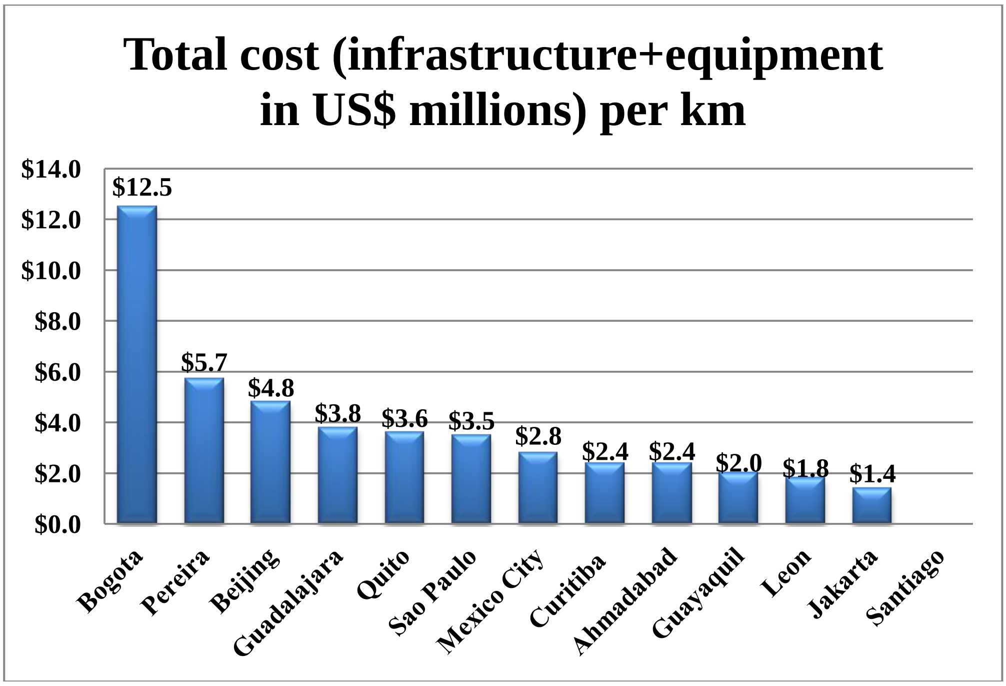

Figure 19: Capital Costs per Kilometer (2009)

Source: Modernizing Public Transport, Hidalgo et. al, 2010

As seen in the chart total capital costs of BRT systems do not exceed $12,5 million/km., which is the cost of the most expensive system, that is TransMilenio in Bogota. The data is unavailable for Santiago, thus the least costly implementation is shown as Transjakarta in Jakarta which is $1,4 million/km. Transjakarta is operated in three BRT corridors with 37 km median busway including 4 terminals and 34 stations. There are 162 conventional buses using electronic fare collection system.

There are also other successful BRT implementations in Europe and Australia. In Essen, Germany and Leeds, England there are mechanically guided busways, while Rouen in France operates on optically guided busways. In Runcorn in England the entire city is developed around largely grade-separated busway network. (Levinson et. al, 2002)

Adelaide and Brisbane in Australia are two implementations in this country. Alelaide bus system opened in stages between 1986 and 1989; it uses mechanically guided busways, and the route length is 12 km with three major stations. Passenger volume per day is 20.000 passengers, which is lower than the cities of Latin America and Asia described above . Brisbane’s 17 km busway carries around 60.000 passengers per day (Levinson et. al, 2002), which is also a low level, exceeding only the system in Ahmadabad. These passenger levels should be considered in the context of Australia however, which is known to be as automobile-dependent as US.

Figure 20: Brisbane BRT running ways and interchange stations

In addition to the general overview of BRT operating cities provided above, three of them are analyzed below in more detail. These are Curitiba from Brazil, Bogota from Columbia, and Mexico City from Mexico. These three systems are often referred to as best-practice BRT cases. This is the main reason of their being studied in-depth in this research. In addition, they are from Latin American countries, which are considered to be more comparable to Turkey in terms of their urban development characteristics and transport trends. Asian cities could also have been equally comparable and their inclusion in the in-depth analysis below could enrich the comparison to be made in the following chapters of this study. However, availability of data was also a criterion in selecting these three cities for further and in-depth analysis: In addition to research already made on these three cities, contacts through Istanbuls' EMBARQ allowed for access to data in these three selected cities.

3.2. BEST PRACTICE CASES

3.2.1.CURITIBA

3.2.1.1. City Context

Curitiba is the capital city of State Parana in Brazil. Curitiba Metropolitan Region consists of 26 municipalities, and according to 2008 demographic statistics total population of Parana is 3,26 million in an area of 15.622 km^2. In the metropolitan region total population of Curitiba is 1,83 million living in 432 km^2 urban area. Population density is very high in the city: it is approximately 4.232 people per km^2. (Suziki et.al, 2010)

As stated by Suziki et.al (2010), "the city is located at the center of Brazil's largest economic corridor, which includes Brasilia, Porto Alegre, Rio de Janerio and Sao Paulo, and near major cities, such as Buenos Aires and Monteviedo, in other Latin American countries."

According to Hidalgo (2010), "Curitiba is the Cradle of the BRT concept with the introduction of busways and feeder services in the 70s and the Integrated Transport Network (Rede Integrada de Transporte-RIT) in the 80s, including prepayment level access and large buses with multiple doors."

According to Lindau et al (2010), "Curitiba is the only city in Brazil that has directed its growth by integrating urban transportation, land use development and environmental preservation."

3.2.1.2. Background and Objectives

In the 70s Curitiba's planning team initiated planning objectives towards future development. The main objective was to implement integrated public transportation system while reducing private automobile usage; they aimed to integrate urban development plans with transportation plans. The previous plan prepared in 1943 had proposed construction of wide boulevards radiating from the core of the city. Wide boulevards promoted uncontrolled development along radial axles with high private automobile usage. In year 1965 city officials prepared a new Master Plan which promoted linear development along designated corridors with public transportation facilities, and zoning and land development policies supporting high density residential and industrial development along these radial corridors. Thus with policies downtown of the city would no longer be the primary destination, transport demand would be converted to other areas along the axles. (Goodman et.al, 2006)

Curitiba's city administrators have modified bus based transit operations with improvements in performance and capacity concepts. Bus system in Curitiba were converted from conventional bus in mixed traffic to busways, in which at-level boarding, prepayment and articulated buses were introduced later, creating the first full bus rapid transit system in the world. Later on, the system started to use high-capacity bi-articulated buses and electronic fare collection systems. (Lindau et. al, 2010)

Its strong coordination with land use planning and land development is one of the well-known characteristics of the BRT system in Curitiba. According to its implementation objectives bus corridors were designed for higher densities and mixed uses, and it is well integrated with main trip-attractors such as downtown, city sub-centers, industrial zones and recreational areas. In addition, the system aimed high accessibility via well designed pedestrian and bicycle pathways. (Hidalgo, 2010)

It is also stated by Taniguchi (2001) that "Curitiba's strategy integrates a world class all-bus transit network, well-defined structural axles accommodating and channeling the city's growth, and complementary land uses."

3.2.1.3. Implementation

As mentioned previously BRT operations require high degree of cooperation among different institutions, and the RIT and its urban development supportive features have been implemented since the 80s with a partnership between local private sectors including industrialists, commerce and transport companies and the local authorities. (Hidalgo, 2010).

Figure 30 shows the evolution of RIT in Curitiba from 1974 to 1995 and the final state of the system in year 2009. The system started with a single route; with emergence of other routes and feeder services the network has become more complex serving citywide. Figure also shows which kind of buses is used and the characteristics of route.

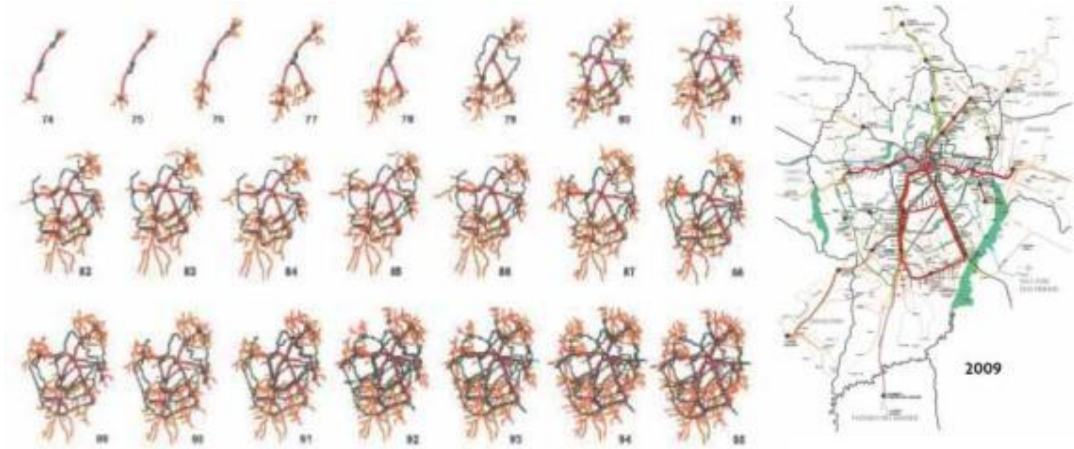

Figure 21: Evolution of BRT configuration in RIT system

Source: Eco2 Cities; Ecological Cities as Economic Cities, Suziki et. al, 2010

The RIT aims an integration of transportation and land use in Curitiba, and today it covers 14 cities among 26 cities in Parana. RIT was implemented around structural axle which promotes transit oriented development (TOD) with low cost and high impact interventions. RIT operates with trinary system which is a structural axle including two side blocks and three roadways. The central avenue among three roadways is dedicated to bus transit and local traffic to access buildings and parking. The parallel streets are used by higher speed traffic including direct buses and each street provides one direction service either from suburbs to city center or from city center to suburbs. Also land use pattern is designed as mixed uses and high density development in side blocks, and blocks further from trinary system are designed as low density areas. RIT provides linear transit oriented development along structural axle. (Lindau et. al, 2010) (Figure 22)

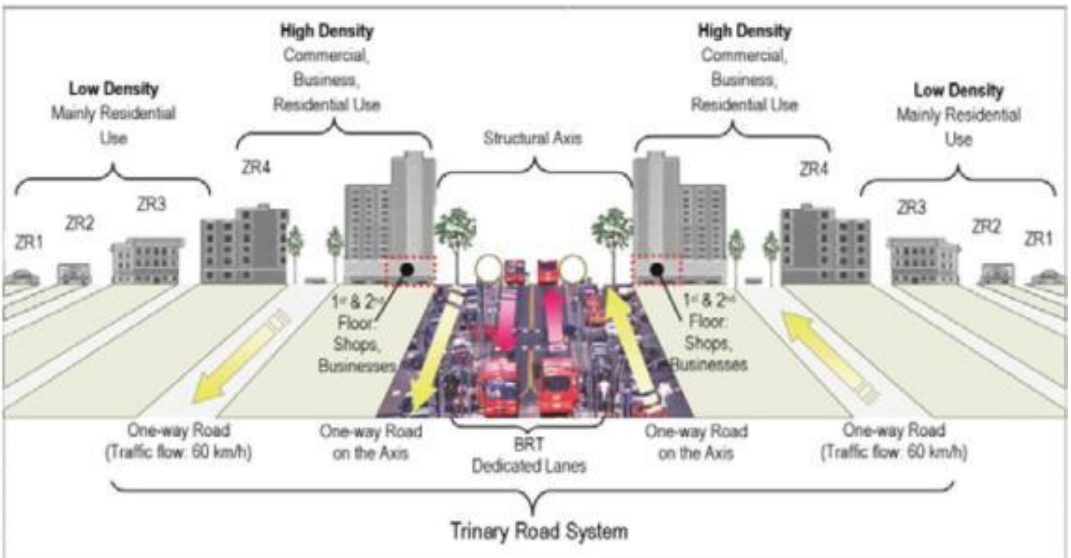

Figure 22: Conceptual Representation of Trinary System of RIT of Curitiba

Source: Eco2 Cities; Ecological Cities as Economic Cities, Suziki et. al, 2010

3.2.1.4. Operation

“RIT has a series of components including median busways longitudinally segregated, tube stations with fare prepayment and level access, physical and fare integration among diverse services, dispatch control at terminal stations and differentiated services.” (Hidalgo, 2010). Differentiated services include express radial routes and accelerated radial routes with limited stop which run in the median busways using bi-articulated large buses, direct radial routes running in the fast streets of the trinary system using articulated or conventional buses and integrated to structural axle at terminals and mid-point stations, inter-neighborhood circumferential routes using either conventional or articulated buses according to user demand, and they are integrated with radial routes in terminals and mid-point stations. RIT also uses well integrated feeder services connecting local neighborhoods to the radial and circumferential routes at terminals and mid-point stations. Conventional or articulated buses serve in these routes depending on community demands. Also small buses operate in downtown as circulator. (Figure 23)

Figure 23: Current representation of trinary system of RIT, Curitiba

Source: Curitiba the cradle of Bus Rapid Transit continues to set standard for high performance bus systems and transit oriented development, Lindau et. al, 2010

Curitiba’s RIT is operated with 5 BRT corridors composed of 65 km of median busways, 139 stations, 26 terminals, 340 km of feeder routes, 185 km of inter district circular routes, 250 km of rapid transit bus routes; a total of 340 bus lines and 1.100 km of bus routes. In year 2009 the number of vehicles operating in RIT system of Curitiba was 2.200 including bi-articulated, articulated, conventional, small buses and special service buses. (Hidalgo et. al, 2010) (Table 10)

Table 9: Investment Costs of RIT System in Curitiba in 1999

	Quantity	Unit value US$ per unit (or km)	Total US$
Infrastructure-Public Investment by city government			
Terminals	25	900.000	22.500.000
Exclusive lanes(km)	56	800.000	44.800.000
Tube Stations	213	40.000	8.520.000
Total City			
Buses-Private Investment by bus operators			
Bi-articulated	95	457.000	43.415.000
Articulated	73	252.000	18.396.000
Direct buses	248	174.000	43.152.000
Inter-neighborhood	159	170.000	27.030.000
Feeder	621	91.000	56.511.000
Total Bus Operators			**188.504.000**
Total cost RIT			**264.324.000**

Source: Case Study of the Integrated Transit Network RIT, Curitiba, Brazil, Hidalgo, Dario, 2010

Improvements and quality of service increases ridership of the system. Curitiba RIT is one of the leading BRT operations in the world with 2,26 million passenger per day.

Electronic ticketing has been used in RIT since 2002 including contactless cards. Tube stations and mid-point stations provide prepayment facilities. Some buses are operated with on-board ticketing; this operation can be done either via smart cards or paying directly to the conductor. (Hidalgo, 2010)

There are also some free services to elderly (+65), children under 5 years old, disabled people, and some governmental officials. Also for students there is reduced fare payment. (Hidalgo, 2010)

The stations of the system are also recognized for their special design and contribution to city and system image. Figure 24 shows a typical RIT BRT station.

Figure 24: Station design of RIT, Curitiba, because of its physical configuration it is called tube station

Source: Curitiba the cradle of Bus Rapid Transit continues to set standard for high performance bus systems and transit oriented development, Lindau et. al, 2010

3.2.1.5. Lessons Learned

BRT system in Curitiba is regarded as a successful application. Hook (2009) listed the key characteristics that contributed to success as follows;

- Physically segregated exclusive bus lanes,
- Large comfortable articulated or bi-articulated buses,
- Fully enclosed bus stops that feel like a metro station, where passengers pay to enter the BRT station through a turnstile rather than paying the bus driver,
- A bus station platform level with the bus floor,
- Free and convenient transfer between lines at enclosed transfer stations,
- Bus priority at intersections, largely by restricting left hand turns by mixed traffic vehicles,
- Private bus operators paid by the bus kilometer.

LRT proponents such as Black (1993) and Cevero (1984) claim that bus operations do not have strong land development impact like LRT operations. However, Curitiba is a good example demonstrating the impacts of BRT on land development. As stated by Junge et. al (2008), the main goal of the system was to protect downtown of Curitiba by creating radial corridors with land use and density policies; with BRT implementation the aim was achieved. Trinary system used in Curitiba allowed density and zoning regulations to be more effective and led the development of city on five important axles radiating from core of the city. Also zoning incentives and restrictions made car usage more difficult when compared to using

BRT system. In order to increase ridership of the system, prohibiting cars on designated roads and parking restrictions were also effective policies. (Junge et. al, 2008)

On the other hand, in peak hours the service is insufficient, some passengers prefer to use other transportation modes such as private automobile, and thus service quality should be improved. Improvements in quality of service should include operational improvements and centralized control with automatic vehicle location should be implemented in order to respond to contingencies. (Hidalgo, Dario, 2010)

3.2.2. BOGOTA

3.2.2.1. City context

Total population of Bogota is 7,8 million which is 15,2% of total population of Colombia. Total area of city is 1.732 km^2 with 15.058 people per km2 population density and the city is located 2.640 meters above sea level. City has a flat terrain, only southern part of the city has some hilly areas. Because of being an administrative and political center, the city is the most important city in Colombia. Employment is mainly concentrated in central business district (CBD) and an industrial corridor is located at the west part of CBD. Low income groups are mostly living in the periphery especially southern and north-western part of the city. In 1995 daily trips generated within the city boundaries was 10 million, 67% of total trips were motorized and 48% was via public transportation. Bogota has a hierarchical road network composed of many avenues and urban expressways. 60% of arterial system was planned; there were some lack of appropriate infrastructure in periphery, due to unplanned and illegal developments. (Hidalgo, 2010)

3.2.2.2. Backgrounds and objectives

In Bogota public transportation was mainly provided by electric trams from 1884 to 1952. After emergence of buses they have became the major transportation mode since 1952. Pienaar et. al (2005) argued that “just before the turn of the century (1990s) urban transport has deteriorated to the extent that it was characterized by severe congestion, poor network condition, long travel times, high occurrence of accidents and high levels of pollution.”

The last two decades before the BRT implementation, the city suffered from highly congested roads because of high rates of private car usage. Private cars occupied 64% of roads while they carried only 16% of passengers out of total transportation demand. By the end of the 1990s bus transportation system also suffered from underuse due to poor quality of service and efficiency. Highly congested roads reduced travel speed of buses; average speed of buses was 10 km/hour and reduced to 5 km/hour in peak hours. Lack of price regulation policies led private operators to increase ticket prices at their own will and profit more than public bus operators. (ESMAP EECI Good Practices in Cities, 2009)

As stated by Hidalgo (2010), “the strategy included; construction of bikeways and pedestrian facilities; implementation of bus rapid transit system (TransMilenio); traffic management improvements; road constructions and maintenance.” Also the strategy aimed to change habits and attitudes of the community. Car use restrictions during peak hours for 40% of private vehicles, car-free weekdays and a ballot consultation on policies related to car usage were the most important activities of this mobility strategy.

Pienaar et. al (2006) claim that poor public transportation conditions led to a new focus on:

- The re-construction and maintenance of sidewalks
- The construction of cycle paths

- Campaigning against the use of private cars
- The development of a formalized public transportation system "

A Mobility Strategy based on sustainable transport principles was initiated by the local government in 1998. The aim was reducing private car usage in the city with focusing on public transit and alternative transport modes. (Hidalgo, 2010)

TransMilenio's one of the most important characteristics is its supportive policies and actions about long-term urban renewal and prioritizing walking and cycling for urban mobility as well as discouraging private vehicle usage (Cain et. al, 2006).

In order to deal with public transportation problems local government decided to implement BRT system in Bogota, and as Pienaar et. al (2006) state, "the proposed system had two main goals: to improve the quality of life of citizens of Bogota, and to improve the productivity of the city."

