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Assessment of Effectiveness of Metrobuses and Their Further Development

Posouzení efektivnosti metrobusů a jejich další rozvoj

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Anotace

Cílem této diplomové práce je seznámení se s poměrně novým systémem rychlé autobusové dopravy – BRT, v Evropě častěji nazývaným jako BHLS nebo Metrobus, a dále posouzení jednotlivých příkladů z hlediska kvality a efektivnosti.

V teoretické části jsou specifikovány základní parametry BRT a následně je popsán hodnotící dokument, nazývaný BRT Standard. Praktická část se zaměřuje na tři města, ve kterých je systém BRT, respektive systém metrobusů, zaveden – Buenos Aires, Rio de Janeiro a Praha. Metrobus v Buenos Aires a BRT v Rio de Janeiro jsou ohodnoceny podle BRT Standardu. Metrobusy v Praze jsou obecně zhodnoceny podle dostupných průzkumů a dále je nastíněn budoucí možný vývoj.

Klíčová slova

Rychlá autobusová doprava ● BRT ● BHLS ● metrobus ● BRT Standard

Annotation

The aim of this diploma thesis is the introduction to a relatively new system of bus rapid transit – BRT, in Europe often called BHLS or metrobus, and the assessment of individual examples in terms of quality and effectiveness.

The theoretical part specifies the basic features of BRT and then, the evaluation document – The BRT Standard – is described. The practical part focuses on three cities in which the system of BRT, or metrobus respectively, is introduced – Buenos Aires, Rio de Janeiro and Prague. Metrobus in Buenos Aires and BRT in Rio de Janeiro are evaluated by The BRT Standard. Metrobuses in Prague are generally evaluated according to the surveys available and a possible future development is outlined.

Keywords

Bus rapid transit ● BRT ● BHLS ● metrobus ● BRT Standard

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LIST OF ABBREVIATIONS

AVL	Automatic Vehicle Location
BHLS	Bus with High Level of Service
BRT	Bus Rapid Transit
BRTS	Bus Rapid Transit System
BTS	Bus Transit System
CAD	Computer-Aided Dispatch
CNG	Compressed Natural Gas
CRCR	Continuously Reinforced Concrete Pavement
DPP	Transport Company of Prague
GBRT	Guangzhou Bus Rapid Transit
GHGs	Greenhouse gases
GPS	Global Positioning System
ITDP	Institution for Transportation and Development Policy
ITS	Intelligent Transportation System
JPCP	Jointed Plain Concrete Pavement
LRT	Light Rail Transit
NOx	Nitrogen Oxides
NZ	New Zealand
PID	Prague Integrated Transport
P/Day	Passengers per Day
P/H/D	Passenger per Hour per Direction
P/Km	Passenger per Kilometer
PM	Particulate Matter
QBC	Quality Bus Corridor
RB	Regular Buses
RIT	Integrated Transport Network
ROPID	Regional Organiser of Prague Integrated Transport
SUBE	System of Electronic Ticket
TSK	Technical Management of Roads
T-Way	Transit Way
VLC	Vehicle on Light Track

1 INTRODUCTION

Urban areas all around the world, in both developing and developed countries, have recorded a significant increase in automobile traffic in the last few decades. The cities became less sustainable and more automobile-dominated and, therefore, also more congested and polluted. Consequently, the public transport started to have longer travel times, the regularity significantly declined, the speed was prolonged and, thus, the operating costs were rising.

Therefore, nowadays, more and more cities are changing their street design in order to replace the outdated practices focused on car traffic with the public rapid transit that can transport more passengers in less space and prioritize people and the quality of their lives (1).

Bus Rapid Transit – BRT in America and Bus with High Level of Service – BHLS in Europe are relatively new bus-based public transport systems. However, they are spreading very quickly and nowadays, there are more than 200 cities in all the continents that have introduced BRT systems which run on over 5 000 km of dedicated bus lanes and are being used by more than 30 million passengers worldwide (2). BRT and BHLS systems place emphasis on speed, capacity, comfort and reliability.

1.1 Motivation

The motivation for this work was the introduction of a relatively new system of bus rapid transit – BRT, in Europe often called BHLS or metrobus, and the assessment of individual examples in terms of quality and effectiveness.

The work was partly developed abroad, in Buenos Aires, Argentina and Rio de Janeiro, Brazil. Latin America is considered the founder of BRT systems because the first full BRT corridor was implemented in Curitiba, Brazil in the 1980s. It was tempting to go and see how these systems work in the continent of their origin. Three cities with high quality BRT systems were visited – Buenos Aires in Argentina, Curitiba and Rio de Janeiro in Brazil while working on this thesis. After that, the work was finished in Prague, Czech Republic, and, therefore, the last part of the thesis is focused on metrobuses in Prague and their possible future development.

The aim was not to compare the BRT, or metrobus systems respectively, of the cities in Latin America with the metrobus system in Prague because they are not comparable, not only in terms of quality but mainly due to the size of each city, its population and the size and the arrangement of the street space. The aim was to earn experiences from high quality BRT systems abroad and try to apply the gained knowledge on metrobuses in Prague.

1.2 Structure of the work

The work is divided into two sections – the theoretical and the practical part. The theoretical part consists of the introduction to the BRT system, its definition and the description of the main parameters of BRT. The main differences between BRT and BHLS – the American and the European system – are described in this section, too. The second part of the theoretical section contains the description of an evaluation document, The BRT Standard.

The practical part focuses on three cities – Buenos Aires, Rio de Janeiro and Prague. The first part of the practical section contains information about the metrobus system in Buenos Aires with the evaluation of its two metrobus corridors according to The BRT Standard. The second part contains information about the BRT system in Rio de Janeiro with the evaluation of one BRT corridor according to The BRT Standard, and the third part describes the metrobus system in Prague, summarizes it according to the surveys and information available and outlines its possible future development.

2 INTRODUCTION TO BRT SYSTEM

2.1 Bus Transit Modes

Many improvements have been introduced in the last decades in order to increase the attractiveness of transit services which can be competitive with cars and would reduce traffic on the roads. A new concept with physical and operational characteristics was developed and identified as a bus rapid transit (BRT). There is not a consensus in the definition of BRT because in many cities the name BRT is used for any bus system which partially uses dedicated lanes, skips a few stops and has a new type of vehicles. This destroys the image of the BRT mode, too. To clarify the difference between different bus modes we can define them as:

- Regular or conventional bus (RB) – buses which operate in mixed traffic, have fixed schedules, the stops are located near the curbside equipped with signs and can have passenger protection and information facilities.
- Bus transit system (BTS) – a system with significant improvements such as provision of dedicated bus lanes, stops with greater spacing, off-board fare collection, multichannel doors, low-floor buses. Those buses have a higher operating speed, efficiency and reliability.
- Bus rapid transit (BRT) – an integrated system with a separate infrastructure independent of other traffic. This system allows buses to have a higher speed, reliability as well as safety in comparison with BTS (3).

Fig. 1: System of BRT (4)

2.2 Definition of Bus Rapid Transit / Metrobus

The concept of BRT expresses a high-quality public transport system based on high-capacity buses. BRT vehicles use segregated lanes, have the right of way and have a high transport capacity. There are shorter intervals between the buses and larger distances between the stops which provides faster and more efficient service compared to traditional bus or tram systems. The system aims to combine the quality, capacity and speed of railway transport or metro with lower costs and greater flexibility of bus transportation.

The name 'BRT' (Bus Rapid Transit) is used primarily in America and China, 'BRTS' (Bus Rapid Transit System) in India and 'T-Way' (Transit Way) in Australia. In some European countries, it is called 'Metrobus' (Metropolitan Bus), in others 'BHLS' (Bus with High Level of Service) and 'QBC' (Quality Bus Corridor) in Great Britain and Ireland.

All these systems have common parameters. The aim is to provide a high standard of public transport, which will be based on buses or trolleys, create a priority network of public transport with attractive parameters for passengers and favour public transport over car transport (5).

The Institute of Transportation and Development Policy defined BRT as "a high-quality bus-based transit system that delivers fast, comfortable and cost-effective urban mobility through the provision of a segregated right-of-way infrastructure, rapid and frequent operations, and excellence in marketing and customer service" (6).

The system consists of one or more main axes which are operated by high-frequency and large-capacity buses and to which related lines are attached. The basic characteristics of the system are the direct lines without unnecessary detours and time losses. Special bus lanes separated from car traffic and located in the center of the road, convenient and safe access from platform stops ensure fast and smooth transport. Off-board fare collection and its control outside the vehicle, a system similar to the ticket system in the subway, minimize handling times. Intelligent computer controlled regulation of traffic, for example by giving priority to buses by switching traffic lights, allows high speed of public transport.

Fig. 1 shows an example of a model of a BRT system with its main elements: high capacity buses, exclusive bus ways, level boarding, off-board ticketing, passenger information, priority at intersections and traffic control (4).

Building a network of BRT is faster and the system allows more variability in the use of vehicles. Lines have a fixed schedule and buses depart with maximum few minutes' intervals during the day, sometimes also during the night.

Foreign experience shows that a simple and transparent system of backbone lines with short intervals is more attractive for passengers and also more economical, as the use of a large number of lines with different routes and long intervals that brings low efficiency of the utilization of vehicles and the need for frequent unnecessary concurrence of various types of public transport (3).

BRT has significantly lower initial and operational costs and maintenance costs in comparison with any type of rail transport. Studies show that a BRT system can cost 10 times less than a light rail transit and up to 60 times less than a subway system of the same length. With the same financial investment that is necessary for building 426 kilometres of BRT it is possible to build 40 kilometres of LRT or 14 kilometres of elevated rail and only 7 kilometres of subway. On the other hand, the transport capacity can be comparable with subway (7).

In Fig. 2, there is a comparison of how much BRT, light rail, elevated rail and subway can be built with the same financial investment.

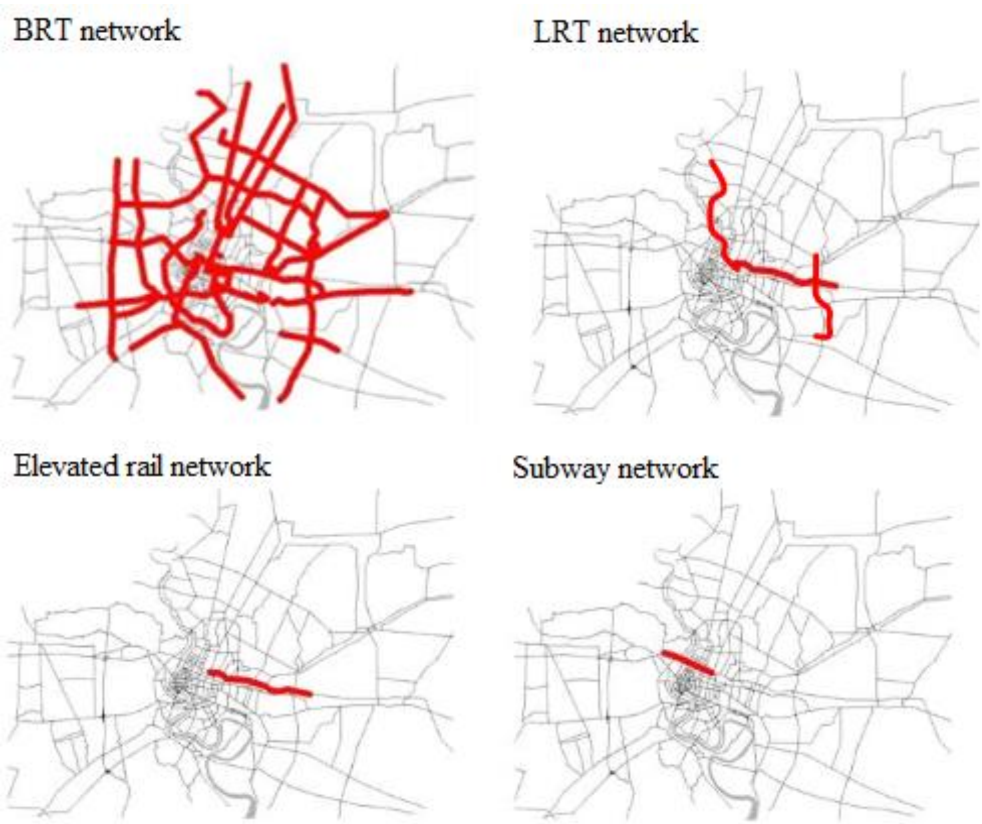


Fig. 2: Four systems of network for the same cost, Bangkok (7)

2.3 BRT features in detail

This section is focused on the characteristics which define the BRT system and make the transport faster, more reliable and comfortable. The chapter is divided into six parts: infrastructure and running ways, stations, vehicles, design and operations, routing and scheduling, ITS applications.

2.3.1 Infrastructure and running ways

Right-of-way is an essential element for BRT buses in order to be able to compete with other means of transport, such as private cars or subway in terms of speed.

The slowest systems are the ones where the buses operate in mixed traffic, on the other hand, in busways the buses have the highest speed as they are not delayed by traffic congestion. The majority of BRT buses run in the center of an arterial road so they are not blocked by parking, standing and right-turning vehicles. This position provides a faster speed for buses but it also requires special station design and regulation at intersections due to turning movements (3).

Not only the grade of separation, but also auxiliary passing lanes at stations, help significantly to increase the capacity of BRT systems. It is one of the keys of success of Bogota's TransMilenio where, thanks to the provision of dual carriageways, the peak throughput capacity rose to around 45 000 passengers per hour per direction (8). Passing lanes are needed only at stations. In the rest of the corridor, there can be just one lane which allows mixed traffic to have a higher capacity (7).

In order for BRT buses to be competitive with subway systems it is necessary to provide some degree of priority at busy signal intersections such as reducing the red phase or extending the green phase for buses in comparison to the normal sequence. Sometimes, prohibition of turns for cars in such intersections is even more important for the smooth passage of buses (8).

Fig. 3: TransMilenio in Bogota – median busways with passing lanes at stations (9)

2.3.2 Stations

BRT systems offer high-quality stations. Their design depends not only on the volume of passengers but also on their access to stations and the method of fare collection. Station should provide reliable passenger information, real-time dynamic information such as “next bus” in the station as well as static information, for example schedules, maps, diagrams, etc. Comfortable seats and waiting areas protected from rain and other unfavourable weather are typical for BRT systems. In Ottawa’s Transitway, for example, there are completely enclosed stations, air-conditioned in summer and heated in winter. Important are also high platforms, which are used mainly for fast and easy boarding of passengers, for easy access for wheelchair and disabled people and also to prevent direct pedestrian access from the street or road (3; 8).

The spacing between the stations can differ but according to The BRT Standard the ideal station spacing is around 450 meters. A longer distance is not favourable because passengers spend too much time walking to the stations, in the case of shorter distances the buses need to stop more often and the speed of the whole system is compromised. Yet, most BRT stations are 500 to 600 meters from each other in built-up urban areas. Longer spacing is used in Australia, US or China (8; 10).

In order to reduce delays caused by buying tickets from the driver it is important to design stations with off-board fare collection. This system is similar to metro – passengers pay before they get into the station. The boarding is much faster and there is better control of fare evasion. This off-board fare collection is spread mostly in BRT systems in Latin America, Asia and France. US and other European BRTs have pre-paid ticketing systems without barriers but proof-of-purchase inspection (8; 11).

Fig. 4 shows a BRT station in Bogota, in Columbia and its turnstiles used for off-board fare collection and verification.