Diaz et. al (2003) state that "the TransMilenio system was designed and developed under the principle of respect":

- For life; by reducing fatalities due to traffic accidents and reducing harmful emissions
- For users and their time; by reducing travel times, on an average by 50%
- For diversity; by offering full accessibility to young, elderly, and handicapped, poor, among others"

3.2.2.3. Implementation

As stated by Hidalgo (2010), "The infrastructure of the system includes busways and general traffic lanes, stations, terminals, bus depots, non-grade intersections, pedestrian overheads, bikeways, sidewalks and local roads for feeder services." In October 1999 a new transit authority was established called TRANSMILENIO S.A. which is responsible for planning and managing the construction of the TransMilenio project and overseeing its operation.

TransMilenio was implemented in three phases. Construction of Phase I started in 1998 and in 2000 the line started operation. The Phase II began construction in 2000 and completed in 2002, thus the total BRT line in Bogota became 41 km. The full BRT line is 84 km in Bogota today after completion of Phase III. As stated by Cain et. al (2006) "the TransMilenio Master Plan consists of 388 km of dedicated trunk corridors to be constructed over a total of 8 separate phases." (Figure 3.11)TransMilenio is built with local and national funds by the city through Institution for Urban Development. According to data gathered by Hidalgo (2010) the total infrastructure cost of the system is $785 million including; busways, stations, terminals, depots and pedestrian access, excluding; general traffic improvements such as resurfacing mixed traffic lanes, land acquisition and flyovers. Total cost for buses and fare collection systems is 210 million. Total cost per km is $11,8 million and total infrastructure cost per km is $9,3 million.

Figure 25: Service plan of TransMilenio in Bogota

Source: http://www.transmilenio.gov.co

3.2.2.4. Operation

TransMilenio started operation in 2000 with 14 km busway and has been enlarged. There are two types of running way in the system: one is single carriage way with 3,5 meter width and the other is dual carriage way with 7 meter width. Trunk corridors are segregated from general traffic and buses run in the central lanes of existing arterial streets and highways. There are 7 busways with 84 km route length (Figure 36). One of the most important characteristics of the service is feeder services which is 509 line-km. There are three different types of stations in TransMilenio; portals, intermediate and standard stations (Figure 37). 7 portal stations are located end points of the each trunk corridor and provide passengers to enter the corridor and transfer from the feeder routes. There are 6 intermediate stations located along trunk corridors providing transfers between trunk routes and/or between trunk routes and feeder routes. 104 standard stations are located approximately 500 meter away from each other along the corridors. Pedestrian access is an important issue for such services, and in TransMilenio it is provided by overpasses, tunnels or signalized intersections. As mentioned previously BRT implementations offer flexibility in operation, thus according to changes in demand TransMilenio service plans are dynamic and flexible. In order to maximize supply and increase ridership, the system offers three types of basic service; local, express and super express. Local services stop all stations along the corridors and run all day between 5.30 am and 11.00 pm. Express services stop at 40% to 60% of the stations, super express service provides faster service in corridors with limited stops, it stops at less than 20% of stations. There are 1.190 articulated, 10 bi-articulated and 448 feeder buses operation in the system. (Hidalgo, 2010)

Figure 26: Running ways and overpass examples in TransMilenio

Source: Case Study TransMilenio, Bogota, Colombia, Hidalgo, D. 2010

Buses have four large doors in the left side of the bus and there is an emergency door in the right side of the bus. Wide doors provide quick boarding and exiting the vehicle, the average dwell time of 25 seconds. TransMilenio uses electronic fare collection system with pre-paid contact-less smart card technology. Total ridership in weekday is approximately 1,6 million passengers per day. Maximum passenger observed load in peak hour is 45.000 passengers per hour per direction and average peak load is 40.000 passengers per hour per direction. (Hidalgo, 2010)

Figure 27: Standard BRT station and portal station in TransMilenio

Source: Source: Case Study TransMilenio, Bogota, Colombia, Hidalgo, D. 2010

3.2.2.5. Lessons learned

It is stated by ESMAP EECI in Good Practices in City Energy Efficiency (2009) report that "one of the great achievements of the TransMilenio BRT system has been the concession contract-based system for regulating service operations. The project encouraged participation of small operators and provided them incentives to play an important role in the public-private partnership (PPP) for bus operations and fare collection, with rights and responsibilities defined by concession contracts."

Cain et. al (2006) state that "TransMilenio's great strength is the fact that it is a true rapid transit network. Constructing such a network, in a relatively short time period, has given the system an economy of scale that has maximized operating efficiency and yielded city-wide mobility and urban renewal benefits."

TransMilenio has also induced some shift to public transit, since it provides time savings to the users. For individual transit users the average time saving is 13 minutes. The highest time saving is observed in low income groups with 18 minutes and 10 minutes for the people in the high income group. In addition, the system decreased traffic accidents by 79 percent in the corridors when compared to past experiences and dramatically reduced the number of injuries and fatalities (Hidalgo, 2010).

It is also argued by ESMAP EECI in Good Practices in City Energy Efficiency (2009) report that TransMilenio has an important role in decreasing traffic congestion; reducing average travel time and accident rates with provision of advanced Euro II and III vehicles and improved operation facilities. People living in and visiting Bogota enjoy reduced travel time, cleaner air and fewer accidents.

TransMilenio has a great ridership among other transportation modes. It has also been successful in attracting private car users: after the system was introduced, the proportion of private cars in traffic decreased from 18% to 11% (Cain et. al, 2006).

As reported by Energy Sector Management Assistance Program (ESMAP) in 2009; "The program was a success due to many factors: strong leadership from the City Mayor; careful design and planning; use of state-of-the-art technology; the establishment of a well managed company; sound investment in infrastructure; and an efficient single-fare pricing system."

The success of TransMilenio encouraged Colombian central government to support more BRT projects in other cities in the country too (Cain et. al, 2006).

Furthermore, poor quality public transportation vehicles were transformed to environmental friendly high technology buses, thus the emission rate has decreased 40% and fuel saving of 47% was recorded when compared to previous operations. (ESMAP EECI Good Practices in Cities, 2009)

3.2.3.MEXICO CITY

3.2.3.1. City Context

Mexico City Metropolitan Area is one of the most populated areas in the world. In total area of 1.500 km^2 there are 18 million people living which is roughly 18% of total national population. Mexico City has been regarded as one of the most polluted cities in the world, thus after the 1980s the focus in managing air quality has been the prior issue for local governments, and the investments on this problem have been increased. Mexico Air Quality Program focused on improvement of transportation with reorganization of public transportation at a metropolitan level, investments in capacity improvements and land use planning and control. (Hidalgo, 2010)

3.2.3.2. Background and Objectives

Existing transportation conditions in Mexico City are poor and private automobile usage is relatively high and it continues to increase. The annual increase rate of car ownership is 6% and the number of private automobile is 3 million and it is expected to double by 2020 (INE reported by CTS, 2005). The congestion on roads led to high travel times: according to Hidalgo (2010) the average daily time required was estimated to be 2,5 hours for personal travel. The use of public transport was low due to weak transportation facilities, only 15% of total trips were done by 200 km metro network and public transportation companies. The use of low quality buses in public transportation caused air pollution in the metropolitan area. The project was an air quality management attempt, thus it was directed by the Secretary of Environment of the Federal District Government. (Hidalgo, 2010)

Objectives of the project are reported by New York City Global Partners (2010); by implementing an efficient, safe, reliable and effective public transportation system, it is aimed to increase the mobility in Mexico City. Main corridors of the city were very congested; with new public transportation facilities the aim was to reduce travel time and the number of accidents in crowded corridors and with clean air management the green house gas emissions were aimed to be reduced. By decreasing economic cost of congestion it was intended to gain economic benefits on macroeconomic level. (Source: http://www.nyc.gov/html/unccp/gprb/downloads/pdf/Mexico%20City_Metrobus.pdf)

3.2.3.3. Implementation

As stated by Hidalgo (2010), "in 2005 the District Government of Mexico City implemented the first BRT corridor, a median busway along a corridor which crosses the city from north to south. For the coming years the District Government intends to implement additional BRT lines among the city and outside the city limits."

The planning and the implementation of the system took a very short time, the idea for implementing a BRT line was first stated in year 2000. After detailed transport and infrastructure planning, it was initiated in 2002, and the construction started in 2004. Implementation was difficult due to low technical capacity and experience of the implementation team, thus external help and technical assistance was provided by Sustainable Transport Center. (Hidalgo, 2010)

Hidalgo (2010) states that "for the project implementation three processes were required; construction of stations, terminals and segregation of the median lanes; negotiations of the conditions with existing concessionaries; and the implementation of the fare collection system and operation."

3.2.3.4. Operation

The Metrobus-Corridor Insurgentes started to be constructed in 2004 and started operation in June 2005 along Avenida de los Insurgentes, one of the most important streets of Mexico City. After its success was observed the corridor expanded in 2008 and new corridor started operation in 2009.

In Mexico City BRT line there are both public and private actors. At first existing bus operators were opposed to BRT implementation, but after local government guaranteed their profits they convinced to be a part of the system like other BRT implementations throughout the world.

As described by Vilchis et.el (2010), "the corridor is regulated by an entity of the Distrito Federal government known as Organismo Publico Decentralizada (Decentralized Public Organism) Metrobus." Companies operating in Mexico City BRT line are; Red de Transporte Pasajeros (RTP), Corredor Insurgentes; S.A. and C.V. (CISA) and Rey Cuauhtemoc S.A and C.V (RECSA).

Hidalgo (2010) states that "in year 2010 the system was including 50 km of segregated median busways, 77 stations with level access and off-board fare collection, and four terminals; high frequency service, centralized control and distinctive image." The system is used by approximately 450.000 passengers per weekday. In peak hours the headway between busses is 1,5 minutes. Despite complaints about high occupancy levels of buses, the public acceptance is 80% for the system.

Figure 28: End point Induos Verdes of the first line, showing pedestrian access and terminal interior

Source: Case Study Metrobus, Corridor Insurgentes, Mexico City, Mexico, Hidalgo 2010

The third BRT line started operation in February 2011. According to a report prepared by an external technical assistant organization CTS-Mexico-EMBARQ (2011) the new line operating between Tenayuca and Etiopia is expected to be used by 120.000 passengers per weekday. Route length of third line is 17 km and includes 32 stations with off-board fare collection, two terminals and two bus depots. The new line is different from other two lines with bus lanes paved concrete. After third line started to operate total BRT line length has increased to 67 km with 113 stations and 280 buses. The total passenger volume of the system is 620.000 passengers per weekday. (Source: http://ctsmexico.org/node/395)

As shown in Figure 39 the first line is north-south direction and intersects with second line in west-east direction. The third line’s end point is on the second line and continues to northwest part of the city intersecting the first line.

Figure 29: Three BRT line in Mexico City

Source: http://www.metrobus.df.gob.mx/mapa.html

Mexico City Metrobus uses ITS elements for central control and collects fares electronically. In the operation there is a cooperation between public and private operators. Since the city has a high population, the BRT system is not the only public transportation mode in Mexico City. Community also uses Metro and regional rail, thus integration of modes is crucial. Metrobus has physical integration with other modes used in the city but fare integration is difficult with Metro system due to different fare rates with Metrobus. For integration purposes there are no parking lots and bike parking areas. (Hidalgo, 2010)

Figure 30: Typical BRT station in Mexico City and off-board fare collection

Source: Case Study Metrobus, Corridor Insurgentes, Mexico City, Mexico, Hidalgo 2010

According to New York City Global Partners report in 2010, Current Metrobus Expansion Program aims to expand BRT line in Mexico City. The aim of this program is to operate a total 200 km of BRT corridor with 800 buses in the city. After implementations total cost of construction (including bus costs) is estimated to be $553 billion. The first three lines account $366,6 billion.

3.2.3.5. Lessons Learned

As claimed by Stevens (2008), “the three benefits of the Metrobus are; the reduction in local emissions and resultant health impacts, the reduction in greenhouse gas emissions, and the reduction in travel time along Insurgentes during peak hours.”

According to the report prepared by CTS Mexico-EMBARQ (2011), the main aim of BRT implementation in Mexico City was improving air quality and reducing green house gas emissions to the city atmosphere. With improvements in bus technology and reduction in private automobile usage, the total BRT application is expected to decrease 100.000 tones of CO_2 emissions every year. (Source: http://ctsmexico.org/node/395)

According to Stevens (2008), “between 2005 and 2015, it is estimated that the Metrobus corridor will reduce on average 144 tons of hydrocarbons, 690 tons of oxides of nitrogen, 2,8 tons of fine particulate matter and 1,3 tons of sulfur dioxide annually.” These emission reductions lead to health improvements; the estimated gain of the government from health improvements is $3 million annually. Time savings of the community is estimated to be over 2 million hours, which means $1,3 million per year.

According to Hidalgo (2010), the planning process, implementation and starting of the operation took very short time, thus most of the problems confronted were solved during operation and limited time for drivers training caused operational problems. Existing bus operators opposed to BRT system, and in the negotiations they were convinced by offering them better conditions and taking advantage from BRT system. Fare integration between different modes, physical integration with park-and-ride facilities and bike parking areas were lacking and would increase the ridership.

3.2.4. SUMMARY AND COMPARISON OF THE BEST-PRACTICE CASES

There are many cities implementing BRT system in their public transportation network either as primary mode or as a feeder service to their rail based transportation systems. BRT is a system of package containing many different components. According to their policies or development strategies cities can apply this system partially, but the benefit gained from the system increases when all the components are implemented. The most well known and well-reported BRT operations are in cities of Curitiba, Bogota and Mexico City, which have been observed here in detail as the best-practice case studies both in Latin America and in the world.

All three cities applied all the BRT components in their system. They have segregated running ways in main corridors of the system. There are also some corridors running in mixed traffic but with traffic regulation practices they prioritized the BRT vehicles movement. There are also different station designs when compared to those in conventional bus operations: since BRT is a rapid mode of transportation, time loses in stations are decreased with special station designs, including level access and off-board fare collection. Stations in all three systems have an image like metro stations.

These three cities also had common objectives in implementing the system, which are, by creating an integrated BRT system, reducing private car usage, improving air quality and quality of life of citizens. In most cities the reason for BRT implementation is the low quality of air and increasing greenhouse gas emissions, since BRT systems use high quality, high technology and environment friendly vehicles it is one of the best options for cities trying to increase environment quality.

The authors who wrote about these case studies also stress that BRT systems can be successful in operation when they are well-integrated with urban development and land-use plans. The Curitiba case is particularly well-known for this aspect. Besides the Bogota case is reported as a good example of integration with land-use plans. These two cases also feature many policies to attract development to stations, promote transit oriented development, and implement land development policies including density regulations. Such supporting urban planning policies are not that much reported for the Mexico City case however. Nevertheless, the Mexico case features sustainable transportation policies, as do the Curitiba and Bogota cases. All three cities supported their BRT investments by implementing policies that restrict private car usage.

In all three BRT systems analyzed here, safety, security, speed, punctuality and service reliability are all high due to the rapid transit characteristics of these systems. On the other hand, it should also be noted in all three systems, overcrowded stations and buses are indicated as major problems.

The systems have different degrees of success in attaining an integrated service provision: Curitiba BRT is again successful in both physical integration and fare integration across public transport modes. In Bogota, many feeder bus services were created to support the system; however, the system could not be integrated well into the old bus system. In Mexico City, physical integration was attained after convincing other bus operators but a combined ticketing system, i.e. fare integration, does not exist.

The comparison shows that the BRT in Curitiba, which is generally referred as the most successful BRT in the world, stands out with a number of its planning and operational aspects: it is a very extensive system; it was very well integrated into the metropolitan and regional plan of the city and hence became the backbone of development; after its implementation it was further supported with urban design and land-use policies that increased densities and created a transit-oriented corridor of development; it was also well supported with transport policies that integrated feeder buses into the BRT and introduced a fully-integrated fare system.

3.3. LIST OF CRITERIA FOR A SUCCESSFUL BRT OPERATION

It was discussed at the end of Chapter 2 that a number of features or criteria were revealed through the review of literature. These criteria point to features that can make BRT systems more successful. With the help of the analysis of three case studies presented in this chapter, a list of criteria is developed to form an analysis framework. They can be summarized as follows, and described in more detail in the next chapter that provides the methodology of the research:

1. Criteria about the planning background
    - Integration with urban plans and surrounding land-use
    - Integration with other transport systems (This should include integration with rail systems, bus feeder systems, as well as non-motorised modes such as cycling and walking. Automobile-based transport should also be integrated through Park-and-Ride lots at BRT stations.)
    - Community participation in decision making

2. Criteria about physical components
    - BRT system coverage and length (More coverage and length mean higher level of penetration and can increase ridership. In addition, more feeder services lead to more ridership on BRT)
    - Number of Stations and average station spacing (For the system to be a rapid transit, station spacing should be high to allow high operating speeds)
    - Off-Board Fare Collection
    - Control Center
    - Being located on a high-demand corridor

3. Criteria about busway characteristics
    - Segregated Right-of Way
    - Alignment (Median alignment helps prevent interference from other traffic)
    - Intersection treatment (Full grade separation or BRT priority at intersections)
    - Passing lanes at stations
    - Center stations (Easy transfer opportunities for pedestrians and cost-effective for builder/operator)

4. Criteria about stations and vehicles
    - Platform level boarding (Ease of boarding and alighting for disabled)
    - Safe and comfortable stations
    - Easy and safe access to stations
    - Number of Doors on Bus (More doors eliminate queuing in front of one door/entrance)
    - Docking Bays and Sub-Stops (Capacity should be enough for more than one bus to stop at the same time)
    - Sliding Doors in BRT Stations (This can protect the passengers waiting and point them to the right direction for boarding the BRT)

5. Operation Characteristics
    - Operational Mode: trunk/feeder

- Commercial Speed
- Peak and off-peak Frequency
- Hours of Operation
- Multiple Routes
- Express, Limited and Local Services
- Fare Integration
- Automated Fare Collection & Fare Verification

6. Criteria about identity building
   - Stations and vehicles (These should create a strong image and a separate identity for the BRT system)
   - Branding and marketing

7. Ridership (as a final performance criteria that the above features have an effect on)
   - Passenger Numbers (These are total numbers and vary according to the length of the system)
   - Passenger Per Km of Route (More reliable indicator for comparison since takes the length of the system into consideration)
   - Peak Hour Passenger/hour/direction (20.000 – 25.000 at least)

These criteria are based on the literature review as well as the experience and analysis of the best-practice cases. With the use of this criteria, the study intends to assess the planning and operational performance of Metrobus, the BRT system in Istanbul. The analysis of Istanbul Metrobus will comprise comparisons with these three systems from.

The next chapter introduces the aim, objectives and method of analysis regarding the Istanbul Metrobus system.

CHAPTER 4

4. METHODOLOGY

4.1. Context

Mobility in urban areas is rapidly increasing and becoming more automobile-oriented. Cities throughout the world suffer from traffic congestion caused by high rate of private car usage. Congestion is not the only negativity of car-dependence however: the extensive use of the car causes air and noise pollution, leads to greenhouse gases resulting in climate change, increases fossil fuel dependency, results in high time costs as well as accident costs, increase expenditures of local governments for road investments, deteriorates street and community life, and results in significant inequalities in accessibility for different users.

In order to deal with these problems, national and local authorities started to focus on investments to improve public transport and provide integrated public transport operation. Without a doubt bus systems are the backbones of the public transportation systems in many cities since they are cheap to implement, flexible, and therefore can provide an extensive coverage of urban areas. Despite being the most common type of transportation mode, conventional bus operations suffer from poor public image, speed, reliability and safety issues. A rapid, high capacity and high-quality transit service is required in high-demand corridors, and many cities have opted for rail based transportation systems since the 1970s as a way of improving public transport service and attracting passengers. On the other hand, these systems are expensive to implement and require long construction times. Bus Rapid Transit systems emerged as a mode that provides the flexibility of buses, and the high capacity, high-quality rapid service characteristics of rail transit at much lower costs. BRTs are getting more popular all over the world both in developed and developing countries, because of their flexibility, ease and low-cost of construction, together with their high quality, reliable and safe services.

BRT includes many components: according to the budget of the national and local governments it can be implemented either partially or as a whole. As mentioned previously the benefit gained from operation increases when all the components are implemented. There are more than 120 cities applied BRT in their public transportation network either as primary mode or as a feeder service to the rail transport system.

BRT system is not a recently rising public transportation trend; especially in Latin American cities it has been implemented for decades. It has started to become more popular in other parts of the world in the past decades too.

In Turkey, both Ankara and Istanbul had implemented a busway system a few decades ago. In Ankara, the system was a 3,6 km, two lane median busway implemented on the main axle between Bahçelievler and Dikimevi. In the mid-1990s the system was removed since an underground LRT system was constructed on this corridor. In Istanbul too, in the 1980s the IETT aimed to increase the speed of buses and reduce the traffic congestion on Taksim-Zincirlikuyu corridor, and started to operate a segregated busway with 5 km route length. This busway is not in use today either (Üstündağ, 1994). These busway examples were segregated from other traffic with physical barriers; however, they were not fully segregated since there were at-grade intersections. Bus fare collection was also still on the buses; and hence while the systems enjoyed congestion-free running ways, they did not reach the high-speed levels expected from a rapid transit system typical to BRTs. As a result, it can be stated that it was in the 2000s and with the introduction of the Metrobus in Istanbul that Turkey had its first example of a BRT system. In Istanbul, which is the largest metropolitan area in the country, The city officials introduced the system to combattraffic congestion and associated problems, as well as to respond to increasing mobility needs in a cost-effective and rapid way. The Metrobus in Istanbul remains to be the only BRT in Turkey.

4.2. Aims, objectives, research questions

Istanbul Metrobus is the only BRT example in Turkey; however, a through performance analysis has not been made for this system. Since there are no other BRTs, it is not possible to compare it with other similar systems in the country. It can be compared with the urban rail systems in Istanbul; however, this may not be sufficient since the system should be compared with other systems similar to its own characteristics.

There are national and international articles that claim the system to be a major success due to its high number of passengers; but there are also many negative publicity due to its crowded stations and vehicles resulting in poor travel conditions for its users. While operational aspects of the system appear to be good on paper, some experts criticise its planning stages and complain that it was too rushed in planning with poor integration into urban development plans and transportation master plan. There is a mixed understanding currently, as to whether this is a successful system or not. The main aim of the research is therefore to assess the planning and operational performance of the Metrobus system in Istanbul.

In order to make this assessment, the study introduces four main research questions;

1. What makes a BRT operation/implementation “successful”?
2. How can “success” be defined in the context of BRT operations?
    - Planning approaches/criteria
    - Physical characteristics/ criteria
    - Operating characteristics/criteria
    - Ridership performance/ criteria
3. Is Istanbul Metrobus a successful system with respect to these criteria?

The analysis of best-practice BRT cases in the world, which was carried out in the previous Chapter, has already revealed certain aspects with regards to the decision making, planning background, implementation and operation of these systems. It is intended to analyse the Istanbul case, by comparing the same aspects with these systems. The performance of the systems in terms of passenger statistics will also be compared.

In addition, where data is available, the operational characteristics and passengers statistics of the urban rail systems in Istanbul will also be compared and contrasted with the Istanbul Metrobus.

Therefore the research, on which this thesis based, will to a certain extent conduct a comparative analysis of the three well-known BRT operations in the world and the BRT in Turkey. This study first analyzes Istanbul Metrobüs, then by comparing it with the three best practice cases from Latin America, as well as the urban rail systems in Istanbul, it aims to evaluate its operation and current situation in terms of performance. The comparisons are expected to reveal areas where the Istanbul Metrobus has a strength as well as areas where there is room for further improvement and development.

4.3. Information on the case study: Istanbul Metrobüs

Istanbul Metrobüs is currently the only BRT operation in the country. Istanbul is a unique city which is located on two continents and divided by the Bosphorus into two parts, with one part of the city lying on the Asian side and the other in Europe. According to Turkish Statistical Institute (TÜİK) data, Istanbul is the most populated city in Turkey with more than 13 million inhabitants in 2010; corresponding to 18% of total population in the country. Same as many highly populated cities, Istanbul also suffers from high rates of traffic congestion, high travel times, severe traffic accident ratess and greenhouse gas emissions.

Istanbul Electric, Tramway and Tunnel Administration (İETT) launched the BRT project with a view to reduce traffic density and to provide faster and more comfortable public transport journeys for the city. The first BRT line was therefore planned in one of the main axles in Istanbul between Avcılar and Topkapı. Construction of this first line started at the beginning of year 2007 and it was completed in September 17th in 2007 with 18,3 km of route length. Second Phase was completed in September 8th 2008 between Topkapı and Zincirlikuyu. of the Third Phase, which was completed in March 9th 2009, provided the connection between the two sides of the city that lay on the two continents, hence allowing the BRT system to pass through the Bosphorus Bridge and providing service at one of the major bottleneck points in the city's transport system. The total BRT line is 52 km today, following the completion of the Fourth Phase between Avcılar and Beylikdüzü in 2011.

In Istanbul Metrobüs, high technology, special BRT buses are running on fully segregated median busways along the corridor. The only part of the route where buses run on mixed traffic is on the Bosphorus Bridge since this piece of infrastructure belongs not to the city government but the Highways Authority of Turkey, which declined allocating a lane dedicated only to buses. However, the most congested parts of the Bridge is at its approach lanes, and at these sections the BRT buses use queue jumper lanes to enteand leave the bridge traffic. As a result they are not severely affected from being in mixed traffic at the Bridge.

There are 45 stations in total along the BRT route. 7 of them are in the Anatolian side, the rest are located in the European side of Istanbul.

4.4. Method of Analysis

In the analysis, the Istanbul Metrobus case will be compared with the three best practice cases RIT in Curitiba, TransMilenio in Bogota and Metrobus in Mexico City. This comparison will be held in 5 main topics; planning background; physical characteristics; operation characteristics; marketing, advertising, identity and image building policies; and finally passenger statistics, i.e. the ridership on the systems.

1. Planning background;

- Why it is built
- Integration into urban planning,
- Integration with other transport modes

In the first part, planning background, reasons to build the systems will be explained and its integration with urban planning and with other transport modes in the city analyzed. The reason for including this aspect in the analysis is because every planning decision related to transportation has a justification; it may be high demand, poor public transport image or air quality etc. In order to assess success it also has to be integrated with urban plans and policies for development and density, all of which are highly effective on performance and ridership of a transportation mode. In addition ridership is linked with integration of different transportation modes. People prefer to use multi-modal transport in order to decrease their travel times in traffic. If the system is well integrated with rail, bus, bicycle and pedestrian movement ridership of the system is increasing. This aspect covers both physical and fare integration. Public participation is also essential in these implementations. Since the system is used by public their needs are important.

Table 10: Planning background

	Curitiba	**Bogota**	**Mexico City**	**İstanbul**
Reasons to implement				
Aim				
Integration with urban plans				
Integration with land use				
Community participation in decision making				
Integration with rail systems				
Integration with bus systems				
Integration with bicycle				
Existance of bike parks				
Existance of Park&Ride				
Integration with good quality				

2. Physical characteristics of system;
- Location, design and other aspects they may have effects on ridership

The other aspect that affects ridership is the physical components of BRT including location and design of the system. In this part the analysis will be done in 3 categories.
Table 11: Physical characteristics of system

	Curitiba	**Bogota**	**Mexico City**	**İstanbul**
Physical Components				
BRT System Coverage				
BRT Busways length				
Number of Stations				
Average Distance Between Stations				
Off-Board Fare Collection				
Control Center				
Located on a high-demand Corridor				

First the physical components will be compared. The total coverage of the system and the busways will be observed. In some cases BRT system coverage which is the total network of the bus systems including feeder services is very high, but in some cases the trunk-only operation which is the corridor that has only BRT system not the official BRT feeders is common. Thus system coverage and BRT coverage differs. More feeder services lead to more ridership on the systems. Number of stations and average distance between stations will also be covered in the physical components part since this affects the "rapid transit" character of the system: when the average distance between station is high, the system can reach significant levels of operating speed, thus providing a good quality service with considerable time savings. Another feature of BRT systems that provide time savings in operation is off-board fare collection. Since it is time consuming to pay to the driver, the most effective way to decrease time needed to validate the ticket is off-board fare collection. Smart cards are also very effective to decrease time losses while boarding to the vehicle. Off-board fare collection allows passengers to board vehicles not only from first door but also from all doors, and this decreases the time needed for buses to wait in the stations. Existence of a control center tracking buses with GPS technologies is also included in the study since this can help to interfere to buses quickly, if an emergency situation occurs. Thus, whole system is not affected negatively from the interruption. And lastly, the best practice cases reveal that it is important to construct the system on a high-demand corridor. If the system is constructed along a corridor that already has significant travel demand, and perhaps a certain level of congestion due to this, it also increases the number of the passengers using it in their daily trips.

Table 11: Physical characteristics of system (continued)

	Curitiba	**Bogota**	**Mexico City**	**İstanbul**
Busways				
Segregated Right-of Way				
Alignment				
Intersection Treatment				
Passing Lanes at Stations				
Center stations				

The second and one of the most important features that affect BRT operations' performance is the busway characteristics. Segregated busways are the distinctive characteristics of BRT systems when compared to conventional bus operations. It allows buses to move quicker and not to be affected by traffic congestion. The degree of segregation is important: fully-segregated bus lanes with physical barriers are preferable because it minimizes intervention of other vehicles to the BRT corridor. Segregated right-of-ways increase the commercial speed and decrease time losses, thus increase ridership. Busway alignment is the location of BRT corridor on a road: median alignment prevents the system from being interrupted by other vehicles coming from service road and has less conflict with turning vehicles, this also increases the commercial speed of the system. But median lanes needs extra treatment in intersections because buses come face to face with other flowing traffic in intersections. With signal control, or BRT priority, or full grade-separation, time losses can be minimized. Another aspect that can help minimize time loss is passing lanes at stations so that buses do not have to wait for the bus in fron of them to leave the station before they can start to move. While using median running ways center station which serves both directions of BRT system makes transfers for passengers easy and it is also more cost-effective. Hence center stations can also be considered as an important aspect of BRT busways. There are other characteristics of the stations however, and these are considered in the third aspect of physical characteristics, given below.

Table 11: Physical characteristics of system (continued)

	Curitiba	Bogota	Mexico City	İstanbul
Stations and Vehicles				
Platform Level Boarding				
Safe and Comfortable Stations				
Easy and safe access to stations				
Number of Doors on Bus				
Docking Bays and Sub-Stops				
Sliding Doors in BRT Stations				

The other physical characteristic that affects ridership is design of stations and vehicles. Platform level boarding allows people to board and alight quickly and easily which is important during peak hours. Also platform level boarding increases use of the system by handicapped people. Safe and comfortable station design is the distinctive characteristic of BRT systems when compared to other bus operations. Safety and comfort include also weather protection. It also includes the capacity of the station to safely accommodate waiting and alighting passengers. Since off-board fare collection is a feature of BRT, the number of doors on buses also become important. Since passengers can use all doors, time loss while boarding and alighting is decreased. Frequency of BRT operations is very high especially in peak hours, thus platforms should be long enough to accommodate more than one bus at the same time in order not to increase waiting times of buses in each station. Finally, sliding doors at stations are an important feature that have two missions: one is to protect people from falling to the BRT road, the other is to define the exact place where bus will stop, and this informs passengers to wait close to the doors.

3. Operation Characteristics: level of service, fare schemes, etc. that may have effects on ridership

Table 12: Operation Characteristics

	Curitiba	Bogota	Mexico City	İstanbul
Operation Characteristics				
Operational Mode: trunk/feeder				
Commercial Speed				
Peak Frequency				
Off-Peak Frequency				
Hours of Operation				
Multiple Routes				
Express, Limited and Local Services				
Fare Integration				
Automated Fare Collection & Fare Verification				

Third issue in the analysis is operation characteristics. The mode of operation is important for the network, because existence of feeder services increases coverage of the system which is very important for ridership. As already mentioned, a fast operation is the main characteristic of a BRT system. Many aspects in planning and physical design affects speed and these were covered above under the relevant criteria. Commercial speed is included here to assess the outcome of all these planning and design criteria on the actual operating speed. The frequency of buses in both rush hours and at off-peak times is a good reflection of level of service. High frequency can attract more people to use the system. Operation hours of a system are also effective on system performance and level of service provided. Having multiple routes is a positive aspect of advanced BRT systems since this reduces transfers, thus decrease door-to-door travel times which attract more passenger to the mode. If there are passing lanes at stations, which is an aspect covered above under physical characteristics, this can allow different types of operations, such as express services, limited and local services, thus help to meet the demand in the most effective way. Also with express services travel times are reduced between some destinations. For many users of public transport, economy and cost-efficiency are important: in other words, monetary cost of the public transport journey is as important as the time cost, particularly if transfers are required between different modes. Therefore, besides having physical integration with other transport modes, having fare integration has a positive effect in attracting people to BRT systems. Finally, automated fare collection systems can provide significant advantages for time saving in journeys: with off-board and automated fare collection and fare verification, crowding in front of turnstiles can be prevented.

4. Marketing, advertising, identity and image building policies; operators and/or local authorities' efforts in promoting the system, which may have effects on ridership

Marketing and promoting the system by local or private authorities is also important to attract people, thus stations and vehicles have to be distinctive and more comfortable for BRT system then conventional bus operations like LRT system stations and vehicles.

Table 13: Marketing, advertising, identity and image building policies

	Curitiba	Bogota	Mexico City	İstanbul
Stations				
Vehicles				
Branding				

5. Ridership on the system

At the final part of the comparison, passenger statistics will be analyzed to understand the system performance.

Table 14: Ridership on the system

	Curitiba	Bogota	Mexico City	İstanbul
Passenger Numbers				
Peak Hour Passenger/hour/direction				
Passenger Per Km of Route				

CHAPTER 5

5. İSTANBUL METROBÜS

5.1. City Context

İstanbul, the largest city in Turkey, lies in Marmara Region which is a transition point between Anatolia and the Balkan Peninsula. The city is divided into two parts naturally; one part is in Europe and the other in Asia, which makes city unique in terms of geographic location. The city is located between 28° 01’ and 29° 55’ East longitudes, 41° 33’ and 40° 28’ North latitudes. According to TÜİK data; total area of city is 5.313 km^2. (2010-2013 İstanbul Bölge Planı Raporu, pp. 11)

According to 2009 demographic data total population of the city is 12.915.158 people. Population density of the city is 2.314 person/km^2 with these numbers Istanbul is one of the leading cities that have high population and population density in Europe. (2010-2013 İstanbul Bölge Planı Raporu, pp. 11)

The urban development of the city is mainly determined by geographic features around the city. Istanbul has a limited development area because of forests, water basins, ecologically and biologically unique areas and rugged topography in the northern side of the city. The city has a linear urban macroform located along the Marmara Sea coast. (İstanbul Çevre Düzeni Planı)

Due to the geographical and natural elements along the northern part of the city, past and current development plans of Istanbul have protected the northern areas as city forests and created a green belt for the city, which also accommodates a number water reservoirs that provide drinking water for the city. The latest regional development plan of the city, prepared by the Istanbul Greater Municipality in 2009, also aimed at reinforcing this urban form by keeping the northern parts as the green belt of the city and proposing a linear development on the south along the Marmara Sea (Figure 5.1) The plan also proposed the development of new town centres along this linear corridor with a view to decrease the attraction of the strong CBD on the western (European) side of the city. This policy is related to transport objectives too since the CBD attracts very high numbers of journeys and the creation of new centres intends to reduce the need to travel to the CBD.

The linear development of the city has been a result of the two main highways in this region: First the state highway (D-100) and then the motorway, which is a part of the Trans-European Motorway (TEM), attracted development along themselves, and reinforced the linear growth of the city from east to west (Figure 5.2). However, urban sprawl and development trends are also observed today towards the northern protected areas. Furthermore, building of a third bridge across the Bosphorus is now on the agenda and will be located on the northern tip of the strait, which is likely to increase this development trend towards the north. This bridge is not featured in the regional development plan of the Municipality however. Instead the plan proposed high-quality and high-capacity public transport connections on the eastern-western axis of development. Transport infrastructure and plans are described in the section below.

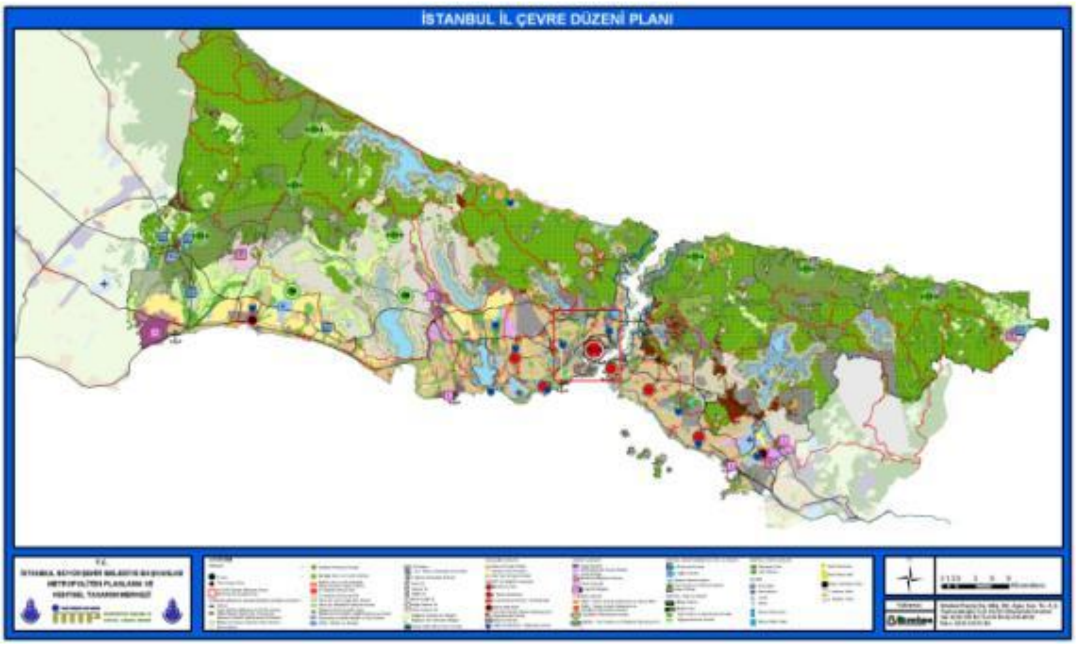

Figure 31: Istanbul Regional Development Plan 2009.