Fig. 4: BRT station and off-board fare collection in Bogota (11)

2.3.3 Vehicles

With the development of BRT systems, the innovation and diversification of bus vehicles started. This implies that the more improved features the bus has, the higher the quality and efficient operation of the lines.

One of the main requirements of BRT systems is the high capacity of buses. Therefore, articulated buses are the most used for BRT lines. They fulfil not only the requirements for capacity, but also for passenger comfort. From the environmental perspective, it is also better to shift passengers from many smaller buses to few bigger buses and thereby reduce air pollution. In cities like Los Angeles, articulated buses are used in combination with regular buses to provide a higher service frequency. In other cities, such as Curitiba in Brazil, where they have to handle very large volumes of passengers, double-articulated buses are used (3; 11).

The size of BRT buses and their capacity:

- Standard bus – 12 m (60-80 passengers),
- Articulated bus – 18 m (120-170 passengers),
- Double-articulated bus – 24 m (240 - 270 passengers) (7).

The doors of the buses are an important element, too. Their size and number is sometimes more relevant than the size of the bus. Therefore, BRT uses double-channel doors, two on standard and three or four on articulated buses. TransMilenio buses in Bogota, for example, have 4 doors 1.1 meters in width (7).

The floor height is also very important for BRT buses. In conventional buses, the passengers spend too much time by stepping up into the bus. It can be difficult for the disabled, elderly people or people with suitcases or strollers to climb even relatively small steps and thus it can cause significant delays of buses. The solution is to build the station platform at the same level as the bus floor. The bus floor can be designed as a low-floor but we can also see BRT buses with a high-floor which are designed for high-level platforms. This system greatly simplifies the boarding and alighting, on the other hand, the buses with high-floor boarding cannot be used at bus stops with street-level platforms (3; 11).

There is also a possibility to use specially designed dual buses which were firstly introduced in Cali in 2009. Those buses have doors on the both sides, on the left side are doors located at the height of high-level platforms and on the right side are doors at curb-height. Those buses can use the exclusive lanes located in the center of the road with high level platforms and they can also exit the main exclusive lane and use normal lanes which are shared with other vehicles and use stations located on sidewalks (12).

Nowadays, BRT buses are produced by many manufacturers. Well known are, for example, Volvo, Mercedes or Scania (8).

Fig. 5: Double-articulated buses in Curitiba, Brazil (11)

2.3.4 Design and operations

The BRT network design often depends on the urban shape of the city. It also reflects the history of cities' public transport and broader policy agendas. In Latin America, in cities like Curitiba or Bogota, they use radial BRT systems. On the other hand, Chinese cities, like Guangzhou, have more flexible, multi-directional systems which minimise transfers (8).

The BHLS system used in Europe can be divided into five different types of network design, shown in Fig. 6:

1. Urban routes – operate in the core urban area (Nantes, Hamburg, Madrid)
2. Local or distributor routes – operate locally in inner or outer suburbs, include feeder routes (Almere, Kent)
3. Collector or radial routes – connect one suburban area with the center of the urban area (Madrid, Purmenrend)
4. Cross-city routes – connect different parts of suburban and urban areas through the city center (Lorient, Twente, Cambridge, Rouen)
5. Peripheral/tangential routes – connect suburban areas without entering the city center (Amsterdam) (13)

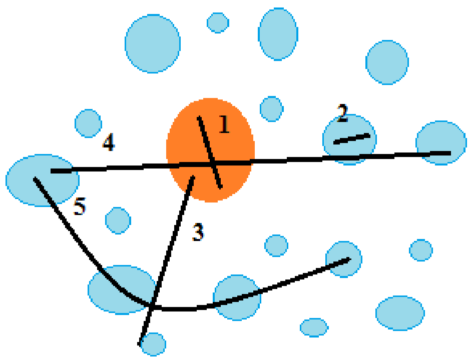


Fig. 6: BHLS – five types of network design

Network integration is essential for the success of BRT. Therefore, the BRT system should be connected with existing rail and regular buses not only physically, but also through the scheduling and tariff system (8).

BRT operations and vehicle routing can be divided into three types:

- direct-service (open system)
- trunk-feeder
- trunk-only (closed system) (8)

Direct-service, also called open system, is a service where buses run both in the BRT corridor and on normal mixed traffic roads. Buses usually enter and leave running-ways on both sides of the corridor. The open system of BRT reduces the need for changing the bus. This system is typical in many Chinese cities, like Guangzhou, Dalian, Hangzhou, etc.

In the trunk-feeder system, BRT buses run mainly on running ways but sometimes leave the busway at one end of the route and transport passengers to the neighbourhood. Passengers have to change buses if they want to continue with the feeder line. Trunk-feeder systems can be found in the cities of Latin America, such as Bogota, Curitiba, Mexico city, Lima and Quito (8; 14).

For the trunk-only system or so called closed system, it is typical that BRT buses run only along dedicated running ways. Usually, there are also regular buses or minibuses which transport passengers to the stations of BRT but they do not belong to BRT and are often operated by different private operators. Those systems can be found in Jakarta, Ahmedabad, Beijing or Istanbul.

In Europe, we can find trunk-feeder services for example in Nantes, Stockholm and Catellón. Direct-open systems can be seen in Lorient, Madrid or Gothenburg (8).

Fig. 7**Chyba! Nenalezen zdroj odkazů.** shows the differences between ‘direct-service’, ‘trunk-feeder’ and ‘trunk-only’ operations.

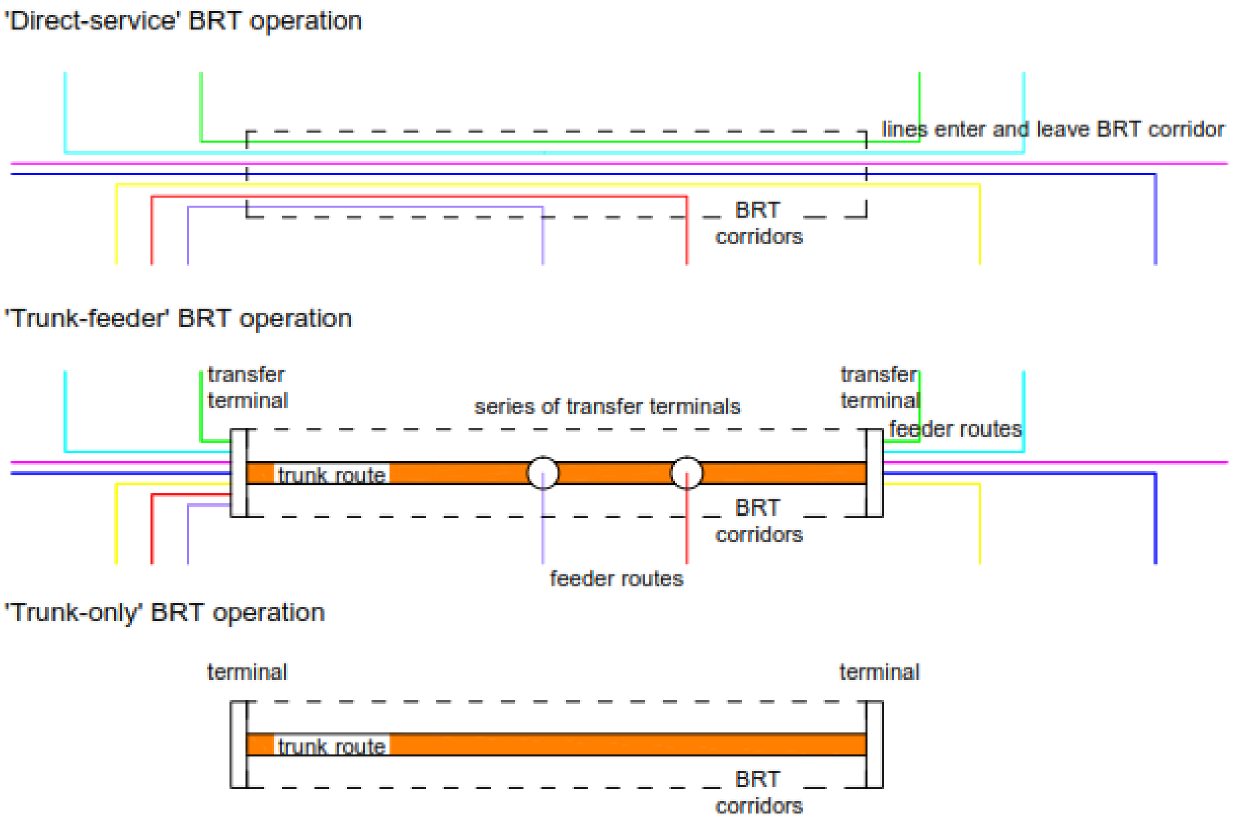


Fig. 7: Simplified scheme of BRT operations

2.3.5 Routing and scheduling

Corridors should be built in the areas and on the roads where there are many buses and where the current bus speed is low. The slower the buses are the higher the benefit from BRT is. Physical separation is necessary in areas with a low speed due to congestion (7).

Schedules of BRT can vary from city to city. During peak hours, the frequency of BRT buses is usually every 5 minutes or less. Theoretically, the buses can run every 10 seconds or even less. In Curitiba and Bogota, the norm is 90 seconds headways during peak hours. The shortest interval, 13 seconds, is at some busy intersections in Bogota's TransMilenio. Istanbul's average frequency during the peak period is 14 seconds (8).

2.3.6 ITS applications

Most BRT systems use some type of ITS elements. The most common are:

- Automatic Vehicle Location (AVL) system – GPS or other technologies are used by control centers to provide bus dispatching, coordination of bus lines, interventions in the case of delays, etc.
- Priority at signalized intersections
- Passenger information systems such as board information about the oncoming stops, transfers, etc.
- Announcements about arrival of the next bus at the station

Those and other ITS elements are used by regular buses but most commonly by BRT buses to provide a high level of service quality (3).

2.4 Evolution of BRT

The creation of improved and high-quality bus systems which are defined as BRT was preceded by a series of innovations. In cities with extensive bus services mixed with other traffic, there was a need of creating a new system with better features than regular buses but with lower costs than rail rapid transit. This led to the development of a bus system with higher capacity, reliability and quality, BRT (3).

2.4.1 History of BRT system

In 1937, the first plan of converting rail rapid transit lines to express bus routes was announced in Chicago. After two years, the first bus-only lanes were implemented (15).

Some cities later tried to carry out their own versions but the system from Curitiba, in Brazil is considered the first BRT system. In 1960, the city's population started to grow rapidly and in less than 20 years the population tripled, from 120 000 people to 361 000. Planners had to deal with such a growth and came up with a plan to make the city more like Brasilia – widen the avenues so that cars can be the primary mode of transport. A young architect, Jaime Lerner, who became the mayor in 1971, had different plans and created a pedestrian mall in the city centers instead of wide avenues full of traffic. However, the necessity of mass transit in a growing city was obvious. Planners wanted to build subway lines but Lerner saw an opportunity in the form of transport that many considered a lost case: the bus. The idea was to give buses as many advantages of urban train systems as possible (16).

The first line was opened in 1974 and the elements were implemented gradually. In the beginning, the system differed from normal buses only by dedicated bus lanes in the center of main arterial roads. Later, in 1979, an integrated transport network (RIT, ‘Rede Integrada de Transporte’) was created to manage the system and new routes were added. In 1991, Curitiba introduced off-board fare collection, platform-level boarding and close tube stations which are typical of Curitiba. With those important additions, the first bus rapid transit network was born (11).

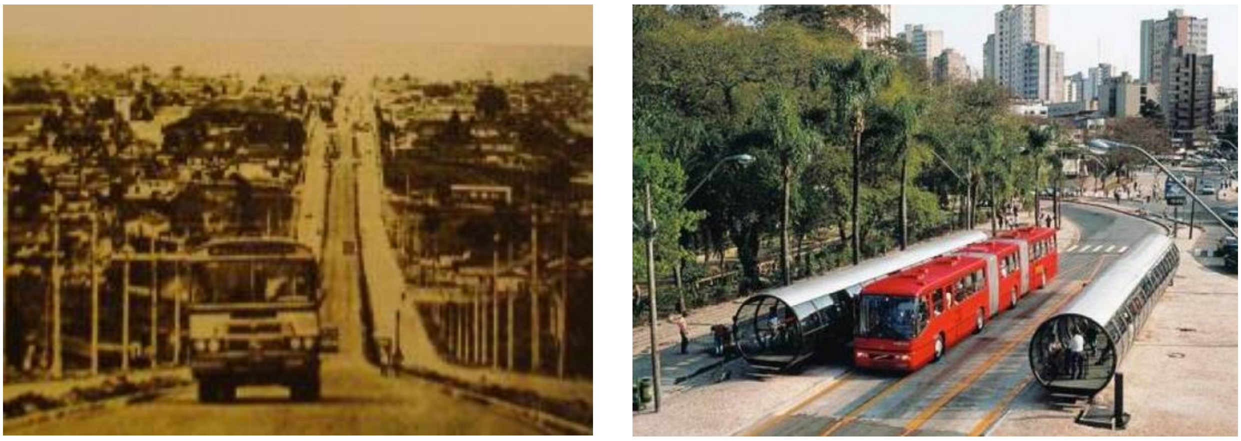


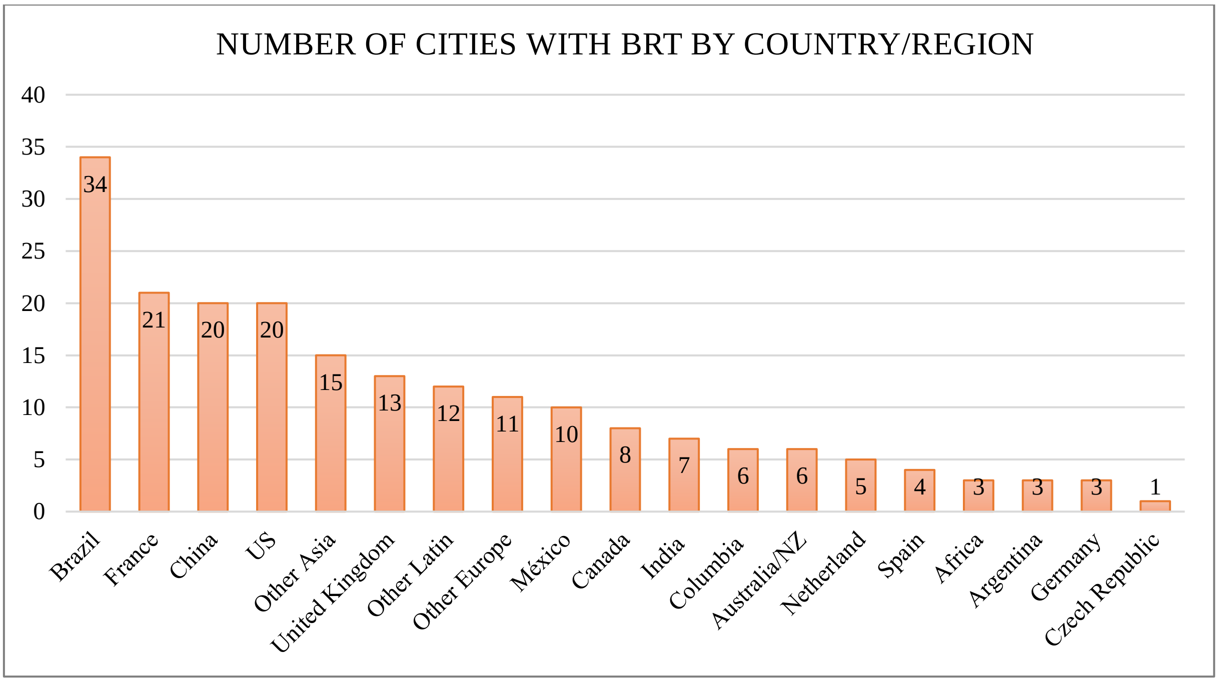
Fig. 8: First Curitiba busway in 1974 (11) on the left and BRT in Curitiba 30 years later (17) on the right

The success of BRT in Curitiba was noticed not only in Latin America, but on the whole continent. The first BRT in the United States was introduced in Pittsburgh, South Busway, in 1977 and operated 6.9 km of exclusive bus ways. Later, in 1983, the Martin Luther King Jr. East Busway was created with dedicated busway, priority at intersections and a frequency of less than two minutes in peak hours (16).

The BRT system was later spread into the whole world and in the last 15 years the vast majority of these systems have been built. The TransMilenio in Bogota, Colombia, was opened in 2000 with its length of 110 km. It is the BRT system with the highest capacity and highest speed in the world and it is recognised as the Gold Standard of BRT. The capacity of TransMilenio matches the capacity of the subway as it carries up to 40 000 passengers per hour (8).

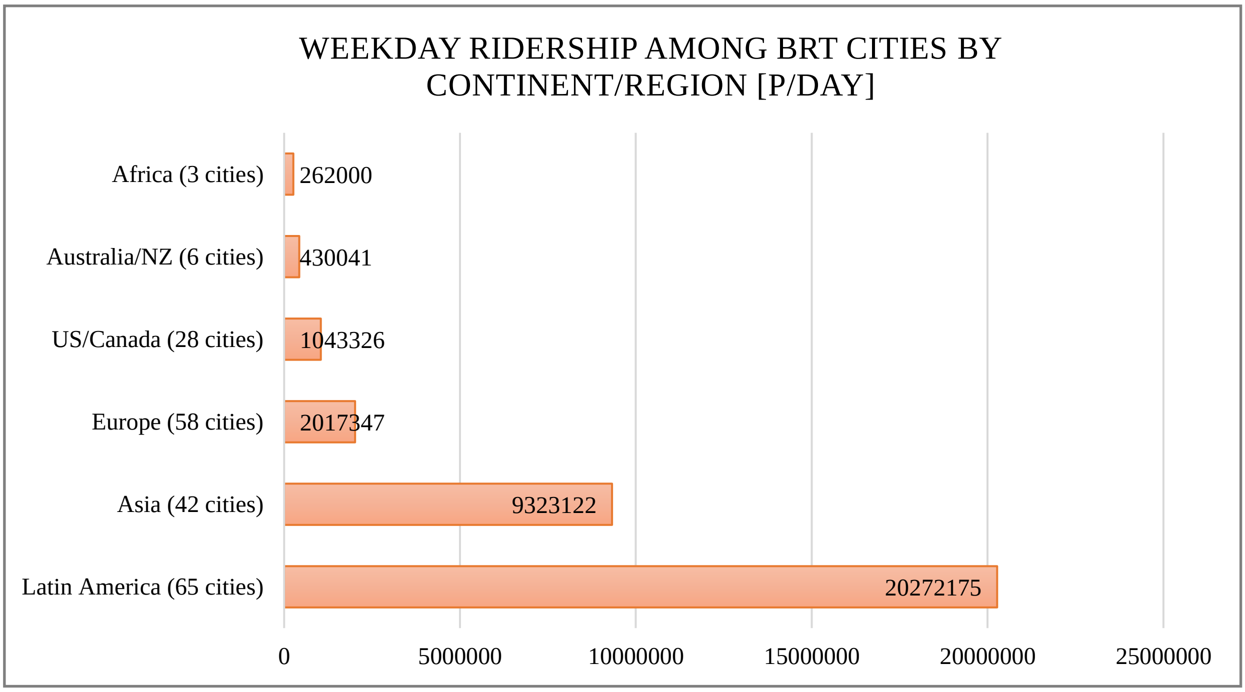
2.4.2 Presence of BRT system

Nowadays, more than 40 years after the first implementation of the BRT system, 202 cities in all continents have deployed BRT systems as of March 2016. About 33.3 million passengers worldwide use BRT daily which runs on 5 318 km of BRT lanes. About 20.3 million passengers use BRT daily in Latin America (60.7 %), 9.3 million in Asia (28.0 %), 2.0 million in Europe (6.1 %), 1.0 million in Northern America (3.1 %), 0,4 million in Oceania (1.3 %) and 0.3 million in Africa (0.8 %). Most cities with BRT systems are in Latin America, only in Brazil BRT it is implemented in 34 cities. Europe is the second with 58 cities, then Asia with 42, the United States and Canada with 28, Australia and New Zealand with 6 and Africa with 3 cities (2).



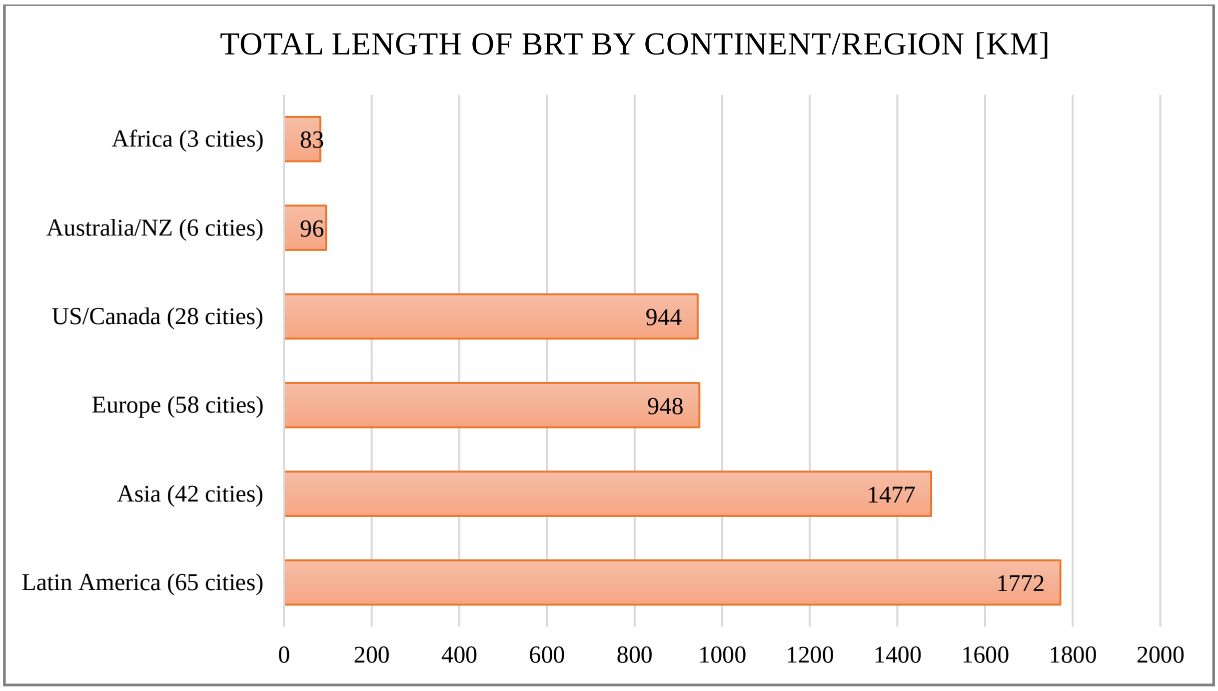
Graph 1: Number of cities with BRT system by country/region as of March 2016

Graph 1 shows the number of cities in which a BRT system was implemented. Together, there are 202 cities with BRT worldwide. Brazil is in the leading position with its 34 cities (16.8 %), then France, China and US.



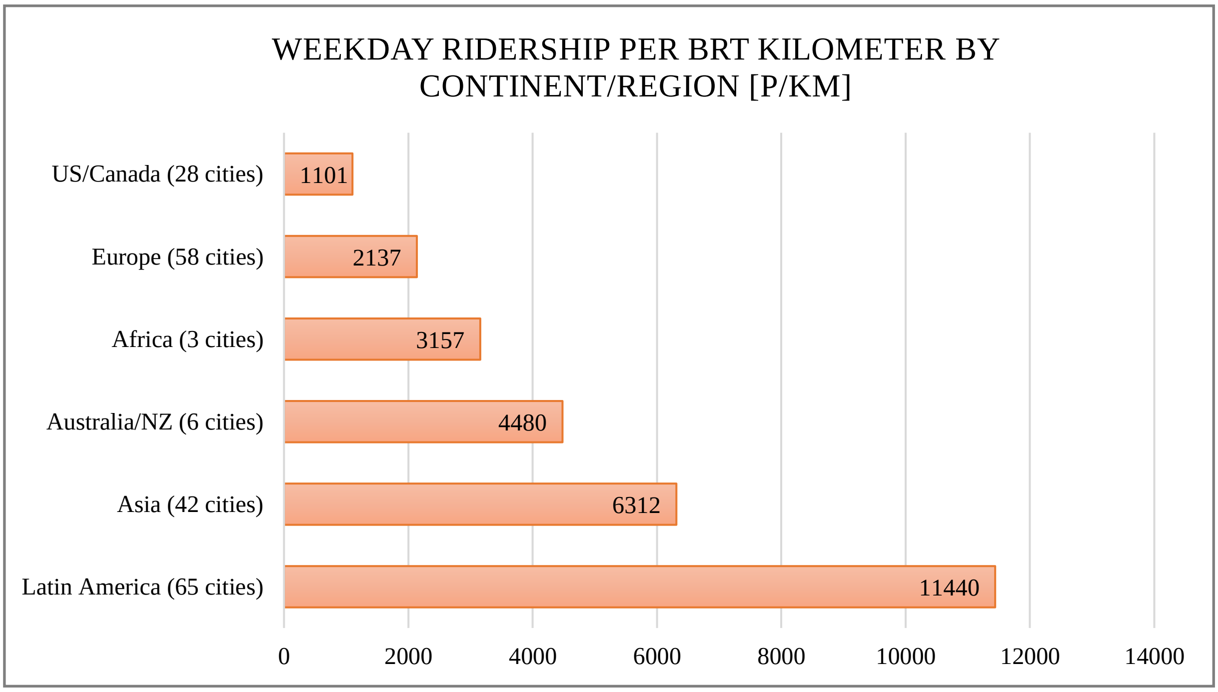
Graph 2: Weekday ridership by continent/region as of March 2016

Most passengers using BRT systems are in Latin America, as shown in Graph 2. As of March 2016, it is more than 20 thousand passengers per day, of which more than a half is in Brazil. The ridership in Latin America is 10 times greater than in Europe and almost 20 times greater than in US and Canada.



Graph 3: Total length of BRT by continent/region as of March 2016

Graph 3 describes the length of BRT by continent/region. The total length of BRT systems worldwide is 5 320 km. In the first place, in terms of the length of BRT, is again Brazil, followed by Asia with a difference of less than 300 km.



Graph 4: Weekday ridership per BRT kilometre by continent/region as of March 2016

According to Graph 4, we can say that the Latin American BRT system is the most productive as there is the highest ridership per BRT kilometre, more precisely 11 440 passengers per BRT km. This is almost twice as in Asia, 2.5 times more than in Oceania and 3.5 times more than in Africa. In Europe, the number of passengers per BRT kilometre is 5 times less than in Latin America, and in US and Canada even more than 10 times less.

2.5 BRT versus BHLS

The main difference between America, where the usage of BRT is very common and popular nowadays, and Europe with still growing BHLS systems since the 1990s is that Europe has very different historical, cultural, political, economic as well as social conditions. European cities are different from the cities in America (13).

America is also known for low usage of public transport in general. It is a more car-oriented continent with wide streets. On the other hand, in Europe – with denser cities and narrower streets – there is a tradition of public transport even in suburbs and smaller cities. Heavy transit is often already satisfied by metros, tramways and suburban trains. Buses are generally not very popular and have a negative image because they are connected with irregularity, congestion and a lack of comfort. There is a significant gap in quality and performance between modern trams and buses even after the implementation of bus lanes (19). The aim of BHLS is to refine the quality and ridership on existing bus lines while offering a wide range of service levels (20).

The term Bus Rapid Transit (BRT), defined as a "bus-based rapid transit system that can achieve high capacity, speed, and service quality at relatively low cost by combining segregated bus lanes that are typically median aligned with off-board fare collection, level boarding, bus priority at intersections, and other quality-of-service elements (such as information technology and strong branding)", is mostly used in America and China (21).

The main BRT features are:

- predominantly dedicated lanes or exclusive bus ways not shared by other modes usually placed in the center of the roadway,
- stops or stations with passenger information, good protection, off-board fare-collection and greater spacing between each other,
- high capacity buses with a large door, low floor or high platform for fast exchange of passengers at the stops,
- priority of the buses at all major intersections,
- lines with frequent and reliable service during the whole day,
- traffic control and use of intelligent transportation system technology (3).

The key BRT features are shown on an example of Macrobús in Guadalajara in Fig. 9.

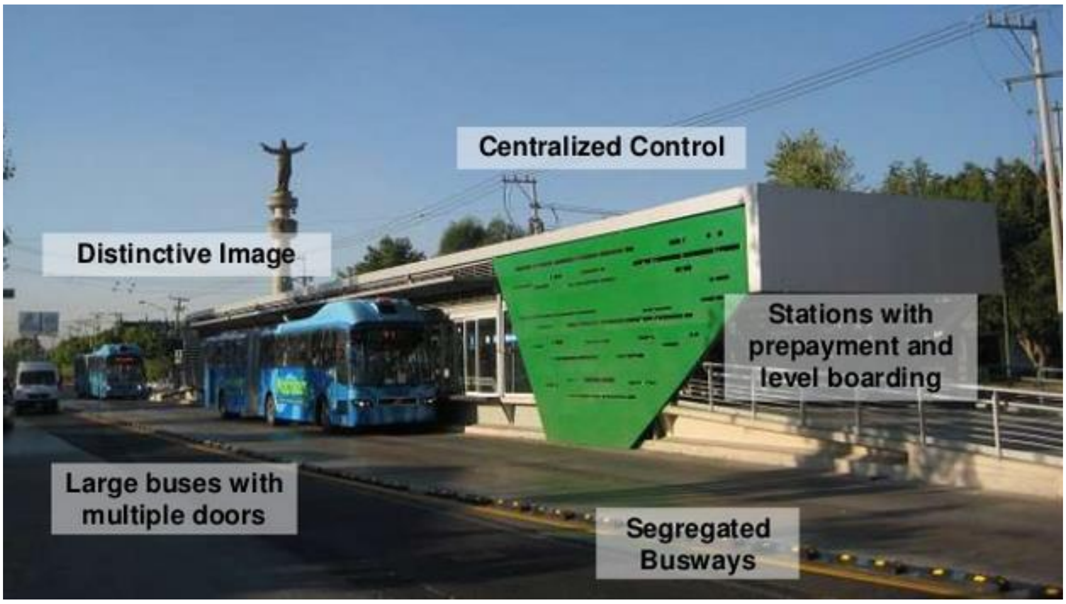


Fig. 9: Bus Rapid Transit features (22)

On the other hand, since 2005, French researchers and planners, inspired by the BRT concept, have defined another term – Bus with High Level of Service (BHLS) and focused more on the quality of bus systems. BHLS uses the advantages of tram, such as comfort, speed, regularity and image while its performance, capacity, cost and flexibility locates it somewhere between regular buses and tramways. It can be defined as follows: "The Bus with High Level of Service is a bus-based system, clearly identified, that is an element of the primary public transport network. It offers a very good performance and comfort level to the passenger, as a rail-based system, from terminus to terminus at station, into the vehicle and during the trip. The "system" approach across infrastructure, vehicles and operating tools has coherent and permanent objectives in accordance with the mobility network and city context" (13).