Source: Istanbul Greater Municipality (2009)

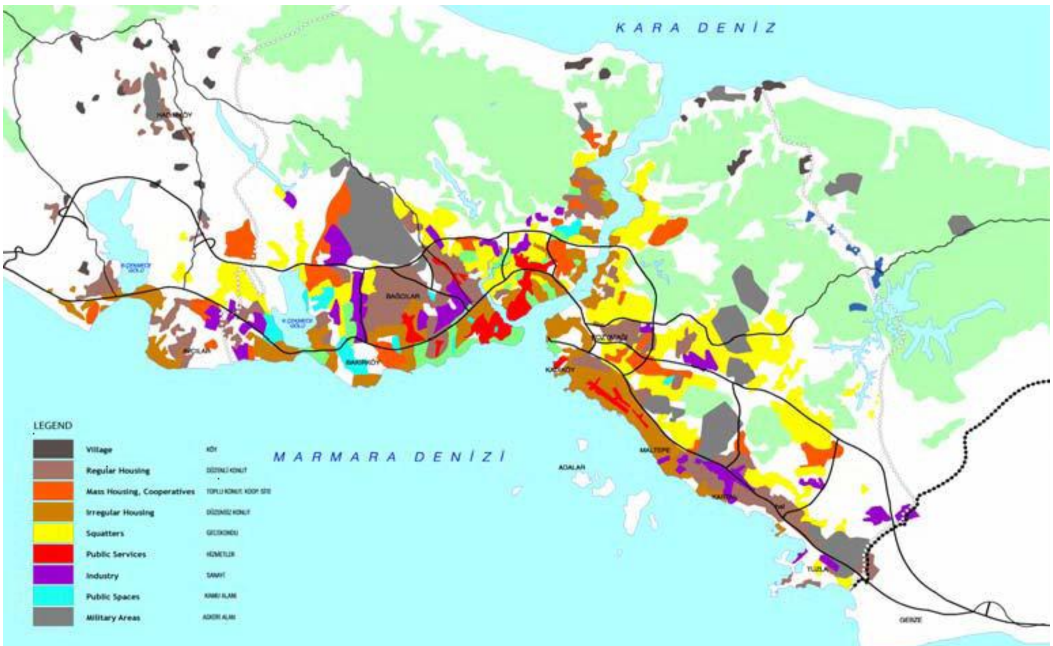

Figure 32: The two main highways of the city and development along them

Source: Istanbul Greater Municipality (2011)

5.2. Transportation in İstanbul

According to Istanbul Master Transportation plan half of the trips in Istanbul is made by foot. This is a high ratio indicating the importance of the development of alternatives to the automobile. In fact car ownership levels are still low in Istanbul when compared to Western European and North American cities: it is about 120 cars per 1000 population. However the rate of increase is high and the ratio of car usage is increasing. Furthermore, due to historical urban pattern, many central inner city areas cannot accommodate increasing volumes of car traffic; and therefore traffic congestion is a major problem in the city.

Istanbul has been investing in its public transport systems since the 1980s. As seen in Figure 43, in addition to the commuter system that uses existing railway lines, 3 new urban rail systems have been developed in Istanbul in the past three decades.

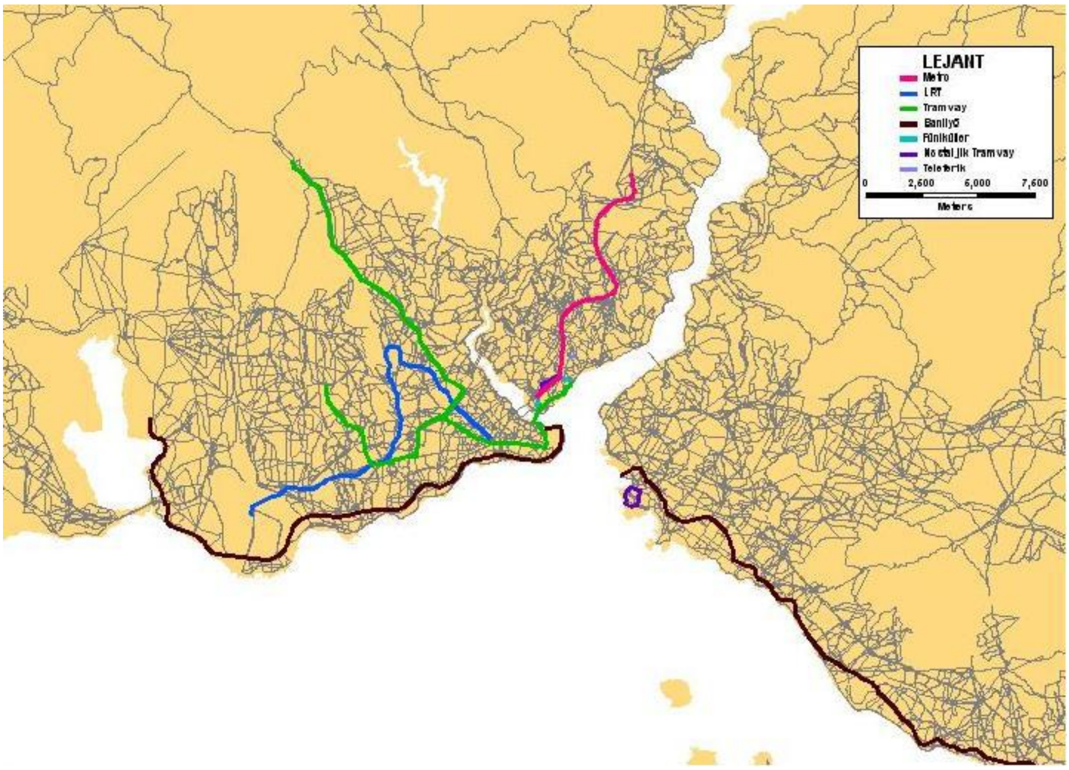

Figure 33: Rail systems in Istanbul

Brown lines are commuter rail systems; blue line is a fully-segregated light rail system known as Light Metro or M1, i.e. Metro 1; pink line is an underground full-metro system, named M2, i.e. Metro 2; the green line is an at-grade street tram system; its southern section is known as T1, i.e. Tramway 1; and the northern section recently opened and is known as T4, i.e. Tramway 4.

Source: Istanbul Greater Municipality (2011)

However, the coverage of the urban rail systems is still rather low. They are constantly being expanded, but progress is slow due to the construction time and cost involved in these systems. In addition, there is no Bosphorus crossing yet although a tunnel connection is under construction for the commuter railways on each side of the strait. As a result the shares of rail systems are relatively low in daily trips in Istanbul (Figure 5.4)

Despite being in a unique location in terms of marine transport, proportion of sea transport is also low.

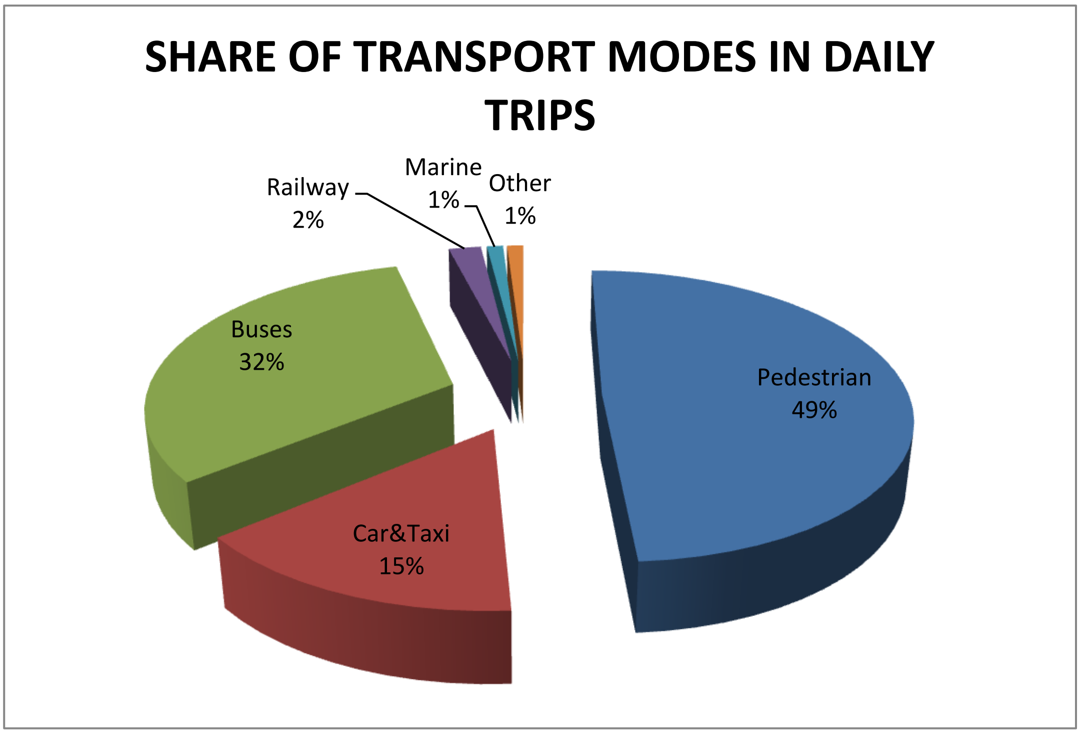

Figure 34: Share of transport modes in daily trips

Source: Istanbul Greater Municipality (2011)

It is seen that buses are used at high rates. When motorized traffic is analysed (Figure 45) this is also clear. The highest proportion is by buses and shuttle services (school and work services, i.e. student and employee shuttles) with 63%.

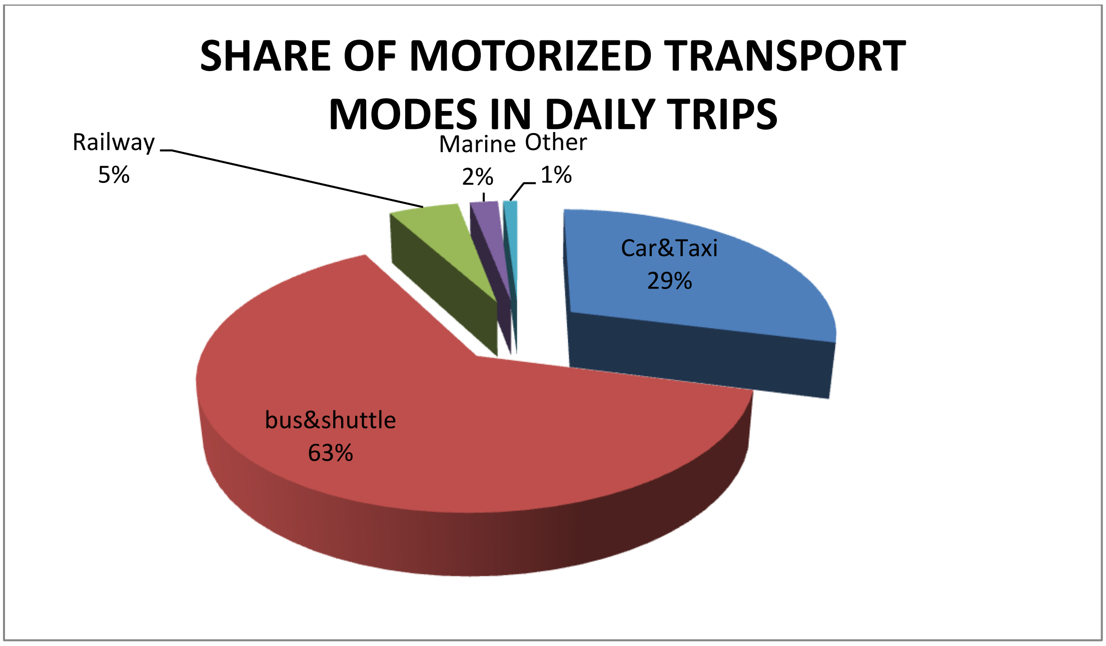

Figure 35: Share of transport modes in daily trips

Source: Istanbul Greater Municipality (2011)

According to data obtained from IETT, distribution of road space is shown in the chart below. According to this data the highest share is used by private cars on roads in İstanbul. İETT buses and Minibuses are following private car usage. Privately owned public transportation (POPT) covers 14% in total road space.

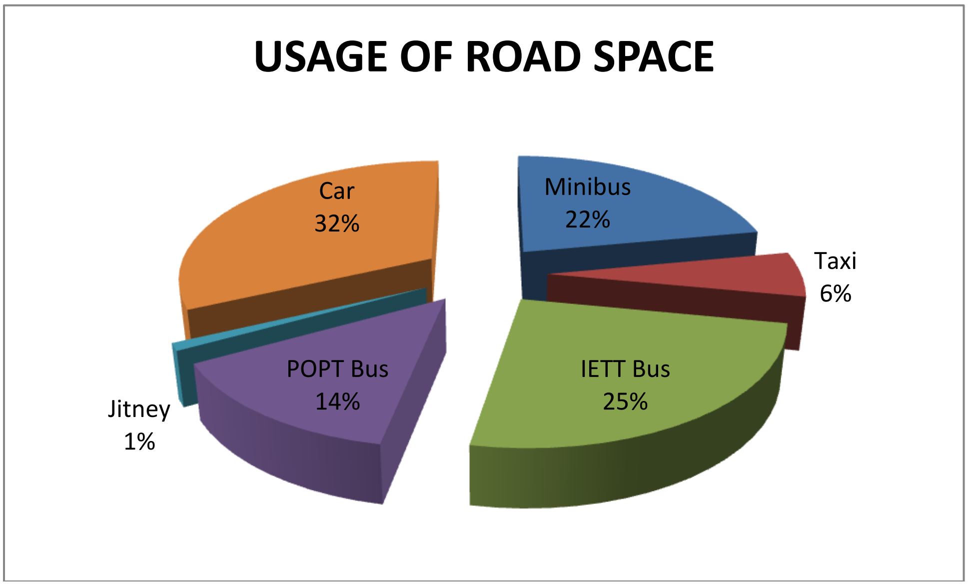

Figure 36: Usage of road space by different transport modes

Around %88,31 of total transportation is done via roads in İstanbul. Distribution of transportation modes on roads in İstanbul is shown in the chart below.

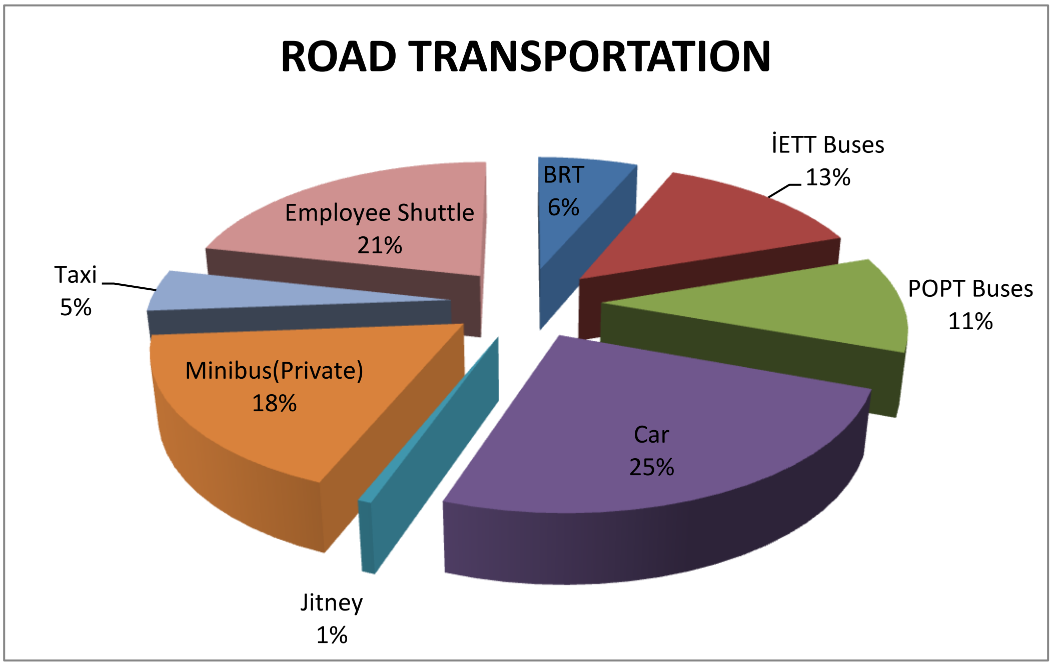

Figure 37: Road transportation by modes

Although the share of railways is still low in total journeys made, the urban rail systems have an important share in rail journeys. According to İstanbul Transportation Master Plan, the Light Metro and the Tram have the highest proportion in rail transport in İstanbul (Figure 38).

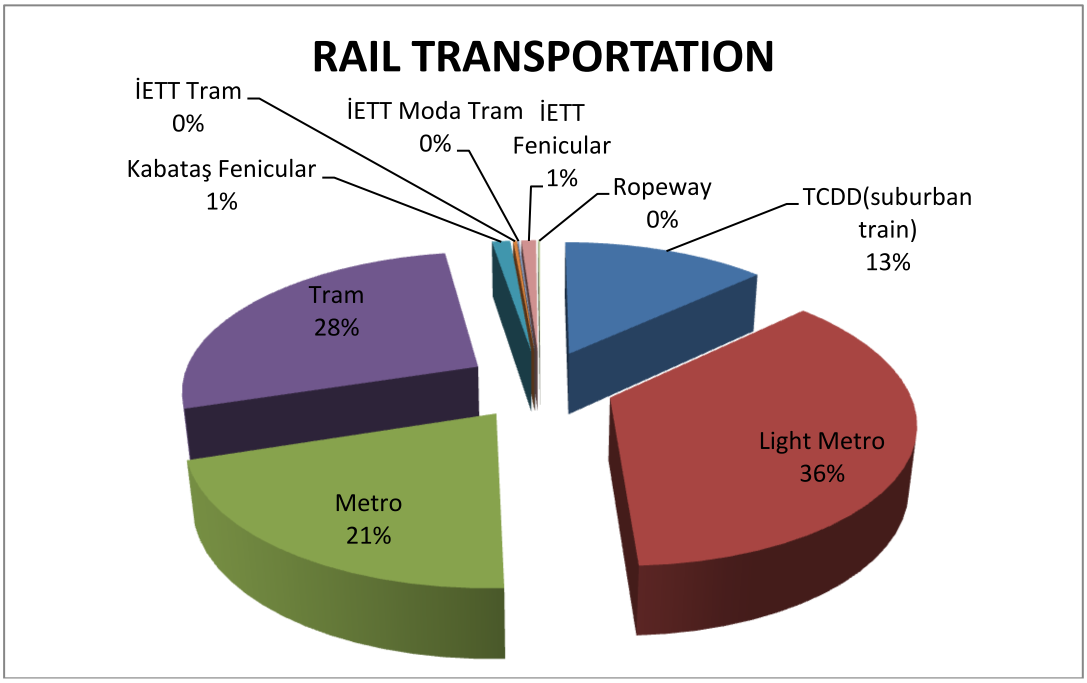

Figure 38: Rail transportation by modes

In order to increase the share of railways and to reduce road congestion by shifting some of the road traffic to rail systems, there is continuous investment in the rail infrastructure: new lines are being constructed, existing lines are being extended, and more are being planned. However, their planning and construction are time-consuming and require high capital costs. Due to these aspects, the mid-2000s saw Istanbul investing in a BRT system too. The system, known as Metrobus, became one of the components of the rapid transit system in Istanbul, as shown in Figure 39 (Metrobus is shown in light-grey line)

Figure 39**:** The rapid transit network in Istanbul: rail and bus transit.

Figure 40: Rail network in İstanbul

In the 2010 İstanbul Master Transportation Plan there is 18,59 km metro line, 19,3 km LRT, 34,22 km tramway, 1,24 km funicular, 4,2 km nostalgic tramway, 72 km commuter train and 0,72 km cable car which makes 150,27 km of total railway system. As it is seen in figure 50 rail systems are concentrated in the European side, and the only transit connection is the BRT crossing the bridge. As of May 2012 Kadıköy- Kartal Metro system started operation (M4) which has 43,32 km route length. The other lines and their historical development are summarized in the Table 15.

Table 15: Railways in İstanbul and opening dates

M1	Aksaray - Atatürk Havalimanı Metro Line	
	Aksaray - Karlıtepe	1989
	Otogar - Zeytinburnu	1994
	Zeytinburnu - Bakırköy	1994
	Bakırköy - Ataköy	1995
	Ataköy - Yenibosna	1995
	Bahçelievler	1999
	CNR Expo - Havalimanı	2002
	Yeni Esenler İstasyonu	2012
M2	Şişhane - Hacıosman Metro Line	
	Taksim - 4. Levent	2000
	Şişhane - Atatürk Oto Sanayi	2009
	Darüşşafaka Station	2010
	Seyrantepe Station	2010
	Hacıosman Station	2011
M3	Başakşehir Metro Line	
	Test drives	June 2012
M4	Kadıköy - Kartal Metro Hattı	
	Test drives	May 2012
T1	Kabataş - Bağcılar Tramvay Line	
	Aksaray - Beyazıt	1992
	Sirkeci - Beyazıt	1992
	Aksaray - Topkapı	1992
	Topkapı - Zeytinburnu	1994
	Eminönü - Sirkeci	1996
	Eminönü - Fındıklı	2005
	Fındıklı - Kabataş	2006
	Zeytinburnu - Bağcılar (T2 line)	2006
	T1 + T2	2011
T3	Kadıköy - Moda	2003
T4	Topkapı - Habipler	2007
F1	Taksim - Kabataş	2006
	Maçka - Taşkışla Cablecar	1993
	Eyüp - Piyerloti Cablecar	2005

An important ongoing rail connection in Istanbul is the Marmaray project, shown in Figure 51. This connection will become the first rail link between the two sides of Istanbul, which create very high levels of travel demand.

Figure 41: Marmaray project

Marmaray project is under construction. It is one of the most important transportation investments in the city. It will connect Halkalı in Europe and Gebze in Asia with uninterrupted commuter rail system. The system is to dive into Bosphorus in Üsküdar and will exit at Sirkeci Yenikapı, which will be an important exchange area for the system. Total length of the system will be 76 km. The project is supposed to be completed by the end of 2013. Marmaray will be the only system that connects Asia and Europe with railway; however, the weakness of the project is that it connects Üsküdar with Historic Peninsula and does not penetrate the CBD, which covers Taksim (seen in Figure) and its northern/northwestern areas .

Until the Marmaray system is completed and opened, the Metrobus remains to be the only high capacity transit connection between the Asian and European side of the city. Furthermore, even after the Marmaray system is opened, Metrobus will hold the advantage of penetrating the CBD of the city.

The planning and operation of Metrobus, the BRT system in Istanbul, is described in the following section.

5.3. Bus Rapid Transit in İstanbul

5.3.1. Background and objectives

Population of Istanbul is rapidly increasing due to economic development, thus urban area is expanding. Registered private car number has increased 6 times and has reached over 1,7 million since 1958 in İstanbul. (Istanbul Greater Municipality, 2011)

Passenger mobility is very high. According to household survey conducted by Metropolitan Municipality of Istanbul, number of daily trips is 20,9 million, 10,3 million trips are pedestrian and the rest is with motor vehicles. (Istanbul Greater Municipality, 2011, pp.19)

According to the same household survey, trip rate per person per day is 1,74. This rate includes pedestrians too: 0,88 per person per day is the trip rate done by motor vehicles. Detailed information is shown in the table below.

Table 16: Total Number of Trips and Number of Trips per Person,

	Classification		**Number of Trips-Ratio**
Population	All		12.009.007
	6 yeras and over		11.049.473
Number of Trips	All Trips		20.924.133
	Trips with Motor Vehicle		10.342.771
Trips/Population	Brut	All Trips	1,74
		Trips with Motor Vehicle	0,88
	Net	All Trips	2,40
Trips/6 years and over	Brut	All Trips	1,91
	Net	Trips with Motor Vehicle	0,95

Source: I. Aşama Analitik Etüd ve Model Kalibrasyonu İşi-Hane Halkı Araştırması (2006)

Daily trip rate per person is high in İstanbul. One of the reasons of this is urban development pattern of the city. As it is mentioned by earlier, sub-center development in İstanbul is very weak. City has expanded from one center to periphery rapidly without any sufficient subcentres being created. (Istanbul Greater Municipality, 2011) This results in long journeys to the city centre for work purposes and for most services and amenities.

Passenger mobility is provided by road, rail and marine transportation in İstanbul. AS described in the previous section, when the ratio of transport modes are compared, the highest rate is road transportation with 88,3%. Rail transport and marine transport consist of only 11,7%.

As discussed previously rail transit investments require high investment and maintenance cost and also long investment time. In the 2000s many rail investmens were continuing, but Istanbul was in need of a quick and lower-cost solution to meet its transportation demand in the main arterial of the city. The corridor that BRT is implemented is one of the most important highways, the D-100 highway, which the city had grown along. On the eastern side (asian side), the road passes through some green and open areas; however, on the western (European side), the corridor and its surrounding areas are densely populated. One of the main objectives of the BRT project on this corridor was to provide fast, reliable and comfortable service to the users and attract especially private car users.

In order to decrease private car usage and attract people to public transportation it was aimed to increase the capacity and quality of the service on this corridor. According to Acar (2005); BRT is advocated as an interim solution in corridors that have high travel demand in large cities instead of constructing rail system requiring high investment cost and long construction term. (Şahin et al. 2009)

It should be noted that since the decision to implement the BRT was linked to traffic congestion and the existing mobility needs, the local government focused mostly on traffic issues and aimed at starting the operation in the shortest time possible. Urban development plans and future development patterns were not considered; and as a result the planning of the system was not integrated into the urban or regional development plans. In fact, the municipality was actually preparing and finalizing its regional development plan at the same time with the BRT decision. Meanwhile a comprehensive transport plan was also being prepared by the Istanbul Municipality for the city. Transport plan studies have been carried out since the mid-2000s, again during the same time with the BRT decision. However, the planning of the BRT was not integrated into the transport plan either. It emerged as a fragmented, separate idea. This had consequences on the route and station integration between the Metrobus and the metro systems in Istanbul. The idea for implementing BRT involved using the D-100 highway, regardless of the fact that this corridor was very much parallel to the M1 Light Metro for certain parts of its route. The D-100 highway allowed a better integration with the M2 metro line although the station integration were problematic, as described below in the relevant sections.

The D-100 highway has always been a congested corridor with a high demand. In fact, the municipality had considered a rapid transit system on this corridor for decades, either in rail or bus technology. However, the corridor belonged to the Highway Agency of the counry and not the municipality. Highway Agency did not permit dedication of a certain part of the road capacity only to buses. However, after a legislation passed that gave the municipalities the planning rights of the highway sections that fel into their jurisdiction area, the implementation became possible. (The Bosphorus connection, i.e. the Bridge, is still under the jurisdiction and control of the Highway Agency however, and that is why the Metrobus does not have its own dedicated lane there).

Figure 42: The photo below shows the D-100 highway before BRT implementation.

Source: İETT presentation, 2011

İstanbul also suffers from high air pollution rates caused by transportation activities. While planning and implementing the BRT in İstanbul, reducing greenhouse gas emissions was another objective: It was intended to decrease the number of private cars in the corridor and also reduce the number of low-capacity public transportation vehicles which pollute the environment most such as low technology conventional buses and particularly the minibuses (Figure 51).

Figure 43: Buses and minibuses

The first BRT corridor in İstanbul has started operation in September 2007 between Avcılar-Topkapı corridor (Figure 5.11). The first phase became successful and fulfilled the objectives: it reduced travel times, reduced private cars by attracting people with high quality service, and via the high technology buses and eliminating low technology conventional transportation modes from traffic, it is estimated that the BRT helped to reduce CO2 emissions.

The high ridership on the 18,2 km BRT route led new routes to be planned. Today all four phases has been completed and in operation. After completion of Phase III two continents were connected via the Bosphorus with the BRT line. Phase IV also opened recently at the western part of the city from Avcılar to Beylikdüzü.

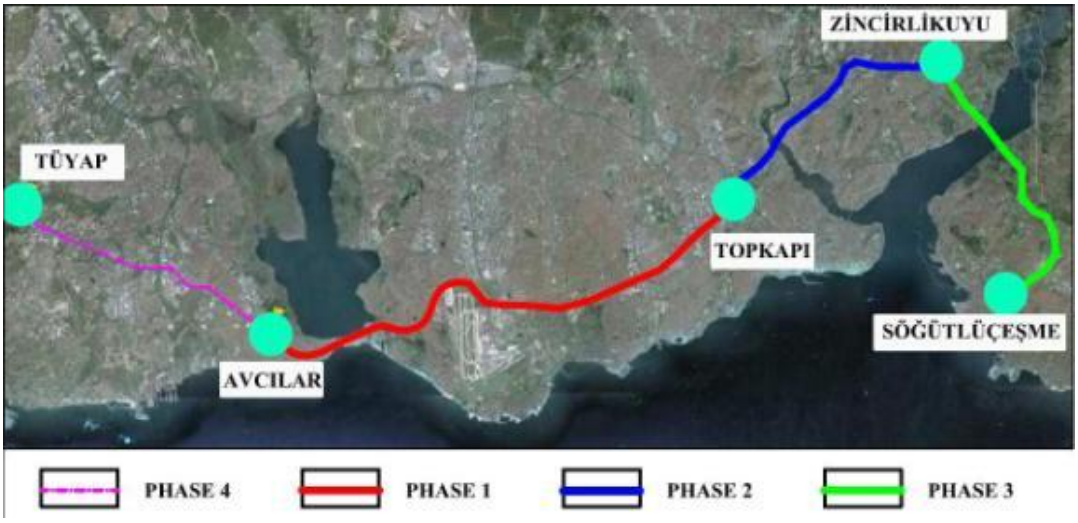

Figure 44: Metrobus route and its phases

5.3.2. Implementation

5.3.2.1. Phase I: Avcılar-Topkapı Corridor

The construction of first BRT corridor was started in 2007 between Avcılar and Topkapı corridor and started operation in September 2007. Total construction time of the corridor was 8 months. Despite being in the middle of the heavily used highway, construction was completed quickly.

Figure 45: Avcılar-Topkapı Phase of the BRT Line

Total route length of the corridor is 18,2 km and total number of stations on the corridor is 16, with 14 bus-stop and 2 turning points. According to İETT data total population in the surrounding area of Avcılar-Topkapı BRT line is 2.809.100 people.


Figure 46: Terminal Station at Avcılar before the extension was made from Avcılar to Beylikdüzü


Figure 47: Topkapı Turning point

Source: İETT Presentation, 2011

The highway which BRT line is constructed is an important international road that connects western cities to Anatolia. Since traffic volume is high, only two lanes could be segregated in total. Thus passing lanes which allow to operate express services could not be constructed.

While planning and constructing BRT the integration with other transportation modes is one of the most important points. Until recently, Avcılar was the end point of the corridor and served as an integration point for other transportation modes. Buses serving to the western part of the city are integrated with BRT in Avcılar station (Figure 5.15). The İETT station in front of BRT station is used by İETT buses, privately owned buses, regional buses and minibuses.


Figure 48: Integration of transportation modes in Avcılar

Şirinevler BRT station is also integrated with Metro line (M1) in Ataköy which provide rail service to Atatürk Airport. Bahçelievler BRT station is an interchange point to Bahçelievler Metro station.

Zeytinburnu Station is one of the most important interchange points in the whole BRT corridor. In Zeytinburnu there are Metro, BRT, Tramway, Park and Ride, conventional bus and minibus operations.

Merter BRT station is also integrated with Merter Metro station. Cevizlibağ station is an interchange point from BRT to tramway (T1).

5.3.2.2. Phase II: Topkapı-Zincirlikuyu Corridor

After the high ridership in the 1st Phase, one year later Phase II started operation in September 2008. Phase II starts from Topkapı and ends in Zincirlikuyu station which is the last station in European side (Figure 58). Zincirlikuyu and previous BRT stations are located in the Central Business District of the city that is an extremely strong trip attractor as already mentioned above. The construction of Phase II was completed only 77 days.

Figure 49: Topkapı-Zincirlikuyu Phase of the BRT Line

Total route length of the Topkapı-Zincirlikuyu corridor is 11,8 km and total number of stations are 12; 11 bus stops and 1 turning terminal. According to İETT data, BRT corridor in Phase II serves 2.505.814 people in the surrounding area.

Figure 50: Zincirlikuyu Turning Point

Source: İETT presentation, 2011

The BRT line is integrated with other conventional bus and minibus routes along the corridor. It also provides transfers to the M2 Metro line in Şişli-Mecidiyeköy and Zincirlikuyu stations. It should be noted that these latter transfers are quite problematic since they were not planned with integration in mind: Metrobus line and its stations were designed without sufficient consideration for station integration with the Metro system. Figures 60 and 61 clearly show this problem, where transfers require certain distances to be walked by users, and the transfers are not clear, direct and convenient. Currently in both stations tunneling works are carried out for a better pedestrian movement between the two systems.

Figure 51: Transferring from M2 Şişli-Mecidiyeköy Station to Metrobus Mecidiyeköy Station

Transferring between these two stations involves a distance of 374.18 meters to be covered above ground, including road crossings.

Source: www.iett.gov.tr

The fact that the corresponding station in the metro and metrobus systems have different names in the Gayrettepe-Zincirlikuyu case may also be considered problematic for a good integration that can clearly inform those who will transfer between the two systems.

Figure 52: Transferring from M2 Gayrettepe Station to Metrobus Zincirlikuyu Station

Transferring between these two stations involves a distance of 429.24 meters to be covered above ground, including pedestrian bridges.

Source: www.iett.gov.tr

As mentioned before, this route serves the CBD of Istanbul as well as many important buildings along the corridor, such as Haliç Convention Center, Okmeydanı Hospital, İstanbul Justice Palace etc. In addition, one of the biggest shopping malls in İstanbul, Cevahir Shopping Mall, is located close to the BRT line.

5.3.2.3. Phase III: Zincirlikuyu-Söğütlüçeşme Corridor

Zincirlikuyu-Söğütlüçeşme line is the 3rd Phase of the İstanbul BRT. This phase of the system connects two continents via Bosphorus (Figure 62). This feature makes İstanbul Metrobüs first and only intercontinental BRT line in the world (Alpkökin and Ergun, 2012). More importantly, it gives the system an important advantage since it provides a high-quality and significantly faster public transport service at one of the most congested bottleneck points of the city.

Figure 53: Zincirlikuyu-Söğütlüçeşme BRT Line

Total route length is 11,5 km, consisting of 7 bus stops and 1 turning terminal. This phase is constructed in 5 months and started operation in September 2009. The line starts from Zincirlikuyu station at the European side and ends in Söğütlüçeşme station in Kadıköy District at the Asian side.


Figure 54: Istanbul Metrobus on the Bosphorus Bridge

BRT line in İstanbul has fully segregated runningways along the corridor except for the section where BRT buses flow in the mixed traffic on the Bosphorus Bridge (Figure 63). Since the planning, ownership, operation, and maintenance of the bridge belong to the Highway Agency of the Central Government rather than the local authority, dedicated bus lanes could not be constructed on the bridge. But in order not to compromise the speed of the system, buses enter and exit the bridge on dedicated lanes, thus buses run only 3 km in mixed traffic.

5.3.2.4. Phase IV: Avcılar- Beylikdüzü

4th Phase of Metrobus was opened in July 2012 between Avcılar and Tüyap Fair and Congress Center. It has 9,7 km route length with 11 stations. This phase carries 74.000 passengers per day. The trip takes 20 minutes between two end stations. There is 24 hours service on the corridor similar with the rest of the system. Figure 64 shows the Avcılar-Beylikdüzü BRT corridor.

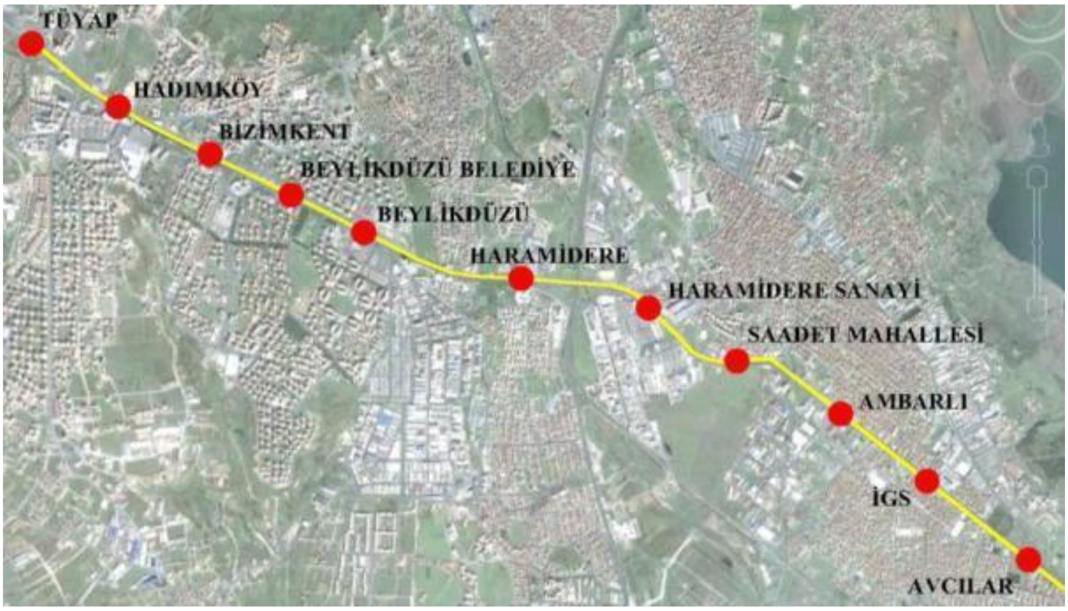

Figure 55: Avcılar- Beylikdüzü corridor and stations

This corridor differs from other three corridors in terms of station design. Accessibility and passenger comfort has the priority on station design. For accessibility issues there are both elevators and escalators in each station that aims to increase accessibility of passengers, including those with reduced mobility (Design for all concept-universal design)

Figure 56: New station design in 4th Phase

In addition, other stations in the rest of the corridor were not capable to protect passengers from diverse weather conditions. This station design provides better protection to passengers from rain and snow. Also the platform width is larger than old stations and hence provides more space for passengers while waiting for the bus.

Figure 57: New Platform design in 4th Phase

Safety of passengers and buses are given further consideration in the 4th Phase when compared to the other 3 Phases. There are fences between BRT road and platform, especially at the entrance part of the platform and on the second floor of the station.

Figure 58: Protection precautions in 4th Phase stations

There are two layer barriers between BRT road and ordinary vehicular road. These barriers are steel and more protective for both buses that may lose control and enter the counter flow traffic, and other vehicles that enter the BRT road. Also there are fences on stations to prevent people from entering the station without ticket validation. This also prevents people from attempting to cross the freeway.