The main BHLS features are:

- priority bus lanes where it is necessary and possible,
- priority at signalized intersections,
- comfortable vehicles with higher quality and image,
- improved stops and terminals,
- customer-support facilities – passenger information, journey planners, fare collection systems,
- operation management tools and ITS,
- branding (to build a positive image) and marketing (20).

The most strategic fundamental indicators of BHLS can be marked as – punctuality/regularity, frequency and speed. It requires the provision of right-of-way that is dedicated and appropriately designed to achieve improvements on all these three fundamental indicators. It is better to have these dedicated lanes on the ground level to keep the infrastructure reasonably prised (13).

The key BHLS features are shown on an example of The Busway in Nantes in Fig. 10.

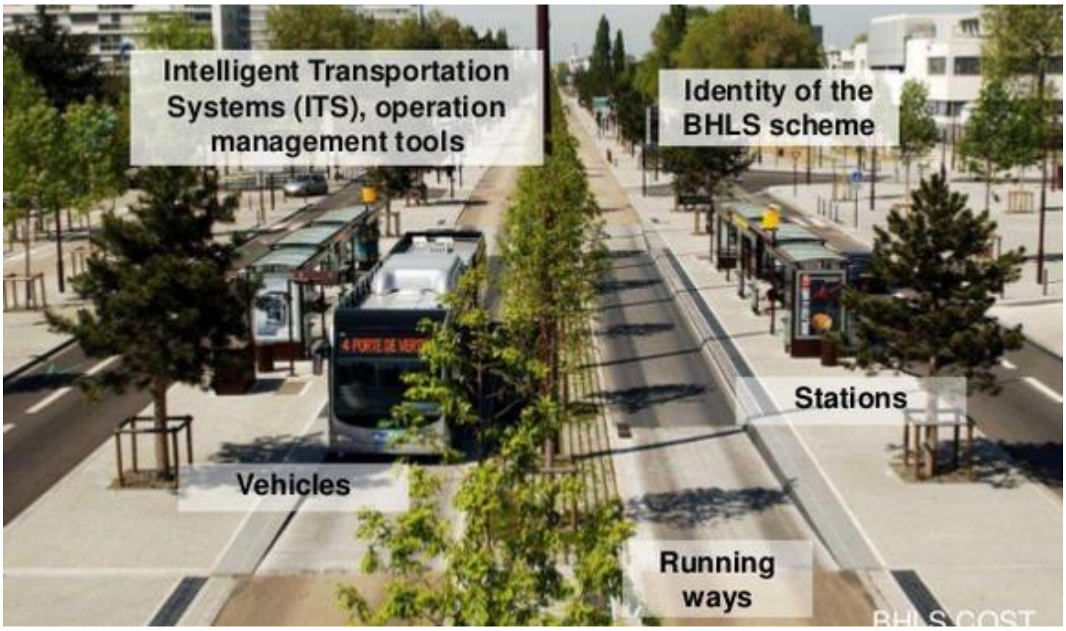


Fig. 10: Bus with High Level of Service features (22)

BHLS with different configurations can already be seen in many countries around Europe, such as France, Spain, Sweden, Ireland, Germany, UK, the Netherlands and many others and it seems that BHLS can be deployed in every European environment (13).

Both BRT and BHLS are systems that achieve higher efficiency at the expanse of the loss of flexibility. They both also use different levels of right-of-way which is usually perceived in a negative way by car drivers (23). Bus systems have to become more attractive or they will not be able to compete with car traffic. For both BRT and BHLS, the political will is also important and the involvement of politicians at an early policy level.

The main difference between BRT and BHLS is that BRT focuses more on speed and capacity in larger cities. On the contrary, BHLS focuses more on reliability and quality that can be applied also in smaller European cities and it intends to improve passenger experience from the travel (13).

European BHLS compared with American BRT has a different choice of components. Especially grade-separated running lanes do not fit in the European urban context because of the lack of available space and low demand. However, as in the case of tramways, on-street exclusive lanes are the basic components that increase speed and improve regularity and reliability and, therefore, they should be implemented in BHLS, too while allowing some permeability of an exclusive lane. Longer distances between stops – another feature that is implemented in most American BRT's projects – is blocked in Europe by the opposition of the users, especially disabled persons. Completely off-board fare collection that increases effectiveness is very rare in Europe but more than 50 % of the USA's projects have this feature. Last but not least, American BRT buses retain a high number of seats due to long commute times but in Europe the capacity needs, lower commute times and the effort to reduce the costs leads to lower numbers of seats in the vehicle (13).

It implies from the aforementioned that BRT and BHLS do not have the same meaning and representation. A wide spectrum of applications are named BRT or BHLS – from bus services with slight improvements in performance and quality running in mixed traffic to completely segregated busways with high quality features. Some experts mark BRT as "BRT-Lite" or "Full-BRT" according to their components. However, there is a big effort from ITDP – a global non-profit organization that designs, implements and evaluates high quality transport systems around the world – to define and qualify BRT systems. They published The BRT Standard, developed by world renowned experts on BRT, where, according to observed measurements, it is strictly defined and categorized which bus system is or is not defined as BRT and according to the score it is labelled.

On the other hand, there is the definition of BHLS. There are three right-of-way categories (from A to C) according to which we can determine the type of system (rapid transit, semi-rapid transit and street transit) (13). However, this is only one element from the set of components that define BHLS systems. Therefore, it would be useful to create categories that will integrate all the elements in a holistic way to gain the improvements in the total product rather than only improvements in specific elements. There is some effort to categorized BHLS similarly as BRT but so far it is described on a general level as "Full-BHLS", "BHLS-Lite" and "Improved bus line" according to their basic features (13). These categories should be based on specific objective performance measures (as in the case of BRT) to be able to evaluate BHLS systems throughout Europe and compare them. This will help, not only planners and decision makers but also a wider public, to understand the meaning of BHLS.

3 THE BRT STANDARD

There is a number of factors which can be measured in BRT systems. The Institution for Transportation and Development policy (ITDP) as first introduced a scoring system for BRT called The BRT Standard.

3.1 Introduction to The BRT Standard

The BRT Standard gives a common definition of BRT, sets a scoring system to evaluate BRT and also serves as a planning tool. It defines the essential elements of BRT and thus provides a supporting structure for designers, decision-makers and the transport community to implement high-quality BRT corridors.

The prominence and success of BRT is increasing but, even nowadays, there are many people who are not aware of the characteristics of the best BRT corridors and this lack of awareness results in preferring rail over BRT, even though BRT is a comparable, more cost-effective and equally elegant solution.

In the past, no common definition of BRT existed, which caused a confusion about the concept of BRT. For every new world-class BRT corridor, dozens of bus corridors which were incorrectly named as BRT, were opened. Because of the lack of control it was possible to claim any modest bus system improvements as a BRT corridor.

There are two committees to manage and control The BRT Standard – the Technical Committee and the Institutional Endorsers. The Technical Committee, consisting of worldwide known experts on BRT, serves as technical advice, certifies corridors and recommends revisions of The BRT Standard, if needed. The Institutional Endorsers, a group of highly respected institutions focused on public transport systems as well as on city building, establish the strategy of The BRT Standard, ensure that awarded BRT corridors uphold the goals of The BRT Standard and promote The BRT Standard as a quality control of all BRT projects, too (10).

3.2 BRT Standard ranking

The BRT Standard defines and recognizes high-quality BRT and certifies corridors as 'gold', 'silver', 'bronze' and 'basic'. The maximum number of points the BRT system can get is 100. A BRT system labelled as bronze, silver or gold means that the corridor is well designed and has achieved excellence. A corridor marked as Basic BRT fulfils the minimum criteria to qualify as BRT but yet does not reach the level of excellence as the ones mentioned above.

Gold-standard BRTs are corridors which get 85 or more points in the BRT score system. These systems include almost all elements of international best practise. They reach the highest level of efficiency and operational performance and they provide high-quality service. GBRT in Guangzhou (China) or Transmilenio in Bogota (Colombia), for example, were rated as a Gold-standard BRTs.

Silver-standard BRTs are BRT systems which reach 70 to 84 points. They include most of the elements of international best practise and achieve high operational performance as well as quality of service.

A BRT corridor getting 55 to 69 points is called Bronze-standard BRT. According to The BRT Standard, BRT ranked as bronze "solidly meets the definition of BRT and is mostly consistent with international best practice" (10). Those systems have higher operational performance and quality of service than Basic BRT.

The last and the lowest category in The BRT Standard is Basic BRT. These BRTs have core elements of BRT which the Technical Committee considered essential to the definition of BRT. This qualification is a precondition in order to receive a gold, silver, or bronze ranking (10).

3.3 Data used in The BRT Standard

The BRT Standard depends on observable design characteristics associated with high performance rather than on performance measurements. This is one of the most reliable and righteous system for identifying quality in different corridors.

The BRT Standard helps to guide planning and design decisions before the implementation of the corridor. The scoring tool can be used for already built corridors as well as for planned ones. On the other hand, performance standards apply only for existing corridors.

One of the most ideal performance appraisal metrics is a passenger's door-to-door travel time but this data is very difficult, time-consuming and expensive to get. Therefore, The BRT Standard uses data which can be observed or easily collected (10).

3.4 Definition of BRT corridor

According to The BRT Standard, a BRT corridor is defined as "a section of road or contiguous roads served by a bus route or multiple bus routes with a minimum length of 3 kilometers (1.9 miles) that has dedicated bus lanes" (10). Firstly, we have to determine whether the section of road is or is not a BRT corridor in order to avoid rewarding systems which do not fulfil the basic requirement.

The BRT Standard should be used on specific BRT corridors rather than on a BRT system as a whole because the quality and level of BRT in cities with more than one corridor can vary a lot (10).

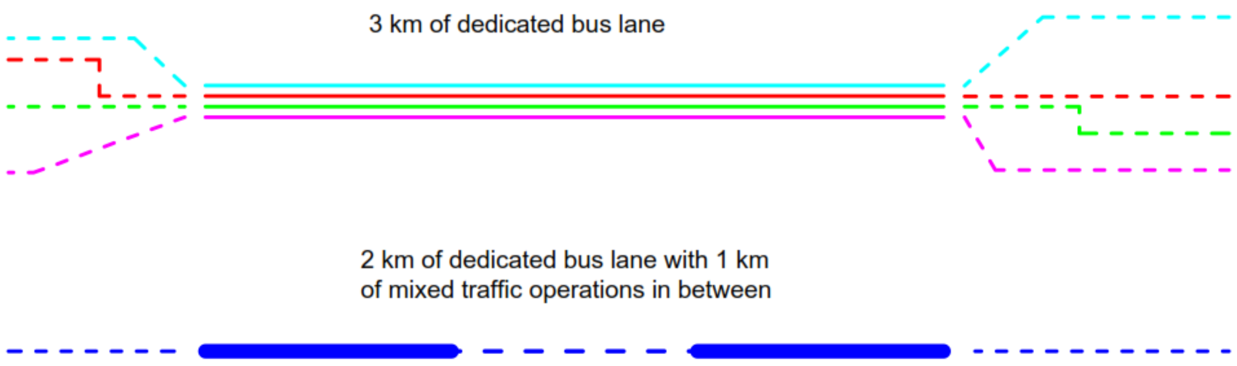


Fig. 11: Example of BRT Corridor (10)

"A corridor considered as BRT has to fulfil four requirements:

- At least 3 km length with dedicated lanes,
- Score 4 or more points in the dedicated right-of-way element,
- Score 4 or more points in the busway alignment element,
- Score 20 or more points across all five BRT Basics elements" (10).

3.5 BRT Standard scorecard

The scorecard is divided into the six categories – BRT basics, service planning, infrastructure, stations, communications, access and integration and points deductions. Each category has several subcategories which are evaluated by points. The BRT Standard scorecard contains point deductions in the case of some deficits (10).

CATEGORY	MAX SCORE
BRT Basics	
Dedicated Right-of-Way	8
Busway Alignment	8
Off-board Fare Collection	8
Intersection Treatments	7
Platform-level Boarding	7
Service planning	
Multiple Routes	4
Express, Limited and Local Services	3
Control Center	3
Located in Top Ten Corridors	2
Demand Profile	3
Hours of Operation	2
Multi-corridor Network	2
Infrastructure	
Passing Lanes at Stations	4
Minimizing Bus Emissions	3
Stations Set Back from Intersections	3
Center Stations	2
Pavement Quality	2
Stations	
Distances Between Stations	2
Safe and Comfortable Stations	3
Number of Doors on the Bus	3
Docking Bays and Sub-stops	1
Sliding Doors in BRT Stations	1
Communications	
Branding	3
Passenger Information	2
Access and Integration	
Universal Access	3
Integration with Other Public Transport	3
Pedestrian Access	3
Secure Bicycle Parking	2
Bicycle Lanes	2
Bicycle-sharing Integration	1

Point Deductions

Commercial Speed	-10
Minimum Peak Passengers per Hour per Direction Below 1 000	-5
Lack of Enforcement of Right-of-Way	-5
Significant Gap Between the Bus Floor and the Station Platform	-5
Overcrowding	-5
Poorly Maintained Busways, Buses, Stations, and Technology Systems	-10
Low Peak Frequency	-3
Low Off-peak Frequency	-2

Fig. 12: BRT Standard Scorecard (10)

3.5.1 BRT Basics

3.5.1.1 Dedicated Right-of-Way

As mentioned above dedicated right-of-way is essential for BRT buses in order to move quickly not being blocked by congestion. This has the biggest importance in areas with very high congestion where it is not possible to separate a lane from mixed traffic for a busway.

Segregation and enforcement of dedicated lanes can be done in different ways. It is advised to have some degree of permeability such as delineators, electronic bollards, colorized pavement or camera enforcement because of a possible bus break down and necessity to leave the corridor (10).

Tab. 1: BRT Standard 2014 – Dedicated Right-of Way (10)

DEDICATED RIGHT-OF-WAY	POINTS
Dedicated lanes and full enforcement or physical segregation applied to over 90 % of the busway corridor length	8
Dedicated lanes and full enforcement or physical segregation applied to over 75 % of the busway corridor length	7
Delineators only or colorized pavement only without other enforcement measures applied to over 75 % of the busway corridor length	5
Delineators only or colorized pavement only without other enforcement measures applied to over 40 % of the busway corridor length	3
Delineators only or colorized pavement only without other enforcement measures applied to over 20 % of the busway corridor length	2
Camera-enforcement with signs only	1

3.5.1.2 Busway Alignment

The best busway alignment or, in other words, the best location of the busway is in the center of the road where there is the lowest number of conflicts with other traffic such as turning movements of cars from mix-traffic lanes. The location closer to the curb is not favourable due to alleys, parking lots, delivery vehicles and taxis. The aim is to minimize the delays caused by turning conflicts and curbside access.

To calculate the score of Busway Alignment we have to multiply the length of the corridor of each configuration (in percentage) by the points allied with that configuration. Then we sum up those numbers (10).

Examples of Busway Configuration used in the scoring system are shown in Annex 10.1.