Figure 59: Two layer barriers on the corridor

5.4. Operation

5.4.1. Running Ways

İstanbul Metrobüs is running on D-100 and O-1 Highways with fully segregated median busways (except for the Bosphorus Bridge section) with 52 km route length. There is one lane in each direction and it is segregated from general traffic with physical barriers and from other BRT lane with road markings (Figure 5.22). Since the doors of the vehicles are located on the right side, buses run on the left side of the traffic and counter to the general traffic flow. There are two terminal stations at the end points of the system in Avcılar and

Söğütlüçeşme, but Topkapı, Edirnekapı and Zincirlikuyu stations serve as terminal stations too for certain services, thus there are turning bridges and gates in these stations. (Şahin et al. 2009)

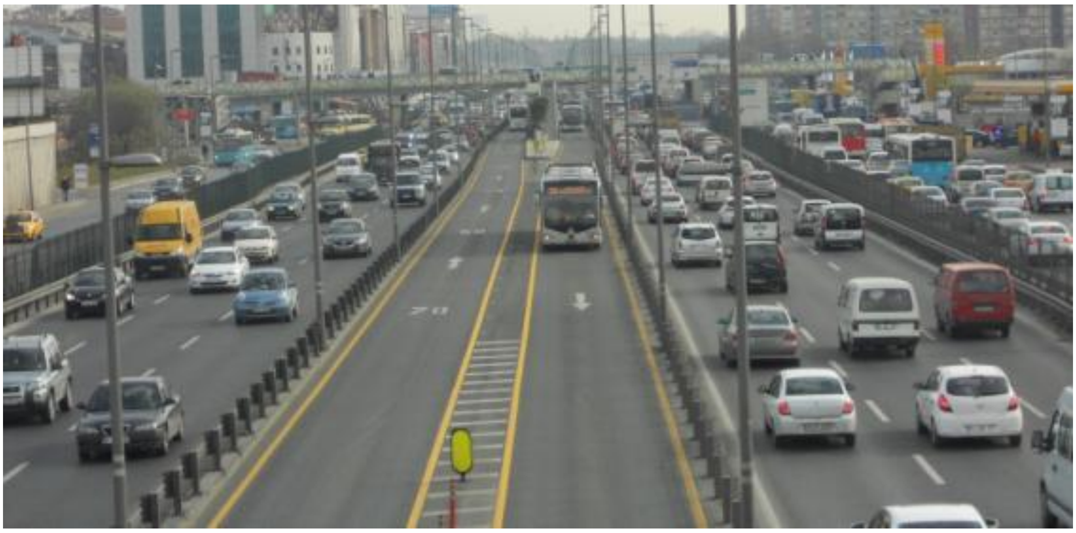

Figure 60: Fully Segregated Median Busways

5.4.2. Stations

There are 45 stations in Beylikdüzü-Söğütlüçeşme BRT corridor. This corresponds to an average station spacing of 1.16 km (average distance between stations), which is quite high and appropriate for a rapid transit system. Since running ways are limited with a total of two lanes, there is no passing lane at stations (Figure 69). Platform length is 60 m which allows two 26 m long buses or three 18 m buses to serve at the same time at the stations. Since BRT corridor is located in the middle of the highway, passengers' access to the stations is provided via under or over passes. Platforms and vehicles have the same level of height with the platforms, thus the time needed for passengers' exiting and boarding is minimized and the capacity of the system is increased. (Şahin et al. 2009)

Figure 61: Median Station

5.4.3. Vehicles

In Avcılar-Söğütlüçeşme BRT corridor, high technology CapaCity and Citaro buses designed by Mercedes and Philas are in operation. In CapaCity and Philas buses less seating place for passengers is provided when compared to their length: the aim is increasing passengers' flow capability in the bus, decreasing the waiting times of the buses in the stations while exiting and boarding. (Şahin et al. 2009)
There are 350 buses in the Metrobus fleet in Istanbul. 250 of them are CapaCity, 50 of them are Phileas and 50 of them are CITARO.

Figure 62: Bi-articulated Philias Buses

Figure 63: Articulated CapaCity Buses

Figure 64: CapaCity Buses inner configuration

Table 17: Features of BRT buses

MODEL	Phileas	CapaCity	CITARO
Configuration	bi-articulated	articulated	articulated
Floor Height	low-floor	low-floor	low-floor
Number of Doors	4	4	4
Capacity of Bus (seated)	52	42	45
Passengers' Standing Area	30	25	20
Capacity of Bus (standing)	120	100	80
Total Passenger Capacity	172	142	125
Fuel	diesel/electric	diesel	diesel
Emission Standard	Euro IV	Euro III	Euro III
Length (m)	26,04	19,54	17,94
Width (m)	2,54	2,55	2,55
Height (m)	2,95	3,16	3,08
Empty Weight (kg)	21530	18550	16758
Full Weight (kg)	34600	32000	26278
Minimum Turning Radius (m)	12,5	22,85	11,41
Maximum Speed	85	80	60

Source: Metrobüs (BRT) Sistemlerinin Planlama, Tasarım Ve İşletim Özellikleri, Şahin et al. 2009

5.4.3. Fares and Fare Collection

In Istanbul, until recently, fares have been fixed at a flat rate both in rail and bus transportation independent from the travel length. However, recently Metrobus introduced a distance-based fare system, where passengers are required to use their cards in bth entering and exiting the system. At the entrance, the ticket machines charge the highest distance to the car but at exit depending on the distance, a certain amount is refunded back to the card. The system works only at the Metrobus currently and not at the rail systems. There are plans to extend it to the rail systems; however, this requires ticket machines at station exits too.

Fare collection is off-board in the system (Figure 75 and 76). Passengers pay or use their cards when accessing to the platforms. This significantly reduces times at the boarding.

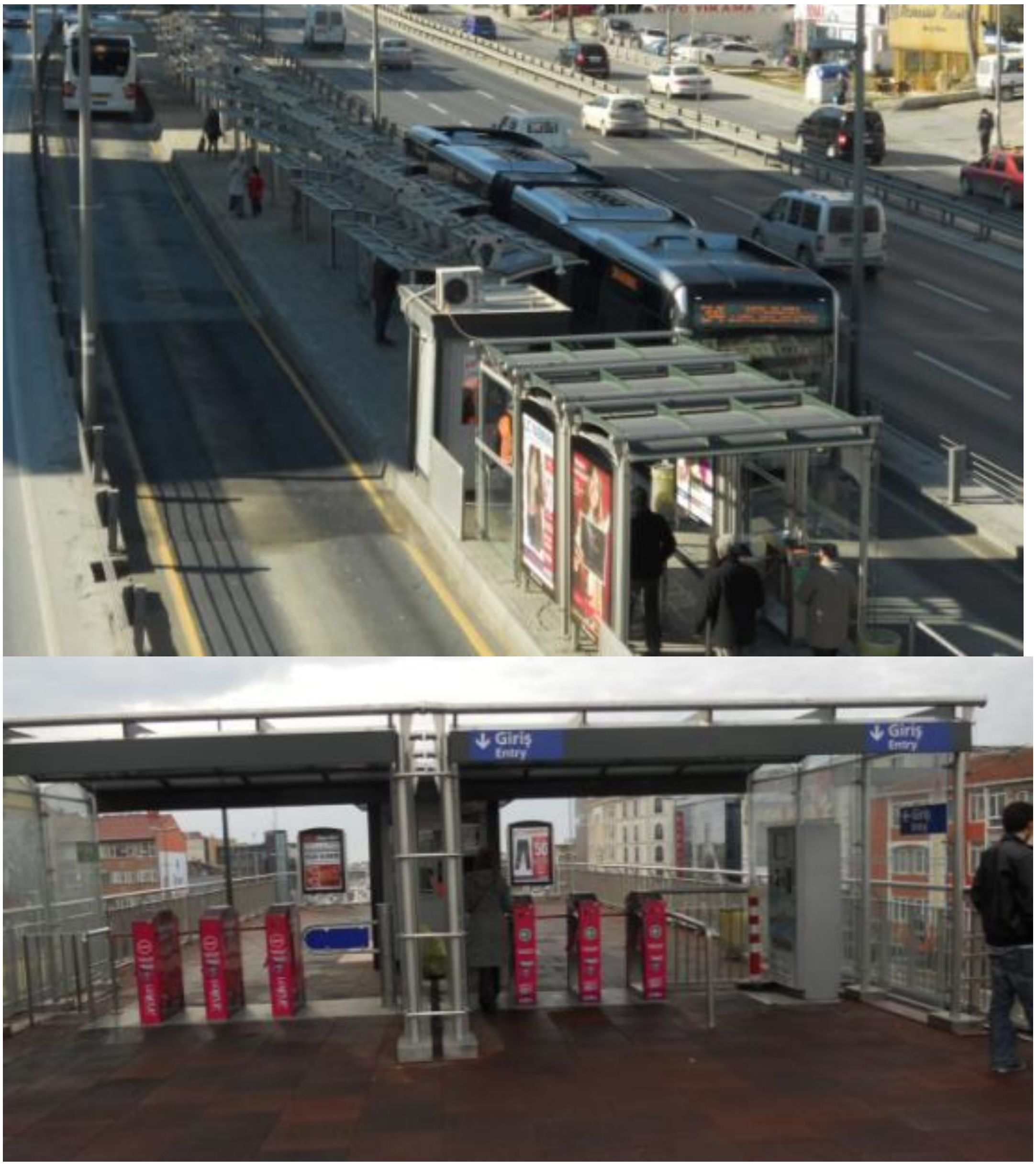

Figure 65: Off-Board Fare Collection

5.4.4. Service Plan

There are five lines in İstanbul BRT: Avcılar-Zincirlikuyu (line number 34), Avcılar-Söğütlüçeşme (34G), Söğütlüçeşme-Cevizlibağ (34A), Zincirlikuyu- Söğütlüçeşme (34Z), and Beylikdüzü Gürpınar-Cevizlibağ (34C). In the corridor buses are operated 24 hours and they stop at every station. Since line has one lane in the both side, there is no overtake capability of buses in the stations, thus different services, such as express services, are not applicable. (Şahin et al. 2009)

5.4.5. Information Technologies

Visual and audio information is provided in every bus for passengers. Real time information is gathered in command and control center (Figure 77 and 78). Every bus is tracked with GPS technologies and any emergency situation can be detected quickly.

Figure 66: GPS tracking of buses

Figure 67: Control Center

5.5. LESSONS LEARNED

One of the important points about the BRT in İstanbul is that it is initially built as a single corridor without further extensions and feeder systems planned in its early design stages. Therefore, it cannot yet be regarded as a system; it is a BRT corridor. Only with branching throughout the city it may be possible to regard it as a system.

Notwithstanding this, the BRT corridor in İstanbul can be regarded as successful in terms of operation characteristics since it has very frequent and high-speed service. The weak point of İstanbul Metrobüs is its planning background. It is not well integrated with development and transportation plans. As claimed by Aplkokin et. al. (2012) "Bus has always been the major form of public transportation in İstanbul, BRT systems had not been included in the bus network development plans until quite recently." It is not possible to say BRT system is included in plans for İstanbul.

According to data obtained from İETT; BRT system provides 52 minutes time saving per day. That is 316 hours per year. A person using BRT system can have 13 more days in a year when compared to using conventional bus transport mode. Some bus and minibus routes are removed from BRT corridor after Metrobüs. This means 209 less buses and 1296 less minibuses in the traffic. After BRT operations 242 tones less fuel is used in public transportation. BRT system has positive effects on the environment too: with BRT system 80.000 vehicles are removed from traffic which means 623 tones CO_2 reduction daily. 282 tones of nitrogenoxide which causes smog, acid rain, global warming and many other health complications are reduced daily.

BRT system also has positive effects on accident rates on the corridor. Fewer vehicles on the D-100 street mean less congestion and less accidents. This means BRT has positive effects on economy in terms of both vehicle industry and health sector. As stated by Alpkokin et. al.(2012) "The statistics of Istanbul Public Transportation Authority show that an accident occurs every day on conventional bus network. With Metrobüs, this has been substantially reduced and only five accidents were recorded in 2010." However there are safety problems on corridor, especially because of counter flow traffic: vehicles enter the BRT lane and crash to either BRT buses or people waiting at stations. In order to prevent this situation steel barriers should be constructed along BRT corridor. As stated by Alpkokin et al (2012) "The İstanbul BRT system has achieved a 9% shift from the car users within 3 years and the car ownership ratio among the Metrobüs users is 10%. In an earlier survey conducted in 2009, almost half of the users have stated that under the same conditions of travel time and fares, they would have again preferred Metrobüs over an underground system.

One of the problems experienced in the Istanbul Metrobus is due to the low capacity station platforms. Central stations provide easy transfer and cost savings in construction; however, in peak hours they cannot meet the demand. This caused safety problems due to passengers spilling on the roads. In addition, at peak times, access to the stations can also be quite congested, with the stairs and bridging being extremely overcrowded. Overcrowding at peak times was a problems also reported by the best-practice cases, such as Curitiba and Bogota, as described in earlier parts of the study. The next chapter provides a more comprehensive comparison of the Istanbul Metrobus with these best-practice cases.

CHAPTER 6

6. ASSESSMENT OF THE ISTANBUL METROBUS IN COMPARISON TO BEST-PRACTICE CASES

In this part of the study the BRT system in Istanbul will be compared with three other BRT systems in the world with a view to assess the strong and weak points of the system in terms of planning, operation, management, ridership, etc. In addition, the system will also be compared to the urban rail systems in Istanbul in order to provide some information on its service quality, rapid transit character, and utilization by citizens, i.e. its usage in daily trips.

As described in the Methodology Chapter of the study, three well-known and well-reported BRT systems in the world are selected for a comprehensive comparison with the Istanbul Metrobus. The first case is Curitiba RIT system in Brazil. Reason for choosing this case is RIT is that it is a pioneer BRT implementation attempt starting from the 1970s and has a great success in terms of ridership and system performance. The other system is TransMilenio in Bogota in Colombia. This system was implemented at the end of the 1990s; and the system coverage, ridership and performance are noteworthy. The third case is the Metrobus system in Mexico City in Mexico. This system started operation two years before İstanbul Metrobus and more or less has same ridership with Istanbul.

Comparison of the systems will be done in 5 categories: planning background; physical characteristics; operating characteristics; marketing, advertising, identity and image-building policies and ridership on the system.

6.1. Planning Background

In the planning background part of the analysis the reasons to implement the systems and their integration with urban plans, land use development and other transport modes are observed and compared.

It was described earlier that daily trip rate is high in Istanbul due to high population and development pattern of the city. Since there is limited area for development, the city has a linear macroform, thus residents have to make long trips to reach their final destination from houses daily. Passenger mobility is provided with road, marine and rail transport, but when the ratio is compared most of the trips are done via roads. High private car ownership is low compared to Western European cities but car usage rate is high and combines with ever-increasing rates of mobility, this causes traffic congestion in many arterials. Rail investments are present in the city, with a number of metro, LRT and tram lines, but their coverage is still limited and the completion of the full network takes long time to construct. Therefore, city officials decided to implement BRT as a cheaper and quicker solution to the traffic problem.

Since the decision to implement the BRT was linked to traffic congestion and the existing mobility needs, the local government focused only on traffic issues and aimed at starting the operation in the shortest time possible. This meant that urban development plans and future development patterns were not considered; and as a result the system does not have any integration with the urban master plan, which was actually being prepared and about to be finalized at the same time with the BRT decision. Meanwhile a comprehensive transport plan was also being prepared for the city, studies for which have been carried out since the mid-2000s, again during the same time with the BRT decision. The BRT is not integrated into the transport plan either.

After the high ridership of the first phase, other corridors were implemented again without any coordination with urban master plan and urban transportation plan.

The system operates in the middle of D-100 Highway, which has already turned into an urban arterial, and thus land use pattern is mostly integrated with the road. Some of the stations in the European side is partially integrated with important nodes, such as universities, shopping malls, dense residential areas and commercial uses. These uses existed before the BRT implementation; they are not a planning decision because of the Metrobus construction. In the Asian part, the highway preserves its highway feature, thus integration with land uses seems more complicated here. Since important land uses do not exist close to BRT stations (because they are at a reasonable distance to the highway), integration becomes weaker.

The BRT system is also only partially integrated with the rail systems in the corridor. The integration is related to proximity of Metro and BRT stations only, and as already illustrated in the previous chapter, they require long walking distances and even road crossings. Many of the bus and minibus operations are removed from the corridor, since Metrobüs has a higher carrying capacity. But there is opportunity to transfer to bus and minibus systems, İETT tried to integrate conventional bus stops to BRT stations. Metrobus system is operating in the middle of highway, thus bike lanes are not applied. Bike integration does not exist; and there are no bike parking areas on the corridor. Bike integration with separate bus lanes does not occur in the whole system and even bike parking areas do not exist on the corridor. There are Park and Ride facilities in some stations. Since pedestrian infrastructure is very weak in the whole of Istanbul, integration with pedestrian areas and streets is also limited.

Information about the best-practice case studies of Curitiba, Bogota and Mexico were given in detail in previous chapters. These data together with the Istanbul data are summarized in Figure 79. Important findings of the comparison to note are as follows: all systems initiated the BRT projects due to congestion problems and high car usage rates, and therefore to improve public transport. In Curitiba, an additional aim was to control development, which is important since this leads to one of the best-known examples of integration between land-use planning and BRT implementation. In other cities too, integration with urban plans existed; and this seems to be one important shortcoming in Istanbul. Integration with other transport systems also appears to be limited in the Istanbul case. Interestingly, all systems have somewhat neglected integration with cycling, perhaps due to the low rate of cycling in these cities.

It is seen that the BRT in İstanbul was implemented without sufficient public participation as it was decided and implemented very quickly. This is evident from the fact that additional stations were built after the system started service, as a result of demands from users. Had the users been included in the planning, decision making and implementation processes, station locations and other design and operation aspects could have been planned with the users' needs in mind.

Table 18: Planning Background

	Curitiba	**Bogota**	**Mexico City**	**İstanbul**
Reasons to implement	uncontrolled development high car usage	high traffic congestion high private car ownership	poor public transport high car usage	high travel times high congestion poor public transport
Aim	integrated public transport reduced private car usage	reduce private car usage	increasing mobility reduced gas emissions	fast & economic transport solution to corridor
Community participation in decision making	yes	yes	Yes	No
Integration with urban plans	yes	yes	yes	no
Integration with land use	trinary system zoning & land development policies	support long-term urban renewal prioritize walking & cycling	yes	partial: better integrated with existing sites along the European side
Integration with rail systems	Not applicable	yes	no	limited (long transfers)
Integration with bus systems	yes	yes	no	yes
Integration with Bicycle	no	partially	no	no
Existance of bike parks	no	yes	no	no
Existance of Park&Ride			no	some
Integration with good pedestrian infrastructure	yes	yes	yes	partially

6.2. Physical Characteristics

An important aspect that affects ridership is the physical characteristics of the systems, including location and design of the system. In this part, the analysis is made in 3 categories. First physical components, then busways, and finally stations and vehicles will be compared (table 14).

Table 19: Physical Components Checklist

	Curitiba	Bogota	Mexico City	İstanbul
Physical Components				
BRT System Covarage	405 km	310 km	67 km	52 km
BRT Busways	65 km	84 km	67 km	52 km
Number of Stations	127	114	112	45
Average Distance Between Stations	600 m	790 m	600 m	1160 m
Off-Board Fare Collection	yes	yes	yes	yes
Control Center	yes	yes	yes	yes
High-Demand Corridor	yes	yes	yes	yes

As Curitiba is the first city that applied total BRT system, its network coverage is the highest. This is also due the feeder service network. In Istanbul there is not an official BRT feeder, thus BRT busway can be observed as the coverage of the system. But in Istanbul BRT corridor is fed by İETT and private buses, thus total system coverage is more than 52 km. In terms of station numbers and average distance between stations; Istanbul represents a faster system with much higher distances between its stations. While determining stations' location, being a trip attraction point is an important factor, and especially in Asian side distances between stations increase.

Another important feature of BRT systems is off-board fare collection. Since it is time consuming to pay to the driver, the most effective way to decrease time needed to validate the ticket is off-board fare collection. Off-board fare collection also allows passengers to board vehicle not only from first door but also from all doors, which in turn decreases time needed for buses to wait in the stations. All four systems have off-board fare collection to increase the performance of the systems. Also all four systems have a Central Control Unit.