Tab. 2: BRT Standard 2014 – Busway Alignment (10)

BUSWAY ALIGNMENT	POINTS
Tire 1 Configurations	
Two-way median-aligned busway that is in the central verge of a two-way road	8
Bus-only corridor where there is a fully exclusive right-of-way and no parallel mixed traffic	8
Busways that run adjacent to an edge condition like a waterfront or park where there are few intersections to cause conflicts	8
Busways that run two-way on the side of a one-way street	6
Tire 2 Configurations	
Busways that are split into two one-way pairs but are centrally aligned in the roadway	5
Busways that are split into two one-way pairs but aligned to the curb	3
Tire 3 Configurations	
Virtual busway[1] that operates bi-directionally in a single median lane that alternates direction by block	1
Non-scoring Configurations	
Curb-aligned busway on a two-way road	0

3.5.1.3 Off-board Fare Collection

Off-board fare collection is an important element of BRT to lower the travel time. There are two types of off-board fare collection. The first and slightly preferred one is 'turnstile-controlled' where passengers verify the ticket and pass through a gate (turnstile) before entering the station. The second option is 'proof-of-payment' when passengers pay at a kiosk and get a paper ticket which is then randomly checked by an inspector inside the vehicle.

The turnstile-controlled verification has a higher score because it is advantageous compared to the proof-of-payment verification thanks to minimizing fare evasion or easier accommodating multiple routes while using the same BRT infrastructure. On the other hand, the proof-of-payment system is useful in terms of time savings in the sections of the bus routes that lie beyond the BRT corridor (10).

Tab. 3: BRT Standard 2014 – Off-Board Fare Collection (10)

OFF-BOARD FARE COLLECTION (during all operation hours)	POINTS
100 % of stations on the corridor have turnstile-controlled off-board fare collection	8
100 % of routes that touch the corridor[2] have proof-of-payment fare collection	7
80 % of stations on the corridor have turnstile-controlled off-board fare collection	7
80 % of routes that touch the corridor have proof-of-payment fare collection	6
60 % of stations on the corridor have turnstile-controlled off-board fare collection	6
60 % of routes that touch the corridor have proof-of-payment fare collection	5

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[1] The virtual busway, used in the scoring system, is a single bus lane located in the center of a road, shared by vehicles driving in both directions. At the signalized intersection, a signal phase for public transport vehicles allows BRT buses to leave a virtual lane and enter a mixed traffic lane. Buses then continue in this lane until the virtual lane is dedicated to the BRT buses' direction of travel again. Virtual busways can be used in narrow roads (10).

[2] By ‚routes that touch the corridor' are meant all the bus lines which enter the corridor at some point, without the need of using the corridor from the beginning till the end. (*Jacob Mason – Transport Research and Evaluation Manager, ITDP*)

40 % of stations on the corridor have turnstile-controlled off-board fare collection	5
40 % of routes that touch the corridor have proof-of-payment fare collection	4
20 % of stations on the corridor have turnstile-controlled off-board fare collection	3
20 % of routes that touch the corridor have proof-of-payment fare collection	2
< 20 % of stations on the corridor have turnstile-controlled off-board fare collection	0
< 20 % of routes that touch the corridor have proof-of-payment fare collection	0

3.5.1.4 Intersection Treatments

The aim of intersection treatments is to increase the bus speed at intersections. This can be done by increasing the green-signal time for the bus lane or by forbidding turns across the bus lane where possible (10).

Tab. 4: BRT Standard 2014 – Intersection Treatments (10)

INTERSECTION TREATMENTS	POINTS
All turns prohibited across the busway	7
Most turns prohibited across the busway	6
Approximately half of the turns prohibited across the busway and some signal priority	5
Some turns prohibited across the busway and signal priority at most intersections	4
Some turns prohibited across the busway and some signal priority	3
No turns prohibited across the busway but signal priority at most intersections	2
No turns prohibited across the busway but some intersections have signal priority	1
No intersection treatments	0

3.5.1.5 Platform-level Boarding

The key to reduce boarding and alighting times per passenger is to have the bus-station platform at the same level as the bus floor. The gap between the vehicle and the platform should be reduced to minimum for passengers' safety and comfort, too. There are many ways to achieve gaps of less than 5 cm such as alignment markers, Kassel curbs, guided busways at stations and boarding bridges (10).

Tab. 5: BRT Standard 2014 – Platform-level Boarding (10)

PLATFORM-LEVEL BOARDING	POINTS
100 % of buses are platform level; system-wide measures for reducing the gap in place	7
80 % of buses are platform level; system-wide measures for reducing the gap in place	6
60 % of buses are platform level; system-wide measures for reducing the gap in place	5
100 % of buses are platform level with no other measures for reducing the gap in place	4
40 % of buses are platform level; system-wide measures for reducing the gap in place	3
20 % of buses are platform level; system-wide measures for reducing the gap in place	2
50 % of buses are platform level with no other measures for reducing the gap in place	2
10 % of buses are platform level; system-wide measures for reducing the gap in place	1
No platform-level boarding	0

3.5.2 Service Planning

3.5.2.1 Multiple Routes

It is preferred to have multiple routes operating on a single corridor in order to lower door-to-door travel times by reducing transfer penalties. There are two possibilities, either the lines operate over multiple corridors (TransMilenio in Bogota, Metrobús in Mexico City) or multiple lines operate in a single corridor that leave the corridor in the end and go to different destinations (Guangzhou in China, Cali in Colombia or Johannesburg in South Africa) (10).

Tab. 6: BRT Standard 2014 – Multiple Routes (10)

MULTIPLE ROUTES	POINTS
Two or more routes exist on the corridor, servicing at least two stations	4
No multiple routes	0

3.5.2.2 Express, Limited, and Local Services

By providing limited and express service we can considerably increase operational speeds and, therefore, reduce passenger travel times. The difference between local and limited services is that the local ones stop at every station but limited services stop only at major stations with higher passenger demand and skip stations with low demand. Express services are services which take passengers from one end of the corridor to the other end almost without stopping during the journey (10).

Tab. 7: BRT Standard 2014 – Express, Limited, and Local Services (10)

EXPRESS, LIMITED AND LOCAL SERVICES	POINTS
Local services and multiple types of limited and/or express services	3
At least one local and one limited or express services option	2
No limited or express services	0

3.5.2.3 Control Center

Control centers for BRT are getting more and more important as the BRT service is improving. A full-service control center featured by GPS or similar technology monitors the location of all buses, identifies problems/incidents and responds to them quickly, controls the spacing of buses to avoid bus bunching, records the boarding and alighting of passengers for future service adjustment and uses CAD/AVL for performance monitoring and bus tracking (10).

Tab. 8: BRT Standard 2014 – Control Center (10)

CONTROL CENTER	POINTS
Full-service control center	3
Control center with most services	2
Control center with some services	1
No control center	0

3.5.2.4 Located in Top Ten Corridors

If, in terms of total bus ridership, a BRT corridor is located in top ten corridors, this will ensure that a significant ratio of passengers profit from the improvements. If all ten of the top ten corridors with the highest demand already have rapid transit, then the corridor can get points in the case of a good choice for the BRT corridor, even though it lies outside the top ten (10).

Tab. 9: BRT Standard 2014 – Located in Top Ten Corridors (10)

LOCATED IN TOP TEN CORRIDORS	POINTS
Corridor is one of top ten demand corridors	2
Corridor is outside top ten demand corridors	0

3.5.2.5 Demand Profile

The most significant number of passengers will benefit from the improvements if the highest-quality BRT systems are built in the sections of a road with the highest demand. This is very important for deciding whether to build a corridor or not.

The BRT corridor must contain a road segment with the highest demand in a two-kilometer distance from both ends of the corridor which also has the highest quality of busway alignment in that section (10).

The trunk corridor configuration which is defined in Busway Alignment, chapter 3.5.1.2, is used in demand profile scoring.

Tab. 10: BRT Standard 2014 – Demand Profile (10)

DEMAND PROFILE	POINTS
Corridor includes the highest demand segment with a Tier 1 Trunk Corridor configuration	3
Corridor includes the highest demand segment with a Tier 2 Trunk Corridor configuration	2
Corridor includes the highest demand segment with a Tier 3 Trunk Corridor configuration	1
Corridor does not include the highest demand segment	0

3.5.2.6 Hours of Operation

The BRT service should be available to passengers as many hours as possible throughout the day and week. 'Late-night service' used in the scoring system means the service is until midnight (10).

Tab. 11: BRT Standard 2014 – Hours of Operation (10)

HOURS OF OPERATIONS	POINTS
Late-night and weekend service	2
Late-night, no weekends OR weekend service, no late-nights	1
No late-night or weekend service	0

3.5.2.7 Multi-corridor Network

It is useful when the BRT system includes multiple corridors which intersect and create a network. Passengers have more travel options and the system becomes more viable. While constructing a corridor it is also important to consider the possibility of constructing future corridors and apply developments. Therefore, a long-term plan is important (10).

Tab. 12: BRT Standard 2014 – Multi-corridor Network (10)

MULTI-CORRIDOR NETWORK	POINTS
BRT corridor connects to an existing BRT corridor or to the next one planned	2
BRT corridor connects to a future planned corridor in the BRT network	1
No connected BRT network planned or built	0

3.5.3 Infrastructure

3.5.3.1 Passing Lanes at Stations

It is important to have passing lanes at stations so both express and local services can operate and so the stations can accommodate a high number of buses without creating a convoy of buses. This element saves passenger travel time and allows system's growth (10).

Tab. 13: BRT Standard 2014 – Passing Lanes at Station (10)

PASSING LANES AT STATIONS	POINTS
Physical, dedicated passing lanes	4
Buses overtake in on-coming dedicated lanes [3]	2
No passing lanes	0

3.5.3.2 Minimizing Bus Emissions

Minimizing bus emissions, like particulate matter (PM) and nitrogen oxides (NOx), is critical to the health of passengers, the people living or working close to the road and general urban population. The bus tailpipe is usually a great source of urban air pollution. The scoring system certifies BRT according to emissions standards rather than the fuel type. Emissions standards Euro VI and U.S.2010 result in very low emissions of both PM and NOx. For diesel buses, it is required to use PM traps, ultra-low-sulphur diesel fuel, and selective catalytic reduction (10).

Tab. 14: BRT Standard 2014 – Minimizing Bus Emissions (10)

EMISSIONS STANDARDS	POINTS
Euro VI or US 2010	3
Euro IV or V with PM traps or US 2007	2
Euro IV or V or Euro III CNG or using verified PM trap retrofit	1
Below Euro IV or V	0

3.5.3.3 Stations Set Back from Intersections

To avoid delays of buses, stations should be located at least 26 m, ideally 40 m from intersections. If stations are located right before an intersection, the buses waiting for the green light can reduce the functioning of the bus station. On the other hand, if stations are located right after an intersection, the buses can disrupt the intersection by queuing at the station. Those risks increase with the increasing frequency of buses (10).

Tab. 15: BRT Standard 2014 – Station Set Back from Intersections (10)

STATION LOCATION	POINTS
75 % of stations on the corridor are set back at least 40 m from intersection or meet at least one of the following exemptions: - Fully exclusive busway with no intersections - Stations located near intersections due to block length (short blocks in the downtown)	3

[3] An example of buses which overtake in on-coming dedicated lanes would be on a two-lane busway (one northbound bus lane and one southbound bus lane), where buses on the northbound lane are permitted to pass another northbound bus at a station by using the southbound lane. This configuration only works on lower-demand corridors. (*Jacob Mason – Transport Research and Evaluation Manager, ITDP*)

75 % of stations on the corridor are set back 26 m from intersection or meet above exemptions	2
25 % of stations on the corridor are set back 26 m from intersection or meet above exemptions	1
< 25 % of stations on the corridor are set back 26 m from intersection or meet above exemptions	0

3.5.3.4 Center Stations

Having a single center station used for both directions of the BRT system is more comfortable and convenient for the passengers who want to transfer and also less costly than having two centrally aligned separated stations, so called split stations (10).

Tab. 16: BRT Standard 2014 – Center Stations (10)

CENTER STATIONS	POINTS
80 % and above of stations on the corridor have center platforms serving both directions	2
50 % of stations on the corridor have center platforms serving both directions	1
< 20 % of stations on the corridor have center platforms serving both directions	0

3.5.3.5 Pavement Quality

The recommendation for the pavement life span is 30 years. The pavement should have good quality for better service and operations. The aim is also to reduce the need for the maintenance of the busway in order not to close roadways frequently or lower the bus speed because of damaged pavement (10).

Examples of pavement types which can be used on BRT busways:

1. *Asphalt*: Well designed and well constructed asphalt pavement can have a 30-plus-year life span with surface replacement every 10 to 12 years. For stations, rigid pavement is recommended to withstand higher breaking forces and prevent potential pavement damage.
2. *Jointed Plain Concrete Pavement (JPCP)*: As in the case of asphalt pavement, JPCP can have 30-plus-year life. This type of pavement has round dowel bars at transverse joints, which are tied lanes that use reinforcing steel with appropriate thickness.
3. *Continuously Reinforced Concrete Pavement (CRCR)*: Additional pavement strength can be added by continuous slab reinforcement. This is the most expensive option and is used only for certain design conditions (10).

Tab. 17: BRT Standard 2014 – Pavement Quality (10)

PAVEMENT QUALITY	POINTS
Pavement structure designed for 30-year life over the entire corridor	2
Pavement structure designed for 30-year life only at stations	1
Pavement design life less than 30 years	0

3.5.4 Stations

3.5.4.1 Distances between Stations

The optimal station spacing in build-up areas is around 450 m but the acceptable distance between the stations varies from 300 m to 800 m. A station spacing bigger than 800 m is not favourable because passengers have to walk to stations for longer time than is the time saved by a higher bus speed. A station spacing smaller than 300 m is not beneficial either because the bus speed is reduced more than the time saved with shorter walking distances to stations (10).

Tab. 18: BRT Standard 2014 – Distance Between Stations (10)

DISTANCE BETWEEN STATIONS	POINTS
Stations are spaced, on average, between 0.3 and 0.8 km apart	2

3.5.4.2 Safe and Comfortable Stations

Save and comfortable stations are one of the characteristics which differentiate BRT systems from standard bus services. Stations should be at least 3 meters wide and should be protected from bad weather such as rain, snow, wind, heat or cold. For maintaining ridership it is important to create attractive stations which are safe, secure, well-lighted and transparent (10).

Tab. 19: BRT Standard 2014 – Safe and Comfortable Stations (10)

STATIONS	POINTS
All stations on the corridor are wide, attractive, weather-protected	3
Most stations on the corridor are wide, attractive, weather-protected	2
Some stations on the corridor are wide, attractive, weather-protected	1
No stations on the corridor are wide, attractive, weather-protected	0

3.5.4.3 Number of Doors on the Bus

In order to increase the volumes of passengers getting on and off the bus, it is important to provide buses with multiple wide doors. This is essential for the speed of boarding and alighting. The recommendation for articulated buses is three or more doors on the station side, for regular buses two wide doors on the station side. In both cases, boarding through all doors is required (10).

Tab. 20: BRT Standard 2014 – Number of Doors on the Bus (10)

NUMBER OF DOORS ON THE BUS	POINTS
100 % with 3+ doors or 2 wide doors on the station side and all-door boarding	3
65 % with 3+ doors or 2 wide doors on the station side and all-door boarding	2
35 % with 3+ doors or 2 wide doors on the station side and all-door boarding	1
< 35 % with 3+ doors or 2 wide doors on the station side and all-door boarding	0

3.5.4.4 Docking Bays and Sub-stops

To increase the capacity of a station and to provide multiple services at the station, multiple docking bays and sub-stops can be designed. A station consists of sub-stops which should be separated from each other by a distance which allows buses to pass one sub-stop to dock at another.

A station has to have at least one sub-stop and two docking bays. It is preferable that one sub-stop has not more than two docking bays and in the case of necessity another sub-stop should be added. Irrespective of the level of ridership, it is important that stations have multiple docking-bays and sub-stops (10).

Tab. 21: BRT Standard 2014 – Docking Bays and Sub-stops (10)

DOCKING BAYS AND SUB-STOPS	POINTS
At least two sub-stops or docking bays at the highest-demand stations	1
Less than two sub-stops or docking bays at the highest-demand stations	0

In Fig. 13: Example of Sub-stops with multiple docking baysFig. 13, there is an example of a station with two sub-stops and multiple docking bays. Each sub-stop has two docking bays for each direction.

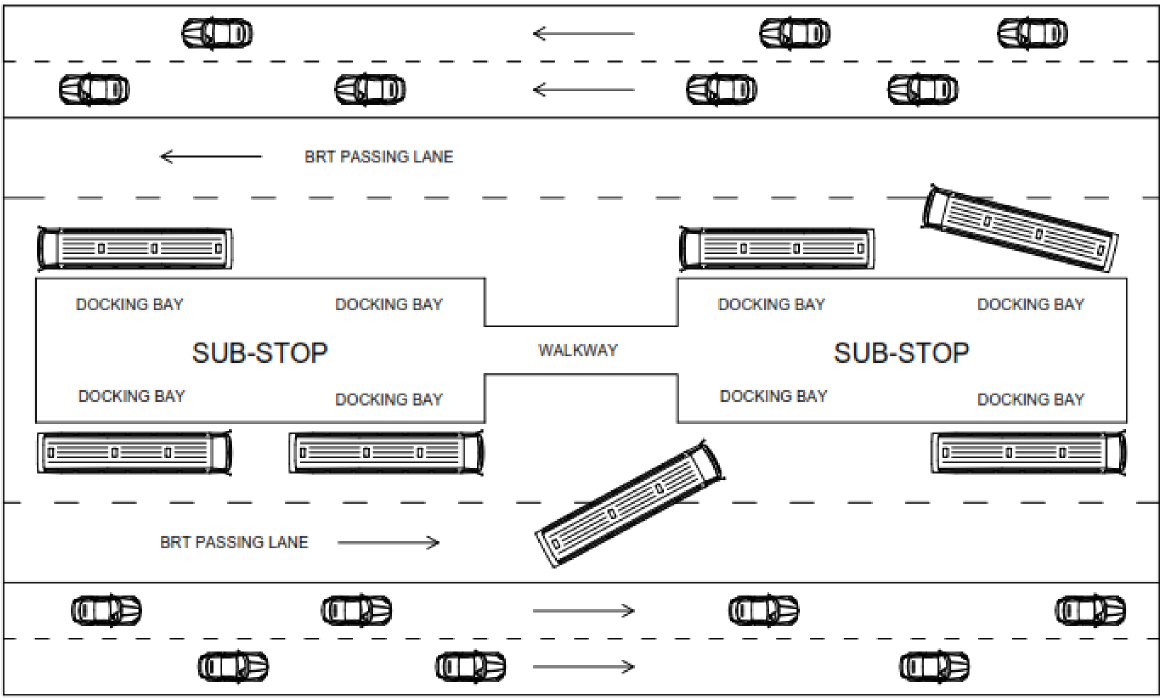


Fig. 13: Example of Sub-stops with multiple docking bays

3.5.4.5 Sliding Doors in BRT Stations

Sliding doors in stations have many functions such as reduction of the risk of accidents, protection of passengers from the weather, prevention from entering the station in unauthorized locations and in general improving the quality and environment of the station (10).

Tab. 22: BRT Standard 2014 – Sliding Doors in BRT Stations (10)

SLIDING DOORS	POINTS
All stations have sliding doors	1
Otherwise	0

3.5.5 Communications

3.5.5.1 Branding

A unique brand and identity of BRT are appealing to costumers (10).

Tab. 23: BRT Standard 2014 – Branding (10)

BRANDING	POINTS
All buses, routes, and station in the corridor follow a single unifying brand of the entire BRT system	3
All buses, routes, and station in the corridor follow a single unifying brand, but different from rest of the system	2
Some buses, routes, and station in the corridor follow a single unifying brand, regardless of the rest of the system	1

No corridor brand	0

3.5.5.2 Passenger Information

It is important to give appropriate information to passengers in order to have a positive experience from the travel. Electronic panels and digital audio messaging like "next bus" at the stations and "next stop" on the bus belong to real-time passenger information. Static passenger information includes network, route and local area maps, emergency indications, etc. Dynamic information can be shown on handheld devices (10).

Tab. 24: BRT Standard 2014 – Passenger Information (10)

PASSENGER INFORMATION (at stations and on vehicles)	POINTS
Functioning real-time and up-to-date static passenger information corridor-wide	2
Up-to-date static passenger information	1
Very poor or no passenger information	0

3.5.6 Access and Integration

3.5.6.1 Universal Access

Universal access means that the BRT corridor should be accessible to physically, visually and hearing-impaired people, children, elderly people, people with temporary disabilities, parents with strollers or other load-carrying passengers.

Full accessibility in the scoring system indicates that all stations, vehicles and fare gates are accessible on a wheelchair and each corridor has to have drop curbs at all close intersections, tactile ground surface indicators which lead to all stations and Braille readers at all stations (10).

Tab. 25: BRT Standard 2014 – Universal Access (10)

UNIVERSAL ACCESS	POINTS
Full accessibility at all stations and on all vehicles	3
Partial accessibility at all stations and on all vehicles	2
Full or partial accessibility at some stations and on some vehicles	1
Corridor not universally accessible	0

3.5.6.2 Integration with Other Public Transport

The BRT system should be integrated with other existing public networks of the city by physical design as well as fare payment. Physical transfer points minimize passenger's walking between modes, do not require to exit one system in order to change for another, are well-sized and should be build where the lines cross. Integration should be provided through fare pavement, too so that one fare card can be used for all modes (10).

Tab. 26: BRT Standard 2014 – Integration with Other Public Transport (10)

INTEGRATION WITH OTHER PUBLIC TRANSPORT	POINTS
Integration of both physical design and fare payment	3
Integration of physical design or fare payment only	2
No integration	0

3.5.6.3 Pedestrian Access

Good pedestrian access is necessary for good functioning of the BRT system and the safety of passengers. Pedestrian access is considered as good, if: pedestrians cross a maximum of two lanes of traffic before reaching the sidewalk or median; there is a provision of a signalized crosswalk in the case of crossing more than two lanes; crosswalks are well lighted, the footpath is continuous and remains level and the minimum width of sidewalks along the corridor is 3 meters (10).

Tab. 27: BRT Standard 2014 – Pedestrian Access (10)

PEDESTRIAN ACCESS	POINTS
Good, safe pedestrian access at every station and for a 500-meter catchment area surrounding the corridor	3
Good, safe pedestrian access at every station and many improvements along the corridor [4]	2
Good, safe pedestrian access at every station and modest improvements along the corridor	1
Not every station has good, safe pedestrian access and little improvement along the corridor	0

3.5.6.4 Secure Bicycle Parking

Secure (observed by an attendant or monitored by security camera) and weather-protected bicycle parking should be provided for passengers because some of them are using a bicycle as a feeder to the BRT system (10).

Tab. 28: BRT Standard 2014 – Secure Bicycle Parking (10)

BICYCLE PARKING	POINTS
Secure bicycle parking at least in terminal stations and standard bicycle racks elsewhere	2
Standard bicycle racks in most stations	1
Little or no bicycle parking	0

3.5.6.5 Bicycle Lanes

It is useful to integrate BRT corridors with bicycle-lane networks as it improves costumer access, provides more travel options and increases road safety. Ideally, main residential areas, schools, business and commercial centers should be connected to nearby BRT stations by bicycle lanes.

Some cyclists may use the busway in the case of not existing accommodation for cyclists. This can be a safety risk if the busway has not been designed for dual – bike and bus – use. Bicycle lanes, at least 2 meters wide for each direction, can be built either within the same corridor or on a parallel street (10).

Tab. 29: BRT Standard 2014 – Bicycle Lanes (10)

BICYCLE LANES	POINTS
Bicycle lanes on or parallel to the entire corridor	2
Bicycle lanes do not span the entire corridor	1
No bicycle infrastructure	0

[4] Many improvements on the corridor refer to sidewalk extensions, refuge islands, sidewalk refurbishing, and any significant improvement in the walking infrastructure along a corridor. (*Jacob Mason – Transport Research and Evaluation Manager, ITDP*)

3.5.6.6 Bicycle-sharing Integration

Provision of connections to some destinations by a shared bicycle is a good option to make short trips from the BRT corridor. It is a low-cost alternative in comparison to a bus service to the last kilometer (10).

Tab. 30: BRT Standard 2014 – Bicycle-sharing Integration (10)

BICYCLE-SHARING INTEGRATION	POINTS
Bicycle-sharing at minimum of 50 % of stations on the corridor	1
Bicycle-sharing at less than 50 % of stations on the corridor	0

3.5.7 Point Deductions

3.5.7.1 Commercial Speed

In general, the BRT features included in the scoring system result in higher speed. However, a BRT system with high demand with too many buses which are only concentrated in a single lane can cause low speed, sometimes even lower than in mixed traffic. In such a case, penalty should be imposed to avoid a risk of rewarding this system with a quality standard (10).

Tab. 31: BRT Standard 2014 – Commercial Speeds (10)

COMMERCIAL SPEED	POINTS
Minimum average commercial speed[5] is 20 km/h and above	0
Minimum average commercial speed is 16 km/h - 19 km/h	-3
Minimum average commercial speed is 13 km/h - 16 km/h	-6
Minimum average commercial speed is 13 km/h and below	-10

3.5.7.2 Minimum Peak Passenger per Hour per Direction below 1 000

If a BRT system has less than 1 000 passengers per hour per direction (p/h/d) during the peak hour it carries fewer passengers than a normal mixed-traffic lane. Such a low ridership can be caused either by other bus service operating along the BRT corridor or by poor selection of the corridor.

The majority of cities have corridors which carry at least 1 000 p/h/d in peak hours. There can also be smaller cities with corridors where transit demand is very low (even smaller than 1 000 p/h/d) but BRT features bring benefits even in these conditions. Therefore, this penalty should not overly penalize smaller cities with low transit demand but corridors that are poorly selected and planned (10).

Tab. 32: BRT Standard 2014 – Minimum Peak Passenger per Hour per Direction Below 1 000 (10)

MINIMUM PEAK PASSENGERS PER HOUR PER DIRECTION	POINTS
P/H/D below 1 000	-5

3.5.7.3 Lack of Enforcement of Right-of-Way

The BRT systems that do not enforce the right-of-way for buses properly to prevent the intrusion of other vehicles are penalized. There are some possibilities how to minimize invasions of the

[5] The ‚minimum average commercial speed' refers to the average speed on the BRT corridor and it includes the time spent at stations and intersections. (*Jacob Mason – Transport Research and Evaluation Manager, ITDP*)

corridor by non-authorized vehicles such as on-board camera, regular policing in places of frequent encroachment and high fines for violators (10).

Tab. 33: BRT Standard 2014 – Lack of Enforcement of Right-of-Way (10)

LACK OF ENFORCEMENT	POINTS
Occasional encroachment on BRT right-of-way	-1
Some encroachment on BRT right-of-way	-3
Regular encroachment on BRT right-of-way	-5

3.5.7.4 Significant Gap between the Bus Floor and the Station Platform

Although the BRT system is designed with platform-level boarding, if the bus does not dock properly it can create a gap between the platform and the bus floor. This can occur because of poor basic design or poor driver skills and training and it can cause the reduction of time-saving benefits of platform-level boarding as well as increased safety risks for passengers.

There are many possibilities how to eliminate gap problems such as the usage of painted alignment markers, special curbs at station platforms (the driver can feel the curb touching the wheel but the curb does not damage the wheel), boarding bridges or optical guidance systems (10).

Tab. 34: BRT Standard 2014 – Significant Gap between the Bus Floor and the Station Platform (10)

GAP BETWEEN THE BUS FLOOR AND THE STATION PLATFORM [6]	POINTS
No gap at most stations, slight gap at remaining stations	-1
No gap at some stations, slight gap at remaining stations	-2
Slight gap at some stations	-3
Slight gap remaining at some stations, large gap at remaining stations	-4
Large gaps everywhere or kneeling buses required to minimize gaps	-5

3.5.7.5 Overcrowding

Although many systems are generally well-designed, they can be very overcrowded and thus they become uncomfortable for passengers. Passenger standing density is a reasonable but hardly assessable indicator, therefore more subjective measurement such as 'obvious overcrowding' (doors on the buses are unable to close, overcrowded stations) can be used (10).

Tab. 35: BRT Standard 2014 – Overcrowding (10)

OVERCROWDING	POINTS
Passenger density on more than 25% of buses in peak direction during peak hour is > 5 m^2	-5
Passenger density at one or more stations during peak hour is > 3 m^2	-5
Passengers unable to board buses or enter stations	-5

3.5.7.6 Poorly Maintained Busways, Buses, Stations, and Technology Systems

It is possible that even a well-built BRT system falls into disrepair. Therefore, it is necessary that the busway, buses, stations, and technology systems are regularly maintained. A penalty can be granted for each type of poor maintenance, in total -10 points (10).

Tab. 36: BRT Standard 2014 – Poorly Maintained Busways, Buses, Stations, and Technology Systems (10)

[6] A system which does not have platform-level boarding should not be penalized.

MAINTENANCE OF BUSWAY, BUSES, STATIONS, TECHNOLOGY SYSTEMS	POINTS
Busway has significant wear, including potholes or warping, or debris, such as trash or snow	-4
Buses have graffiti, litter, seats in disrepair	-2
Stations have graffiti, litter, occupancy by vagrants or vendors, or structural damage	-2
Technology systems, including fare collection machines, are not functional	-2

3.5.7.7 Low Peak Frequency

Peak frequency is a good indicator of the quality of service. Passengers want to be sure that their waiting time will be as short as possible and that the next bus will come soon. Peak frequency measurement is done by observation of the number of buses per hour for each route that pass the high-demand segment of the corridor during the peak period. If observations cannot be done it is also possible to obtain bus frequencies through route schedules (10).

Tab. 37: BRT Standard 2014 – Low Peak Frequency (10)

LOW PEAK FREQUENCY	POINTS
100 % of all routes have at least 8 buses per hour	0
75 % of all routes have at least 8 buses per hour	-1
50 % of all routes have at least 8 buses per hour	-2
< 50 % of all routes have at least 8 buses per hour	-3

3.5.7.8 Low Off-Peak Frequency

Like peak frequency, off-peak frequency is a good indicator of the quality of service. The way of measuring the frequency is the same as in the case of peak frequency measurements, the only difference is the timing which, in this case, is in the off-peak (mid-day) period (10).