If the system is constructed one of the highest demand corridors, it also increases the number of the passengers using it in daily trips. Same as all three best practice cases, the BRT system in İstanbul is implemented on one of the most important arterials. Passing through the Bosphorus Bridge also meant that the system served a very high demand bottleneck crossing.

Comparison of the Busway Characteristics are given in Table 23.

Table 20: Busways Checklist

	Curitiba	Bogota	Mexico City	İstanbul
Busways				
Segregated Right-of Way	fully segregated	fully segregated	fully segregated	fully segregated*
Alignment	median	median	median	median
Intersection Treatment	yes	yes	yes	not applicable
Passing Lanes at Stations	%20 of total	%100 of total	no	no
Center stations	yes	yes	yes	Yes

(* except for the Bosphorus Bridge crossing of 3 km)

Segregated lanes are the distinctive characteristics of BRT systems when compared to conventional bus operations. It leads buses to move quicker and not to be affected by traffic congestions. All systems analysed here have fully segregated busways. BRT system in Istanbul crosses the Bosphorus Bridge, the only place where BRT buses flow in the mixed traffic is on the bridge: that is because the property of the bridge belongs to the General Directorate of Highways, who did not permit reserving one lane exclusively to BRT. But buses enter and exit the bridge in dedicated lanes, and since it is the approach to the bridge that suffers from worst traffic congestion, the BRT is not affected much by congestion.

All systems are located in the medium lane which prevents interruptions from other traffic. But Istanbul has the advantage since it runs on the highway that already has most junctions in grade-separation; and therefore the BRT does not have any at-grade intersections. There is no intersection where BRT buses have to stop for traffic lights.

Passing lanes at intersections is another feature of the system that increases the ridership. Passing lanes located at the stations prevents buses to wait the other bus to move. Also it gives opportunity to operate express services which do not stop all stations, just at those with higher passenger demand. Passing lanes is one of the reasons that Curitiba and Bogota BRT systems have higher ridership than Mexico City and İstanbul BRT because this gives them an opportunity to provide higher service levels. Since the highway that Metrobus implemented has a limited area, it was hard to implement passing lanes, thus the system has only two lanes in the corridor and at the stations that brings a limit to the passenger numbers carried.

While using median running-ways, center stations that serve both directions of BRT system makes transfers easier and it is also more cost-effective. All four systems have center stations.

The other physical characteristics that affect ridership are design of stations and vehicles (Figure 82). Stations have to be designed to allow passengers board and alight quickly and buses have to be designed not to prevent passenger circulation in the bus. Platform level boarding allows people to board and alight easily which is important especially in peak hours. Buses docking properly or using extra platform between bus and stations helps handicapped people to use the system also. Platform level boarding can be applied only if bus and platform have the same height. It can be either high or low floor buses. There are technologies that help driver to dock properly, but in Mexico City docking is totally left the drivers skills, because they have been trained well and therefore without any technology they dock to the station properly.

In Istanbul buses and stations have same level, but drivers are afraid of crashing to the platform, thus they do not dock to the station. This sometimes leads passengers either to jump a long distance or step down and step up to access the vehicle. This also decreases the performance of the system. Safe and comfortable station design is the distinctive characteristics of BRT systems when compared to other bus operations. In RIT, TransMilenio and Metrobus systems stations have safe and comfortable design. In RIT, tube stations are used, in Bogota and Mexico City there are similar station design with Curitiba. This type of design provides total weather protection. In addition they are safer, because they have sliding doors protecting people from falling down or stepping into the road. In addition, sliding doors helps handicapped users to know where to wait to board easily with wheelchair or with special pavements blind people can be directed to the doors. Mexico City and Istanbul BRT systems do not have sliding doors.

Despite having diverse severe weather conditions in Istanbul, weather protection is very limited, since stations have only roofs. Also neither sliding doors nor guard rails exist to protect passengers from flowing bus traffic. Especially in peak hours people wait for the bus standing on the road. Since BRT operations are very frequent in İstanbul, seating areas are not provided at the stations.

It was also stated above that access to the stations can be problematic at peak hours in Istanbul due to the overcrowding of stairs and bridges. While overcrowding is mentioned for the other systems too, they are all reported to have good pedestrian access whereas access to the stations is one of the most widely criticized aspects of the Istanbul Metrobus system.

Since off-board fare collection is a feature of BRT operation, the number of doors on buses becomes important. Passengers can use all doors, and time losses are minimised while boarding. In the RIT system, buses have 5 doors; the other three systems are using buses with 4 doors. Frequency of BRT operation is very high especially in peak hours, thus platform length should be long enough to accommodate more than one bus at the same time to decrease waiting times of buses in each station. There are sub-stops and docking bays in three best practice cases. In Istanbul, platform length is enough for 3 buses to stop.

Table 21: Stations and Vehicles Checklist

	Curitiba	**Bogota**	**Mexico City**	**İstanbul**
Stations and Vehicles				
Platform Level Boarding	yes	Yes	yes	yes
Safe and Comfortable Stations	yes	Yes	yes	yes
Easy and safe access to stations	yes	Yes	yes	limited
Number of Doors on Bus	5	4	4	4
Docking Bays and Sub-Stops	yes	Yes	yes	yes
Sliding Doors in BRT Stations	yes	Yes	no	no

6.3. Operation Characteristics

Operation characteristics of the four systems are given in Figure 83 and compared below.

Table 22: Operation Characteristics Checklist

	Curitiba	Bogota	Mexico City	İstanbul
Operation Characteristics				
Operational Mode	trunk-feeder	trunk-feeder	trunk-only	trunk-only
Commercial Speed	17,5 km/h	18-28 kım/h	<20 km/h	35-40 km/h
Peak Frequency		2 minutes	48 seconds	15 seconds
Off-Peak Frequency		6 minutes		1 minute
Hours of Operation	weekday 20 hours	weekday 5am-11pm	weekday 4:30am-0:30am	weekday 24 hours
	weekend 19 hours	weekend 6am-11pm	weekday 4:30am-0:30am	weekday 24 hours
Multiple Routes	yes	Yes	yes	No
Express, Limited and Local Services	yes	Yes	no	No
Multi Corridor Network	yes	Yes	yes	yes
Express, Limited and Local Services	yes	Yes	no	No
Fare Integration	yes	Yes	yes	yes but no transfer reductions
Automated Fare Collection & Fare Verification	yes	Yes	yes	Yes

Having good feeder services is an important determinant that increases ridership of systems. Curitiba and Bogota systems have feeder operations to support the BRT. Mexico City and İstanbul has only BRT corridor not including an official feeder system. But these two systems have conventional bus operations to support the system which is only based on proximity of stations. Istanbul has a good conventional bus feeder operation but vehicles cannot enter the corridor. Buses discharge people to a İETT bus stop close to BRT stations.

BRT systems have higher commercial speeds then conventional bus operations, because like rail operations they have their own roads. But especially intersections slow down vehicles when they meet mixed traffic and decrease commercial speeds. All three best practice cases have at grade crossings and intersections. Thus commercial speeds are 17,5 km/h for Curitiba, 18-28 km/h for Bogota and it is less than 20 km/h for Mexico City. Since Metrobüs in İstanbul is located in the middle of a highway and intersections are eliminated from flowing traffic, commercial speeds are as high as 35-40 km/h, which results in faster and more reliable operations.

Istanbul Mertobus has the highest frequency especially in peak hours among other cases. Also peak-off intervals between buses are very short which increases total ridership of the system. In peak hours every 15 seconds a bus leaves the station. 3 buses dispatch from terminal stations and in order to meet high demand on crowded stations some buses leave terminal stations empty. In day time off-peak intervals are 1 minute. The system is operated 24 hours both in weekdays and weekends while this is not the case in any of the other comparison systems. It can be concluded that operating characteristics are quite superior in IstanbulMetrobüs, providing a high quality service level. On the other hand, as mentioned before, there is only one corridor in İstanbul and since there are no passing lanes it is not possible to operate express or limited services. Despite having only one corridor there are 5 different lines in the same corridor, defined by origin and destination stations. Same electronic card is used in Istanbul for all transportation modes except minibuses. Same cards are used for Metrobüs also; this provides easy transfers between other transport modes. However, it should be noted that with the introduction ofa distance-based system in Metrobus, the fare structure in this system differed from the rest of public transport and therefore there are no reductions made in cases of transfers. When passengers transfer from a bus to a rail system, there is a transfer reduction on the second journey. This is no more the case for Metrobus; full fare is paid even if it is made immediately after another journey, hence clearly a transfer. This is a negative aspect for fare integration.

Table 23: Marketing, Advertising, Identity and Image Building Policies Checklist

	Curitiba	**Bogota**	**Mexico City**	**İstanbul**
Stations	distinctive	distinctive	distinctive	distinctive
Vehicles	distinctive	distinctive	distinctive	distinctive
Branding	yes	Yes	yes	Yes

Stations and vehicles should be distinctive for BRT systems, because they show the customer that they provide different and higher-quality services than conventional bus operations. Since the idea behind the implementation BRT is “think rail, use buses”, it should provide comfortable, reliable and frequent services like rail systems, thus it should have different vehicle and station designs like tube stations in Curitiba or Bogota. In Istanbul, buses and stations are different than conventional bus operations, but unlike other cases, stations do not provide full protection for users like tube stations do. Also for increasing ridership, the branding of the systems by local private or public authorities is important. Before starting the operation in Curitiba, Bogota and Mexico City a large campaign was made to introduce BRT systems to the users. Since planning and implementation was very quick in İstanbul, branding was limited initially. However, there are now some commercials for the system.

6.5. Ridership on the System

After presenting the features that are likely to affect the ridership and performance of the systems, in the last part ridership on systems will be discussed. As stated before Curitiba is the pioneer BRT system and because of its integrated planning background and high coverage, total ridership is very high with 2.26 million passengers per day. Since there are 6 different corridors and multi centered urban pattern, peak hour passenger/hour/direction are only 13.000. When the only BRT corridor of 65 km without the feeder services are taken into consideration, passengers carried per km is 34.770 in Curitiba (Figure 85).

TransMilenio in Bogota also appears to be a highly used system: 1.65 million passengers are carried daily on the corridor. In peak hours passenger/hour/direction is 34.000 on 84 km BRT corridor. 19.047 people are carried per km of the BRT.

Metrobus in Mexico City has ridership numbers close to İstanbul: total number of passengers is 620.000 daily on the 62 km route. Approximately 9.250 passengers are carried per km. In peak hours, it carries 9.000 passenger/hour/direction.

Total number of passengers carried daily in Istanbul Metrobus is 700.000. With 52 km route length, this amounts to 13.462 passengers carried per km of route. It carries 21.400 in peak hour passenger/hour/direction.

When the total ridership is compared, Curitiba and Bogota has very high numbers but they have very extensive feeder services too. Despite using only existing conventional bus operations and having a rather limited integration based on proximity of stations, İstanbul BRT has a rather high ridership that is higher than the BRT system in Mexico City. In addition, Istanbul BRT has shortest route length when compared to other systems. The reason to have high ridership for İstanbul is probably a combination of two factors: the corridor's location and high service level. It is located on one of the most demanded axis and it provides a rather fast journey with very frequent services and for 24 hours all days of the week. In addition, the system provides a relatively fast crossing across the Bosphorus, a major physical barrier for the two sides of the city. In addition, many of the conventional and minibus operations are removed from this corridor, thus people have to use the system. Despite having high frequency especially in peak hours, it is often reported that operation is inadequate to meet the demand.

Table 24: Ridership Checklist

	Curitiba	**Bogota**	**Mexico City**	**İstanbul**
Passenger Numbers	2,26 million/day	1,6 milion/day	620.000/day	700.000/day
Peak Hour Passenger/hour/direction	13,000	43,000	9,000	30,000
Passenger Per Km	34,770	19,047	9,000	13,462

6.6. Comparison of the Istanbul Metrobus with urban rail systems in Istanbul

While the main aim of the study is not to compare the Metrobus with rail systems, the comparison helps to provide a better understanding of the performance of the Metrobus. Since complete data is given for the full-year of 2011 (rather than 2012), the data to be compared is based on 2011, and hence the ridership and route length information is also for 2011.

Table 6.8 shows a comparison of the Metrobus with the three main urban rail systems in Istanbul, M1 (Aksaray-Airport Light Metro), M2 (Hacıosman-Şişhane Metro), and T1 (Bağcılar-Kabataş Tramway). It can be seen that the Metrobus has certain advantages over the rail systems: Its station spacing is almost as high as M2, the full metro. Its commercial speed (the actual average speed from one end to the other end of the line) is also high – in fact higher than the two Metro systems. It provides an extremely frequent service, which is not possible to catch up for rail technology. Of course the frequent service provides a limited space of one bus (or three buses dispatched together) as opposed to the multiple-car trains, but still the frequency is a very critical aspect for passengers waiting at stations. In addition, Metrobus operated all day and night, whereas th,s is not the case for the urban rail systems.

Table 25: System and operating characteristics of Metrobus and urban rail systems in Istanbul

	Metrobus	M1	M2	T1
Route length (km)	42	19,6	16,5	18,5
Number of stations	37	18	13	31
Duration of end-to-end journey	63	32	27	65
Commercial (operating) speed (km/hr)	40	37	37	17
Average distance between stations (km)	1,14	1,09	1,27	0,60
Peak headway	15-20 seconds	5 minutes	4 minutes	2 minutes
Operating hours	24 hours	06:00-00:00	06:15-00:00	06:00-00:00

Figure 87 and 88 show the daily and annual ridership figures respectively. Metrobus carries significant numbers of passengers, followed by the tram system. In fact they are both relatively smaller capacity system carrying higher numbers than the metro systems. This may indicate that citizens prefer the ease of using at-grade systems rather than underground or aboveground systems. However, this is most likely to be the result of the routes of the Metrobus and the tram. They both provide access to the CBD from a very highly populated (and public-transport-dependent) part of Istanbul. M2 also provides access to CBD but from a relatively more affluent area. AS for M1, its route is rather indirect and does not extend to the CBD. Furthermore, the Metrobus goes parallel to this system at certain parts of its route and it certainly attracted some of the M1 passengers after opening.

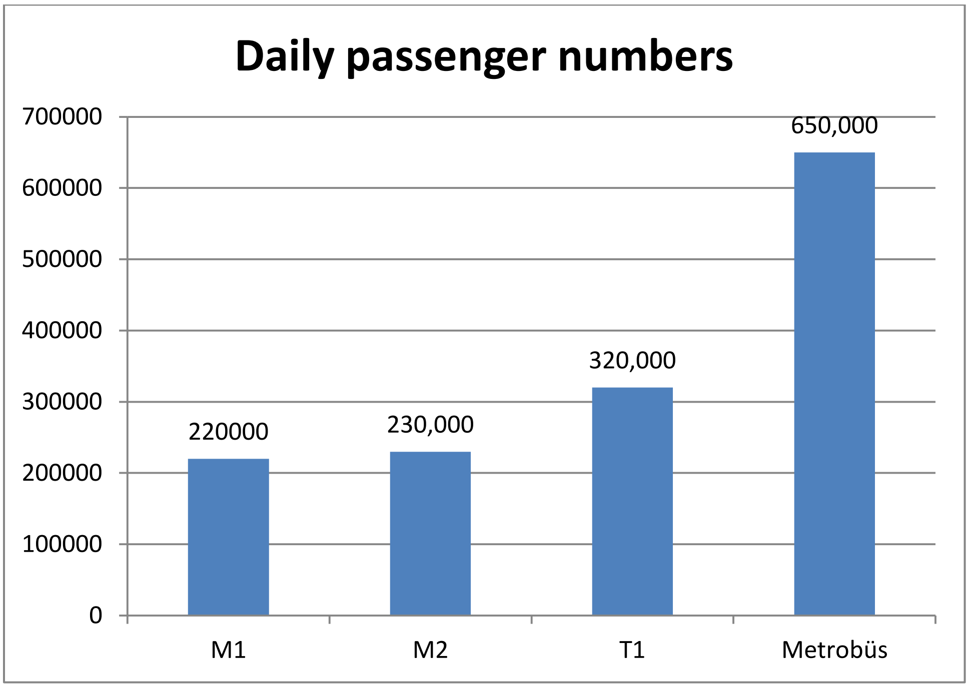

Figure 68: Daily ridership on the urban rail systems and Metrobus

Source: Ulaşım A.Ş. and IETT: data provided at their internet sites

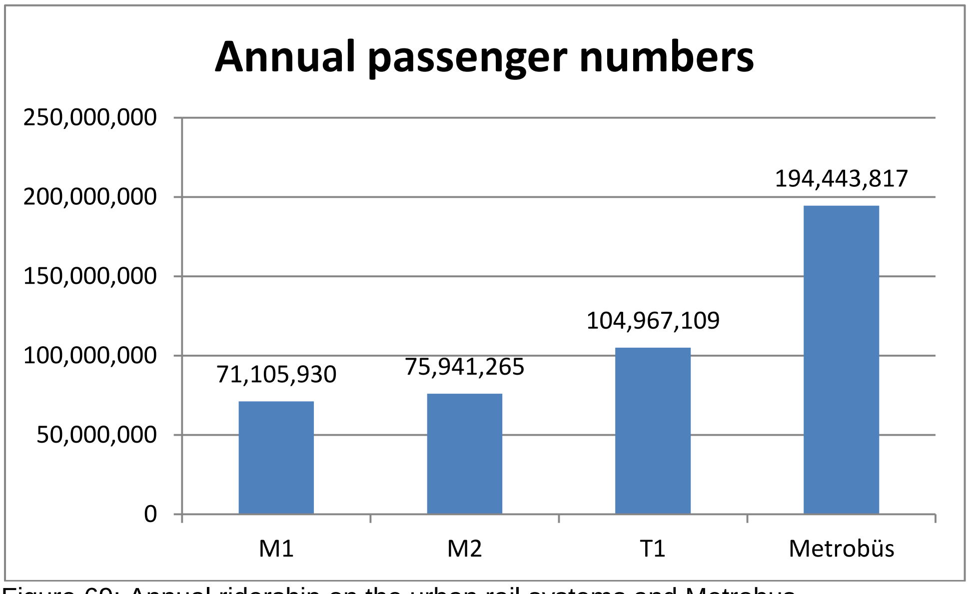

Figure 69: Annual ridership on the urban rail systems and Metrobus

Source: Ulaşım A.Ş. and IETT: data provided at their internet sites

The number of passengers per route km is shown in Figure 6.3. When the length of the system are taken into consideration, the tram is the most successful in terms of passengers per km of route. The performance of Metrobus and M2 Metro line are very similar. M1 line, which does not extend to the CBD and goes parallel to the Metrobus at certain parts of its route, has the lowest figure.