Tab. 38: BRT Standard 2014 – Low Off-Peak Frequency (10)

LOW OFF-PEAK FREQUENCY	POINTS
100 % of all routes have at least 4 buses per hour	0
60 % of all routes have at least 4 buses per hour	-1
< 60 % of all routes have at least 4 buses per hour	-2

4 METROBUS IN BUENOS AIRES

4.1 Transportation system in Buenos Aires

Buenos Aires, with its city population of 2 890 151 inhabitants (Greater Buenos Aires - Buenos Aires city and several administrative areas with their population of 15 625 084 inhabitants) is the capital and the largest city of Argentina. The city is located on the south-eastern coast of the America's continent. Buenos Aires has the second largest population in South and Latin America and belongs to one of the twenty largest urban agglomerations in the world (24). The city is divided into 48 districts (25).

The streets and roads in Buenos Aires have a square and rectangular pattern. This grid pattern creates blocks which are usually 100 to 120 metres long. Most of the roads are one-way roads.

The main avenues of the city are: Avenida 9 de Julio, Avenida Rivadavia, Avenida Corrientes, Avenida Cordoba and Avenida Santa Fe. These avenues (except Avenida 9 de Julio) run into or out of the city center and they are one-way roads with six lanes or more.

4.1.1 Local public transport

Local public transport in Buenos Aires consists of the underground, local rail, BRT, standard buses, trams and taxis.

The underground, in Buenos Aires called 'subte', is a system of six lines (A, B, C, D, E, and H) which provides access to many parts of the city. The first line – A – was opened in 1913. Nowadays, there are 87.3 km of the underground network which transport 1 180 000 passengers every day (26).

The local rail network of Buenos Aires is very large and consists of seven lines – Belgrano Norte, Belgrano Sur, Roca, San Martín, Sarmiento, Mitre and Urquiza. Circa 1 400 000 passengers use local rail with its 815 kilometers of track to get to the capital. The longest (198 km) and the most used line of Buenos Aires – transporting approximately 500 000 passengers per day – is Roca line (27).

Bus Rapid Transit in Buenos Aires has been opened recently – the first corridor, Metrobus Juan B. Justo, was opened in May 2011. At the moment, there are six corridors – Metrobus Juan B. Justo, Metrobus 9 de Julio, Metrobus Sur, Metrobus Cabildo, Metrobus Au. 25 de Mayo, Metrobus San Martín (28).

More than 150 buses, called 'colectivos', run in the city. They are operated by different, private companies which compete between each other. They do not have a fixed schedule but according to the line and the time of the day they run from four to several per hour (28).

Buenos Aires had an extensive tram network in the early 30s of the twentieth century and it was known as the "city of trams". Trams were in the city until the 1960s when they were replaced by buses. Most of the vehicles disappeared and with them also an enormous railway heritage (857 km) (29). Nowadays, a light rail line called pre-metro which is 7.4 km long is used in Buenos Aires. This line is used as a feeder service for the underground line E (30).

4.1.2 Metrobuses in Buenos Aires

Metrobus in Buenos Aires has been working since 31st of May 2011 when the first corridor was created. It runs through the entire Avenida Juan B. Justo and connects the neighbourhoods of Liniers and Palermo. "The main benefit of the Metrobus is the time that people will save when travelling." said the city mayor Mauricio Macri (31). Nowadays, 150 000 passengers benefit from a 40 % reduction in travel time, which means that each passenger saves 44 minutes per day. The corridor is 12 km long and has 21 stations. Metrobus Juan B. Justo is connected with the railroad Sarmiento and San Martín, underground lines B and D, the public bicycle station Pacific and the new Metrobus San Martín (28).

Another corridor with exclusive lanes for buses was opened in 24th July 2013 in Avenida 9 de Julio. This metrobus with a 3 km extension allows users to save up to 50 % of travel time (28). More about Metrobus 9 de Julio is written in chapter 4.2.

The third metrobus, Metrobus Sur, was opened only three weeks after the second one – on 14th August 2013. This metrobus has two shoulders and its extension, in total, of 23 km with 37 stations connects the south end of the city with Constitution transfer center. 250 000 people benefit from a 20 % reduction in travel time. The corridor Metrobus Sur is connected with the General Roca railway, PreMetro E2, underground lines C and H and more than 50 bus lines (28).

The fourth line, Metrobus Norte, also called Cabildo, was opened on 17th June 2015. Its length of 5 km connects Congreso de Tucumán with Vicente López in Greater Buenos Aires (32). The reduction of time for 200 000 daily passengers travelling with Metrobus Cabildo is 32 %. The corridor joins the underground line D and railway stations in Maipú and Mitre (28).

Metrobus Au. 25 de Mayo is the first line which operates on a single six-meter wide reversible lane. In the morning peak hours, from 6:00 to 12:00, the movement of the buses is only toward the city center, while in the evening peak hours, from 15:00 to 21:00, the lane is opened only for buses going from the city center to the province of Buenos Aires. The lane is inactive three hours between 12:00 to 15:00 (to ensure that the timing of the change in the flow is absolutely clear) and also during the night. It was opened on 5th October 2015 and now, 120 000 passengers profit from a 50 % reduction in travel time. The whole corridor has 7.5 km, runs across the highway 25 de Mayo from Constitución to Perito Moreno (33).

Recently, on 27th April 2016, the sixth metrobus line – Metrobus San Martín – was opened. It has a length of 5.8 km with 12 stations and goes from Av. Juan B. Justo to Av. General Paz. Metrobus San Martín is connected with Metrobus Juan B. Justo and Urquiza railway (28; 34). More about Metrobus San Martín is written in chapter 4.3.

There is a plan to build the seventh metrobus corridor on Avenida Paseo Colón. This corridor will have an extension of only 2.5 kilometers and 18 bus lines will run between Plaza de Mayo in the center and the neighbourhood of La Boca (35).

Nowadays, the metrobus network in Buenos Aires extends over 56.3 km of dedicated lanes used altogether 78 bus lines. The service operates 24 hours per day, 365 days per year. Its frequency is 2 - 4 minutes during the day and 10 - 15 minutes during the night (28).

Fig. 14: Metrobuses in Buenos Aires

4.2 Metrobus 9 de Julio

Metrobus 9 de Julio was the second corridor built in Buenos Aires which started to work on 27th July 2013. This corridor connects two main railroads in Buenos Aires – Retiro and Constitución. A very high number of passengers, approximately 255 000, benefit from this corridor (28).

4.2.1 Development of Metrobus 9 de Julio

Avenida 9 de Julio has two side roads – Cerrito and Carlos Pellegrini. In the past, Avenida 9 de Julio had 8 lanes for each direction used by cars and two side roads with 2 lanes used by buses and cars, but there were no exclusive lanes. These streets with their total width of 140 meters were very congested and buses were very slow.

In 2009, the government of the city of Buenos Aires commissioned a study for the implementation of preferential lanes for public transport in the center of Av. 9 de Julio (36).

In October 2012, the city government, led by Mauricio Macri, announced the construction of the Metrobus system on Avenida 9 de Julio between Retiro and Constitución. The work was inaugurated in July 2013. Later, the project of Metrobus expanded into other avenues of the city. Two tunnels which connect Av. 9 de Julio and Constitución were built two years later (37).

Nowadays, there are 5 lanes used by cars for each direction and in the center of Avenida 9 de Julio the Metrobus which has 2 lanes for buses for each direction and center stations works. Cerrito and Carlos Pellegrini roads are used for turning cars and transit transport.

Fig. 15: Avenida 9 de Julio in Buenos Aires, before and after the construction of Metrobus (38)

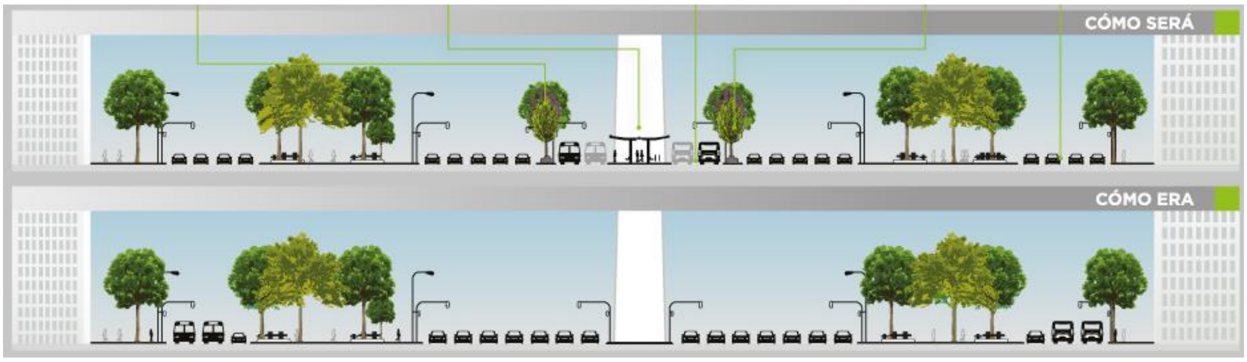


Fig. 16: Cross section of Avenida 9 de Julio – at present (upper picture) and in the past (lower picture) (28)

4.2.2 Facts and objectives

The basic facts about Metrobus 9 de Julio are as follows:

- 3.5 km extension with 17 stations
- 255 000 passengers/day
- 11 bus lines: 9, 10, 17, 45, 59, 67, 70, 91, 98, 100 and 129
- 'direct-service' operation
- connection with metro lines A, B, C, D and with railway stations Retiro and Constitución
- up to a 50 % reduction in travel time (from 40 - 60 minutes to 17 minutes → 30 min/day/one way = 60 min/day/two ways = 15 days/year)
- busways from Constitución to Retiro (from Av. San Juan to Arroyo)
- 25 % reduction in fuel use of the bus fleet
- costs of AR$ 150 million = US$ 10 million = CZK 241 million
- 5 612 tonne reduction in emissions of greenhouse gases (GHGs)
- two tunnels (28)

The main objectives of Metrobus 9 de Julio are:

- connect the central area of the city and areas of Constitución, Retiro and Obelisk with the metropolitan region
- improve mobility in the central area
- reduce travel times for passengers, more regularity
- improve the circulation on Av. 9 de Julio
- help to reduce the number of private cars in the Central Area
- reduce accidents
- improve environmental quality in the Central Area (28)

4.2.3 Assessment of effectiveness and quality of Metrobus 9 de Julio according to The BRT Standard 2014

The information for the assessment of effectiveness and quality of Metrobus 9 de Julio is based on the personal research, the design drawings provided by the Transport department, the Government of the City of Buenos Aires and the information available on the webpage of Metrobus in Buenos Aires.

4.2.3.1 BRT Basics

Metrobus 9 de Julio has dedicated right-of-way along its entire length of 3.0 kilometers (it is 3.5 km including the tunnels at the beginning of the corridor). The Tier 1 configuration – two-way median-aligned busways that are in the central verge of a two-way road – with two bus lanes for each direction is used almost on the whole corridor. Buses ride in their dedicated lanes in reverse to mixed traffic. The cross section of the corridor is shown in Fig. 17. Two bus lanes for each direction are narrowed into one bus lane for each direction in two places of the corridor with a total length of 350 meters.

No approaches to off-board fare collection are used in Metrobus 9 de Julio, neither 'turnstile-controlled' nor 'proof of pavement'. Passengers are paying directly to the driver, which causes queuing at the front door and consequently delays especially during peak hours. Turns are prohibited across the busway along the entire length of the corridor. On the other hand, there is no signal priority.

All bus-station platforms have the same level as the bus floor, except for the station platform for bus 129. This bus stops at three stations along the corridor to pick up passengers and then it goes to the urban area La Plata where passengers get off. Line 129 is not accessible for wheelchairs because it only has one (front) door with stairs. It is used for longer distances.

The horizontal gap between station platform and bus floor is minimized by special yellow curbs which are installed at each station along the entire corridor. These curbs guide the driver and assure that the bus docks close to the platform without the risk of bus damage in the case of a wrong bus-driver's maneuver. The vertical gap between all station platforms and the bus floor of all buses is almost zero centimetres (except for bus 129).

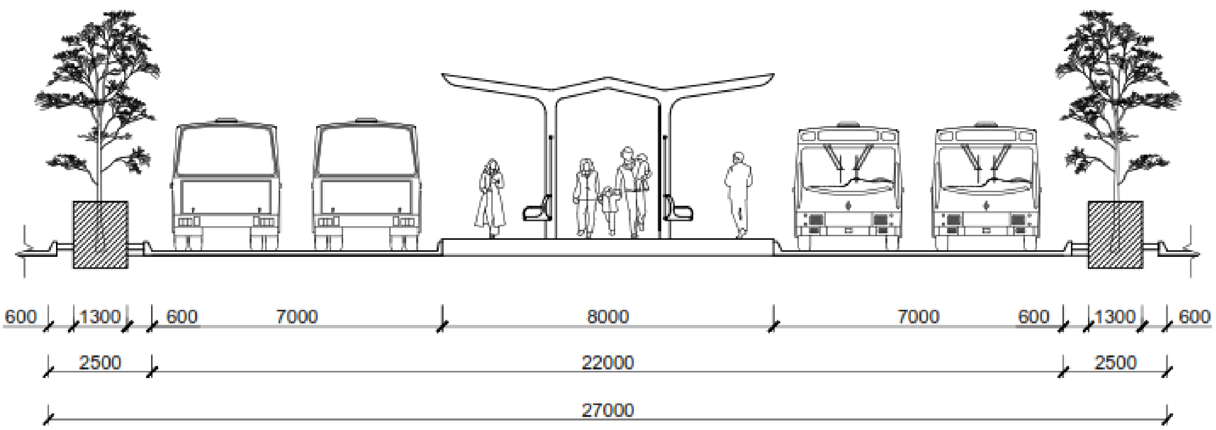


Fig. 17: Cross section of the busway with a station on Metrobus 9 de Julio

In Tab. 39, there is a scorecard with the score reached in this section.

Tab. 39: Metrobus 9 de Julio – BRT Basics – score 29 / 38

BRT Basics	Score		
	Max	Reached	
Dedicated Right-of-Way	8	8	Maximum score
Busway Alignment	8	8	Maximum score
Off-board Fare Collection	8	0	Loss of 8 points out of 8!
Intersection Treatments	7	7	Maximum score
Platform-level Boarding	7	6	Loss of 1 point out of 7
Total	**38**	**29**	Loss of 9 points out of 38

Minimum requirements for a corridor to be considered BRT:

1	At least 3 km length with dedicated lanes	yes – 3 (3.5) km length
2	Score 4 or more points in the dedicated right-of-way element	yes – 8 points
3	Score 4 or more points in the busway alignment element	yes – 8 points
4	Score 20 or more points across all five BRT Basics elements	yes – 29 points

Metrobus 9 de Julio is considered BRT and it is possible to continue with evaluation.

Fig. 18: Station Independencia – queue at the front door; Yellow curbs along the station for reducing the gap between the bus floor and the station platform

Fig. 19: Turns prohibited across the busway

4.2.3.2 Service Planning

The points obtained in the Service Planning section can be seen in Tab. 40.

Metrobus 9 de Julio has multiple routes which operate on this corridor, more precisely 11 lines: 9, 10, 17, 45, 59, 67, 70, 91, 98, 100 and 129. These lines are all local services which stop at every station (approximately 3 or 4 times along the corridor). There are no limited or express services on this corridor. There is a control center for public transport in general which is also responsible for reporting and responding to the incidents in Metrobus 9 de Julio. Although this control center is not exclusive for metrobuses, it informs and acts quickly when needed. Some buses are equipped with GPS.

Even though Metrobus 9 de Julio is not located along one of the top ten corridors, in terms of bus ridership, it gets points because this system was well chosen according to the highest demand on the road. The corridor also gets points for the highest demand segment – Av. Cordoba and Paraguay during the morning peak hour and Estados Unidos and Independencia during the afternoon peak hour (35) – that has a Tier 1 configuration (see 3.5.1.2).