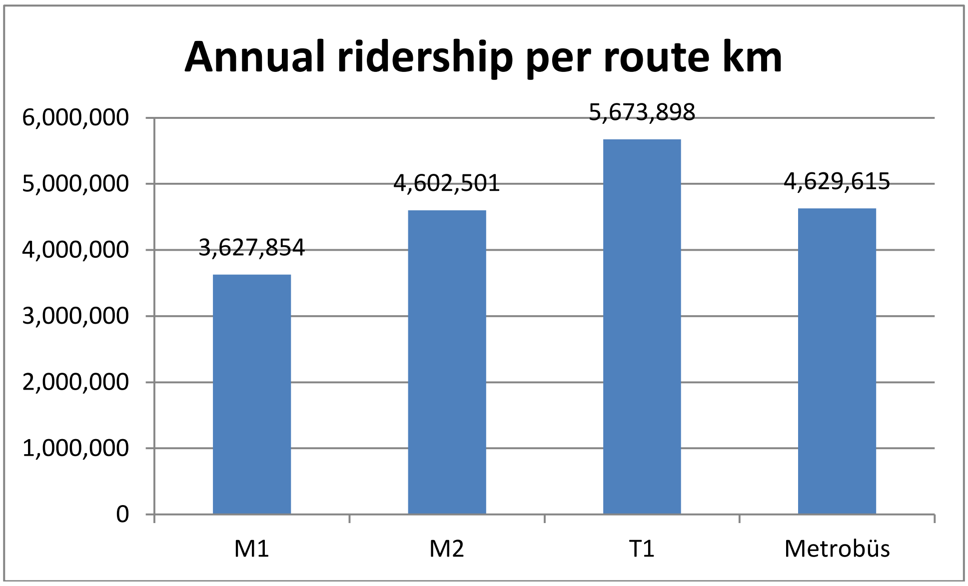

Figure 70: Annual ridership per kilometer of route on the urban rail systems and Metrobus

Source: Ulaşım A.Ş. and IETT: data provided at their internet sites

6.7. Results of the analysis

Istanbul Metrobus appears to be a successful rapid transit system that carries high numbers of passengers, comparable to the urban rail systems of the city. The operation caharacteristics also indicate that the system provides a very high quality service and has a number of advantages over the urban rail services, including speed, frequency, and 24-hour operation. All these result in a ridership that is higher than the urban rail systems, and as high as them when route length is taken into consideration.

When compared to the three well-known best-practice cases of BRT, the Istanbul Metrobüs is found to have a mixed performance. Its major weakness is in its planning background: the system was developed without any integration into the urban development plan and the transportation plan of the city. This has two consequences:

- The Istanbul Metrobüs is developed with only existing passenger demand considerations; and therefore the corridor serves currently existing development areas that already have very high mobility needs. This maybe one of the reason for its high ridership. Such a strategy of serving the existing high-demand corridor may be beneficial indeed to establish the system as a success in its early years of operation. And Istanbul Metrobüs is a young system that proved to be successful in ridership figures. However, this lack of coordination between the system’s planning and urban planning need to be overcome in the future in later stages since the urban plans will inevitably change demand patterns, that the Metrobüs will have to follow.

- Lack of integration into the transportation plan meant that the system was not integrated with existing metro and tram stations at all initially. No transfer stations were designed although some rail stations were in close proximity to the BRT. The same goes for conventional bus systems and stops. They were also poorly integrated although this improved in later years. The transfer stations with rail systems also improved although problems still exist. This is obviously a negative aspect in terms of planning; but it may have two very conflicting repercussions: had the system been better integrated with rail, the passenger numbers might be even higher; however, the opposite appears to be the case: the BRT system competes with the (Light) Metro system and it is stated by the Istanbul Rail Operating Agency that it attracted many passengers from the rail systems.

In spite of these apparent problems of integration, the system carries a reasonably high number of passengers. Its number of passengers per km of route is lower than the systems in Curitiba and Bogota, but higher than that in Mexico City. Furthermore, its number of passengers per km of route is higher than that of the two Metro systems of the city combined, which is about 13,500 passengers/km according to figures given by Özgür (2009). This high level of ridership shows that the level of service provided is a very important factor since this is the clear strength of this system when compared to the best-practice cases. The strong points of the Istanbul BRT can be listed as follows:

- Due to its design with higher distances between stations and full-segregation, it provides the highest speed of service when compared with the best-practice cases, and this is extremely important in a large city like Istanbul where commuting from outer suburbs to the CBD is the dominant mobility pattern.
- Furthermore, the system operates with very high frequency and 24 hour service – in both aspects, the system out-performs the best-practice cases as well as the Istanbul Metro systems.
- Moreover, the Bosphorus crossing, a condition specific to Istanbul, is a major advantage since there is no rail crossing yet and therefore this is the first rapid transit connection between the two sides of the city.
- Although it was noted that integration with other transport modes was limited, conventional buses and minibuses operating at the BRT corridor were reorganized and mostly removed, which made the BRT system the favoured choice in most cases.

Despite having some weaknesses, Metrobüs is reported to have positive effects on the environment. As discussed previously, by Metrobüs in İstanbul, many of the conventional bus and minibus lines were either removed or reorganized as a feeder service. It is reported that 623 tones of CO_2, 283of NO_x and 25 tones of hydrocarbon are reduced daily. BRT buses are making 160.000 km every day and use 70 tons of fuel daily. By introducing BRT system 242 tons of fuel is saved from public transportation. (İETT,2011).

Finally, the comparison with best-practice cases also provides some lessons to improve the Istanbul Metrobüs:

- Station design needs to be improved for both safety and weather protection.
- Station capacities have to be increased.
- In future phases, passing lanes should be incorporated in order to allow for faster operation as well as express services.
- Integration of non-motorised modes, such as cycling and walking, should be improved.
- As already mentioned above, integration with rail systems need to be improved; and future phases must be planned in integration with the urban development plan as well as the transport master plan of the city.

Cities throughout the world suffer from traffic congestion caused by high rates of private car usage and air and noise pollution due to gas emissions led by transportation activities. In order to deal with traffic congestion and traffic related problems national and local authorities started to focus on integrated public transportation activities. Rail based transportation systems are applied in most of the cities in the world, but they are expensive to implement and require long construction time. Despite being the most common transportation mode, conventional bus operations suffer from poor public image, speed, reliability and safety issues. Combining positive aspects of rail and bus technology, Bus Rapid Transit systems are getting more popular all over the world both in developed and developing countries, because they provide flexibility, they are easy and cheap to build, which are characteristics of bus operations; and they can also offer high quality, high capacity, reliable and safe services, which are characteristics of rail transit.

Istanbul has also been suffering from traffic congestion and traffic related problems for decades. As an innovative and quick solution to traffic problems BRT was implemented on one of the most important development and transport corridors in the city.

There is a mixed understanding currently about the performance of the Istanbul Metrobus system. Some claim that the system in İstanbul is a major success because of high numbers of passengers carried. But there are negative points of view about crowded buses and overcrowded stations especially in peak hours. This study was undertaken because there is a need to provide a better understanding of the performance and degree of success of the Istanbul Metrobus system. It was intended to assess the performance of the Metrobus with a view to highlight the strengths of the system as well as areas where there is room for improvement.

In order to assess the success of Metrobus three research questions were formulated.

4. What makes a BRT operation/implementation “successful”?
5. How can “success” be defined in the context of BRT operations?
    - Planning approaches/criteria
    - Physical characteristics/criteria
    - Operating characteristics/criteria
    - Ridership performance/criteria
6. Is Istanbul Metrobüs a success with respect to these criteria?

To find out the answer to the first and second questions, three best-practice and well-reported cases were selected. These are Curitiba in Brazil, Bogota in Colombia and Mexico City from Mexico. According to the experience in these cities and the performance of these implementations, a framework was developed. This framework comprised a checklist derived from these best practice cases and included aspects, such as decision making, planning background, implementation and operation of BRT systems. Passenger statistics were also analysed. This checklist was applied to İstanbul in a comparative approach with Istanbul being compared and contrasted to the three best-practice cases of BRT listed above. In addition, a brief comparison of İstanbul BRT was made with the urban rail systems in İstanbul by analyzing passenger statistics on these systems.

CHAPTER 7

7. CONCLUSIONS

7.1. Main findings of the research:

Istanbul Metrobus appears to be a successful rapid transit system that carries high numbers of passengers, comparable to the urban rail systems of the city. The operation characteristics also indicate that the system provides a very high quality service and has a number of advantages over the urban rail services, including speed, frequency, and 24-hour operation.

When compared to the three well-known best-practice cases of BRT, the Istanbul Metrobüs is found to have a mixed performance. Its major weakness is in its planning background: the system was developed without any integration into the urban development plan and the transportation plan of the city. This has two consequences:

- The Istanbul Metrobüs is developed with only existing passenger demand considerations; and therefore the corridor serves currently existing development areas that already have very high mobility needs. Thus today Metrobus is not sufficient to meet the need. Especially in peak hours the overcrowding at stations and in vehicles is the biggest problem. This also affects system performance and identity.
- Lack of integration into the transportation plan meant that the system was not integrated with existing metro and tram stations at all initially. No transfer stations were designed although some rail stations were in close proximity to the BRT. The same goes for conventional bus systems and stops. They were also poorly integrated although this improved in later years. The transfer stations with rail systems also improved although problems still exist. Currently there are tunnel constructions at two city centre stations to alleviate these transfer and access problems.

In spite of these apparent problems of integration, the system carries a reasonably high number of passengers. Its number of passengers per km of route is lower than the systems in Curitiba and Bogota, but higher than that in Mexico City. Furthermore, its number of passengers per km of route is higher than those at the two Metro systems of the city. This high level of ridership shows that the level of service provided is a very important factor since this is the clear strength of this system when compared to the best-practice cases. The strong points of the Istanbul BRT can be listed as follows:

- Due to its design with higher distances between stations and full-segregation, it provides the highest speed of service when compared with the best-practice cases, and this is extremely important in a large city like Istanbul where commuting from outer suburbs to the CBD is the dominant mobility pattern. Its commercial speed is even higher than the commercial speed of the metro systems in Istanbul.
- Furthermore, the system operates with very high frequency and 24 hour service – in both aspects, the system out-performs the best-practice cases as well as the Istanbul Metro systems.
- Moreover, the Bosphorus crossing, a condition specific to Istanbul, is a major advantage since there is no rail crossing yet and therefore this is the first rapid

transit connection between the two sides of the city. This is an important bottleneck point in the city’s traffic and having dedicated, congestion-free lanes until the bridge entrance makes the BRT service superior to any other form of transport using these bridges.

- Although it was noted that integration with other transport modes was limited, conventional buses and minibuses operating at the BRT corridor were reorganized and mostly removed, which made the BRT system the favored choice in most cases.

Despite having some weaknesses, Metrobüs is reported to have positive effects on the environment. As mentioned, by Metrobüs in İstanbul, many of the conventional bus and minibus lines were either removed or reorganized as a feeder service. It is reported that 623 tones of CO2, 283of NOx and 25 tones of hydrocarbon are reduced daily. BRT buses are making 160.000 km every day and use 70 tons of fuel daily. By introducing BRT system 242 tons of fuel is saved from public transportation. Also system decreased time loss in the traffic. It took more than three hours to commute from Söğütlüçeşme to Beylikdüzü before the introduction of the BRT. But today it takes 83 minutes to commute between the two ends of the system. Daily time gain for a passenger is 109 minutes/passenger and it is 28 days/passenger in a year. (İETT,2011).

7.2. Future of the Istanbul Metrobus and Recommendations

As discussed previously Metrobus has a very high ridership and provides significant time savings, thus the local authorities, i.e. İETT (Public Transit Authority) and İstanbul Metropolitan Municipality, are planning to implement new corridors troughout the city in order to extend this high-quality of bus transit service to other parts of the city and to lessen the demand on the existing BRT, which clearly cannot handle the ever-increasing level of demand in peak hours. Figure below shows the proposed BRT projects in the city.

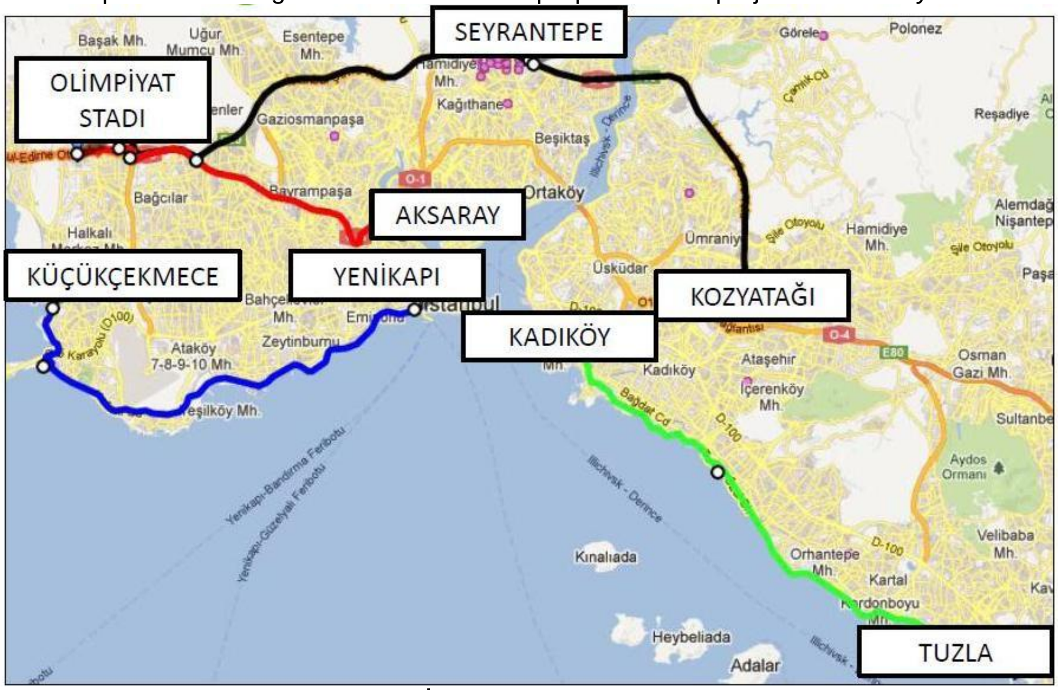

Figure 71: Proposed BRT Corridors in İstanbul

Source: İETT (2012)

A BRT corridor starting from Kozyayatağı and continuing to Seyrantepe and Olimpiyat stadı is planned as a parallel corridor to the existing Metrobus. This corridor will have more or less same features since it is going to be implemented on TEM road, which is a motorway and will cross the second Bridge FSM. Being on a motorway may cause certain problems of access between the systems' stations and land-use along the system: while this has been a problem in most sections of the existing BRT, the TEM motorway is an even further segregated highway in comparison, and therefore the accessibility of users will be a challenge. Lessons learned from the first corridor, including the need for easy access and high-capacity stairs, pedestrian bridges, etc., will be helpful for the planning of this future line.

The other lines are planned at the coastal sides of the city from Tuzla to Kadıköy and from Yenikapı to Küçükçekmece. These will be more similar to the best practice cases from Latin America, since they will be implemented on regular urban roads. Consequently, at-grade crossings and intersection treatments will be needed.

After all these projects İstanbul will have two kinds of BRT. One will be on a freeway which has different strengths and weaknesses such as high-speed on the one hand and passenger accessibility issues on the other. The other type will be the one on regular roads, which has intersections decreasing commercial speeds and creating safety problems, but also providing opportunities for better integration with land-uses alongside as well as with other road transport and biking.

It should also be noted that all these proposed lines are to a certain extent reinforcing the linear form of the city and running on an east-west direction. From this general perspective, the lines appear to be compatible with the urban development plan policies. However, it should be noted that their planning again do not appear to be integrated with the urban or regional development plans since they are not feature in these plans. Nor do these lines appear at the Urban Transportation Master Plan of the city: this plan, which was finalised in 2011, foresees neither the coastal lines nor the TEM motorway line mentioned above. The plan proposes extensions on the current line and only mentions that a feasibility study should be made for a Metrobus at the TEM motorway. It appears that the integrated planning problem continues.

It should be noted that the Transportation Master Plan of İstanbul was completed in 2010; and that the above proposed lines were not featured in this plan. The Transportation Plan only proposed extensions to the existing line and one separate additional line (Figure 91). This shows that once again the planning of the BRT lines are being carried out without a comprehensive transport planning and without any integration in to the existing and recent transportation plan of the city.

It was mentioned earlier that today the BRT in İstanbul does not operate as a "system" but that it is rather a corridor. In neither the Transportation Master Plan's "extension" scenario, nor IETT's additional lines/corridors scenario (as shown in Figure 90), a system approach is adopted, featuring feeder lines and integration across different corridors. Therefore, it seems that the BRT in İstanbul will not transform to a "system" in the short term. Because the proposed projects are corridors only they do not comprise a total BRT system as in Curitiba and Bogota. However, despite being only a corridor, the BRT in İstanbul can compete with other BRT systems in the world in terms of ridership. Nevertheless, it should be noted that being located on a single but extremely high-demand corridor is also contributing to this outcome of high ridership. In other words, after the BRT corridor is extended with feeder lines and secondary BRT corridors, where demand is not as high as in this priority corridor, the overall ridership would increase but the efficiency of the system, i.e. passengers per system km, may be expected to reduce. This is the case in all expanding systems.

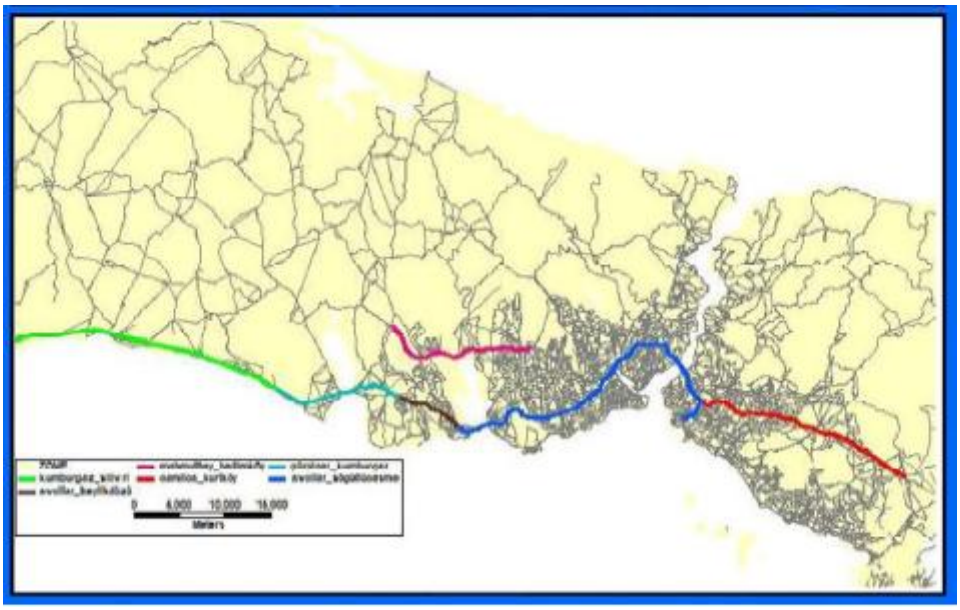

Figure 91: Metrobus extension plan as proposed in the Istanbul Transportation Master Plan

In spite of these problems of integration in planning, the Istanbul Metrobus stands as a good example for BRT operations in Turkey due to its high quality of service that resulted in high passenger statistics. As a result, more cities in Turkey may be expected to include this technology in their agenda and implement BRT as a bus operation in their public transportation network.

Lessons learned from the Istanbul Metrobus case would be useful for these cities too. Some general recommendations derived from this study are as follows;

- Planning of the BRT should be well integrated into regional and urban plans as well as into urban transport plans.
- If there are existing rail operations in a city, the BRT should be planned with maximum integration in mind so that the lines and stations are well-integrated.
- Fare integration should also be provided between the BRT and all other modes of transport.
- Station design should be improved for both safety and weather protection.
- Station capacities should be adequate for peak-period passenger loads, especially in transfer stations.
- Passing lanes should be considered (and for the Istanbul case these should incorporated into the existing system if possible) in order to allow for faster operation as well as express services.
- Integration of non-motorised modes, such as cycling and walking, should be provided. This may require bike parks or vehicles that allow bikes to be taken on board.
- Accessibility for all and universal design should be integrated to the design of stations.

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