This metrobus works during the whole day and night, 7 days a week. Metrobus 9 de Julio connects to an existing Metrobus Sur at station Constitución.

Tab. 40: Metrobus 9 de Julio – Service Planning – score 14 / 19

Service Planning	Score		
	Max	Reached	
Multiple Routes	4	4	Maximum score
Express, Limited, and Local Services	3	0	Loss of 3 points out of 3!
Control Center	3	1	Loss of 2 points out of 3
Located In Top Ten Corridors	2	2	Maximum score
Demand Profile	3	3	Maximum score
Hours of Operations	2	2	Maximum score
Multi-corridor Network	2	2	Maximum score
Total	**19**	**14**	Loss of 5 points out of 19

4.2.3.3 Infrastructure

Metrobus 9 de Julio has two dedicated lanes for buses for each direction physically separated from other traffic along the entire corridor. A bus can overtake easily another bus standing at the station. Therefore, the metrobus gets full points for 'passing lanes at stations'.

In Buenos Aires, there is a large private bus system. Nowadays, vehicles must have catalytic converters but in reality there are mostly old buses without catalytic converters circulating in the city. These old and not very well maintained buses produce almost 50 % of transport emissions. Vehicles in Buenos Aires are certified to Euro IV emission standards. Only one point is awarded because these vehicles give off twice as much PM than vehicles meeting U.S.2010 and Euro VI standards (10; 39).

According to The BRT Standard, stations should be located at minimum 26 meters from the intersection. This statement is not respected in Metrobus 9 de Julio due to the block length. Each sub-stop has two docking bays for each direction, the total length of the sub-stop is, on average, 73 meters. The length of the block is around 110 meters. There are 14 sub-stops with 2 docking bays for each direction and 3 sub-stops with only 1 docking bay for each direction – all together 62 stops of the bus along the corridor. Only 14 of them – 23 % – are located more than 26 meters from the intersection (*Design drawings of Metrobus 9 de Julio*). Stations located near intersections due to the block length is an exception and full points can be awarded.

Metrobus 9 de Julio has center stations which serve both directions of service along the entire corridor. Stations, as well as running ways, are made of concrete. This structure is designed for a 30-year life span, however, small damage can be seen at some places on the corridor already nowadays.

Tab. 41: Metrobus 9 de Julio – Infrastructure – score 12 / 14

Infrastructure	Score		
	Max	Reached	
Passing Lanes at Stations	4	4	Maximum score
Minimizing Bus Emissions	3	1	Loss of 2 points out of 3
Stations Set Back From Intersections	3	3	Maximum score
Center Stations	2	2	Maximum score
Pavement Quality	2	2	Maximum score
Total	**14**	**12**	Loss of 2 points out of 14

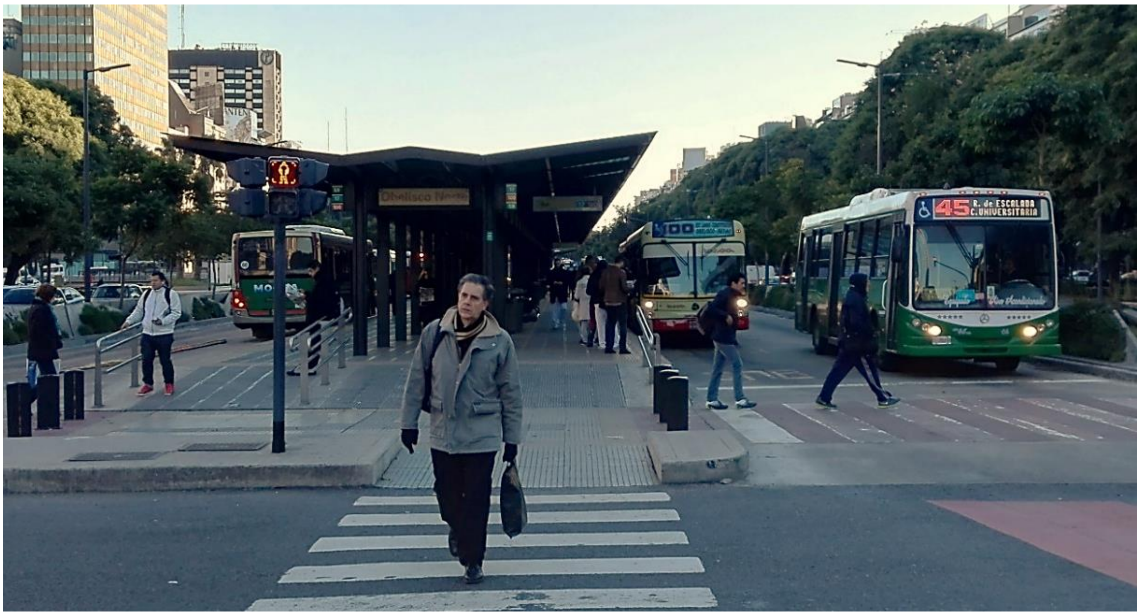


Fig. 20: Center station serving both directions; Stations located near intersections due to block length

4.2.3.4 Stations

The distances between station stops should be between 0.3 and 0.8 kilometer. The station spacing for:

- line 9 is 740 m, 480 m and 680 m,
- line *10* is 480 m, 770 m, 730 m and 320 m,
- line *17* and *59* is 480 m, 770 m, 650 m and 390 m,
- line *45* and *70* is 510 m, 780 m and 650 m,
- line *67* is 620 m, 530 m, 640 m and 450 m,
- line *91* is 740 m,
- line *100* is *350* m, 780 m, 580 m and 590 m,
- line *129* is 500 m, 650 m and 910 m (*Design Drawings of Metrobus 9 de Julio*).

The stops of all the lines are spaced between 0.3 km and 0.8 km apart, except for line 129 with one station spacing of 0.91 m.

Stations should be safe, wide, attractive and comfortable. The stations of Metrobus 9 de Julio are attractive, partially protected from the weather and well-lighted. The total width of the stations is 8 meters but the internal width is only 2.5 m – less than 3 meters. There are no security guards or cameras. Therefore, this section is rated 2 points out of 3.

Regular (non-articulated) buses and, occasionally, articulated buses operate on this corridor. They have 3 doors, the front and back doors are narrow, the middle one is wide. Front and middle doors have level platforms but the back door has 3 stairs. Boarding is possible only with the front door - no points awarded.

Metrobus 9 de Julio has 17 stations but each line stops at maximum at 5 of them. Each sub-stop has two docking bays for each direction at the highest-demand stations. There are no sliding doors in stations.

Tab. 42: Metrobus 9 de Julio – Stations – score 5 / 10

Stations	Score		
	Max	Reached	
Distances Between Stations	2	2	Maximum score
Safe and Comfortable Stations	3	2	Loss of 1 point out of 3
Number of Doors on the Bus	3	0	Loss of 3 points out of 3!
Docking Bays and Sub-stops	1	1	Maximum score
Sliding Doors In BRT Stations	1	0	Loss of 1 point out of 1
Total	**10**	**5**	Loss of 5 points out of 10

Fig. 21: Station of Metrobus 9 de Julio; Total width of the stations is 8 meters and internal width 2 meters

Fig. 22: Regular (non-articulated) bus with 3 doors; Boarding of passengers possible only by the front door

4.2.3.5 Communications

The branding and identity of BRT is very important for the success of the whole system. All stations in the corridor follow the single unifying brand of the entire BRT system. However, the buses and lines are different and they are not unified. It is due to the fact that the lines are operated by different operators which are at different levels of local government and the cooperation between them does not exist. The government of Buenos Aires applied the metrobus system and managed the road infrastructure projects but it cannot make any changes to existing services and bus lines.

In stations along the corridor, there is up-to-date static passenger information – maps of the corridor with stations, cycling routes and bicycle-sharing stations and the city map. There is also some real-time passenger information such as time and date, temperature, the number of bicycles at bicycle-sharing stations but electronic signs with real-time information about “next bus” at the station or “next stop” on the bus are missing.

Tab. 43: Metrobus 9 de Julio – Communications – score 2 / 5

Communications	Score		
	Max	Reached	
Branding	3	1	Loss of 2 points out of 3
Passenger Information	2	1	Loss of 1 point out of 2
Total	**5**	**2**	Loss of 2 points out of 5

Fig. 23: Up-to-date static passenger information and some real-time passenger information (28)

4.2.3.6 Access and Integration

Both, stations and vehicles, on the corridor have to be accessible for all special-needs customers and wheelchairs. The corridor has dropped curbs at immediate intersection, Braille readers at all stations and Tactile ground surface indicators leading to the stations.

Integration with other public transport is done only by fare payment. There are no physical transfer points along the corridor.

Not every station has good and safe pedestrian access. Some of them are not very well lighted and some are not continuous. Especially blind people are in big danger because not every pedestrian crossing has tactile ground surface indicators or they are incorrectly used. There are no or little improvements along the corridor. All crosswalks are signalized.

There is no secure bicycle parking along the corridor and almost no standard bicycle racks but motorbike racks at many stations. There are bicycle lanes parallel to the corridor which run from Belgrano station to the end of the corridor, Santa Fe. Bicycle lanes are not provided along Estados Unidos, Independencia, Chile, México and Venezuela stations but they are planned (40).

There is a possibility of bicycle-sharing on Metrobus 9 de Julio. Altogether, there are 5 stations with shared bicycles – Independencia, H. Yrigoyen, Obelisco Sur, Obelisco Norte and Marcelo T. de Alvear. Along the corridor, there are 17 stations. Bicycle-sharing is not offered at more than 50 % stations on the corridor (40).

Tab. 44: Metrobus 9 de Julio – Access and Integration – score 7 / 14

Access and Integration	Score		
	Max	Reached	
Universal Access	3	3	Maximum score
Integration with Other Public Transport	3	2	Loss of 1 point out of 3
Pedestrian Access	3	0	Loss of 3 points out of 3!
Secure Bicycle Parking	2	1	Loss of 1 point out of 2
Bicycle Lanes	2	1	Loss of 1 point out of 2
Bicycle-Sharing Integration	1	0	Loss of 1 point out of 1
Total	**14**	**7**	Loss of 7 points out of 14

Fig. 24: Damaged access to a pedestrian crossing and incorrectly used tactile ground surface indicators

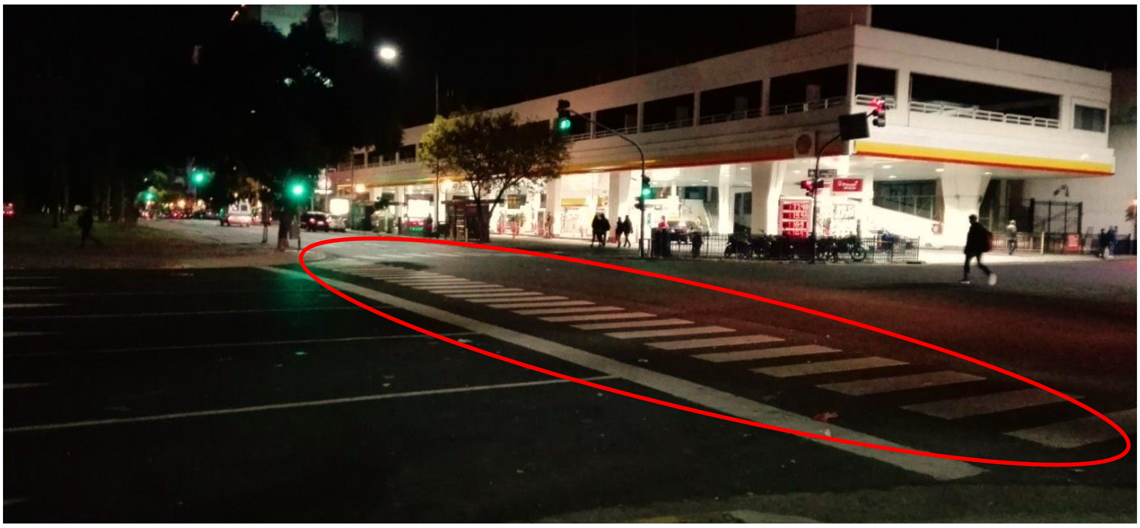


Fig. 25: Not very well-lighted long pedestrian crossing

Fig. 26: Narrow dangerous pedestrian crossing between two busways

Fig. 27: Station with bicycle-sharing - Independencia

4.2.3.7 Point Deductions

The speed of buses varies between 20 and 40 km/h. The average speed of the buses on the corridor 9 de Julio without counting stopping at stations (counting only the speed when the bus is moving) is 35 km/h and the average speed of the buses on the corridor including stopping at stations (relationship between the distance and average time on the corridor) is 20 km/h. Daily demand is 250 000 passenger per day according to the official webpage of metrobuses in Buenos Aires. The ridership on the corridor during the peak-hour is around 5 310 p/h/d – more than 1 000 p/h/d (28).

Along the entire corridor, there is physical enforcement of right-of-way that prevents encroachment from other vehicles. On-site observation showed that there are some slight gaps between the bus floor and the station platform. The corridor is penalized -2 points for slight gaps at some stations.

Passenger density during the peak hour is less than 5 passengers per m^2 on buses, less than 3 passengers per m^2 at stations and there are no visible signs of overcrowding.

On the busway, there are signs of wear at some places and, occasionally, it is possible to find potholes or warping. Buses and stations are not damaged and they are in good condition.

From the traffic survey during the peak period (8:00 - 9:00 am):

- line *9* operates approximately 27 buses per hour
- line *10* operates approximately 22 buses per hour
- line *17* operates approximately 28 buses per hour
- line *45* operates approximately 34 buses per hour
- line *59* operates approximately 22 buses per hour
- line *67* operates approximately 10 buses per hour
- line *70* operates approximately 18 buses per hour
- line *91* operates approximately 16 buses per hour
- line *100* operates approximately 32 buses per hour
- line *129* operates approximately 9 buses per hour

All lines have more than 8 buses per hour during the peak hour.

From the traffic survey during the off-peak period (12:00 - 13:00 pm):

- line *9* operates approximately 10 buses per hour
- line *10* operates approximately 18 buses per hour
- line *17* operates approximately 20 buses per hour
- line *45* operates approximately 26 buses per hour
- line *59* operates approximately 26 buses per hour
- line *67* operates approximately 10 buses per hour
- line *70* operates approximately 14 buses per hour
- line *91* operates approximately 8 buses per hour
- line *100* operates approximately 20 buses per hour
- line *129* operates approximately 8 buses per hour

All lines have more than 4 buses per hour during the off-peak hour.

Tab. 45: Metrobus 9 de Julio – Point Deductions – score -4 / -45

Point Deductions	Score		
	Max	Reached	
Commercial Speed	-10	0	No penalty
Minimum PPHPD below 1 000	-5	0	No penalty
Lack of Enforcement of Right-of Way	-5	0	No penalty

Significant Gap Between the Bus Floor and the Station Platform	-5	-2	Loss of -2 points out of -5
Overcrowding	-5	0	No penalty
Poorly Maintained Busways, Buses, Stations, and Technology Systems	-10	-2	Loss of -2 points out of -10
Low Peak Frequency	-3	0	No penalty
Low Off-Peak Frequency	-2	0	No penalty
Total	**-45**	**-4**	Loss of -4 points out of -45

Fig. 28: Bus did not dock properly and has a slight gap between the bus floor and the station platform

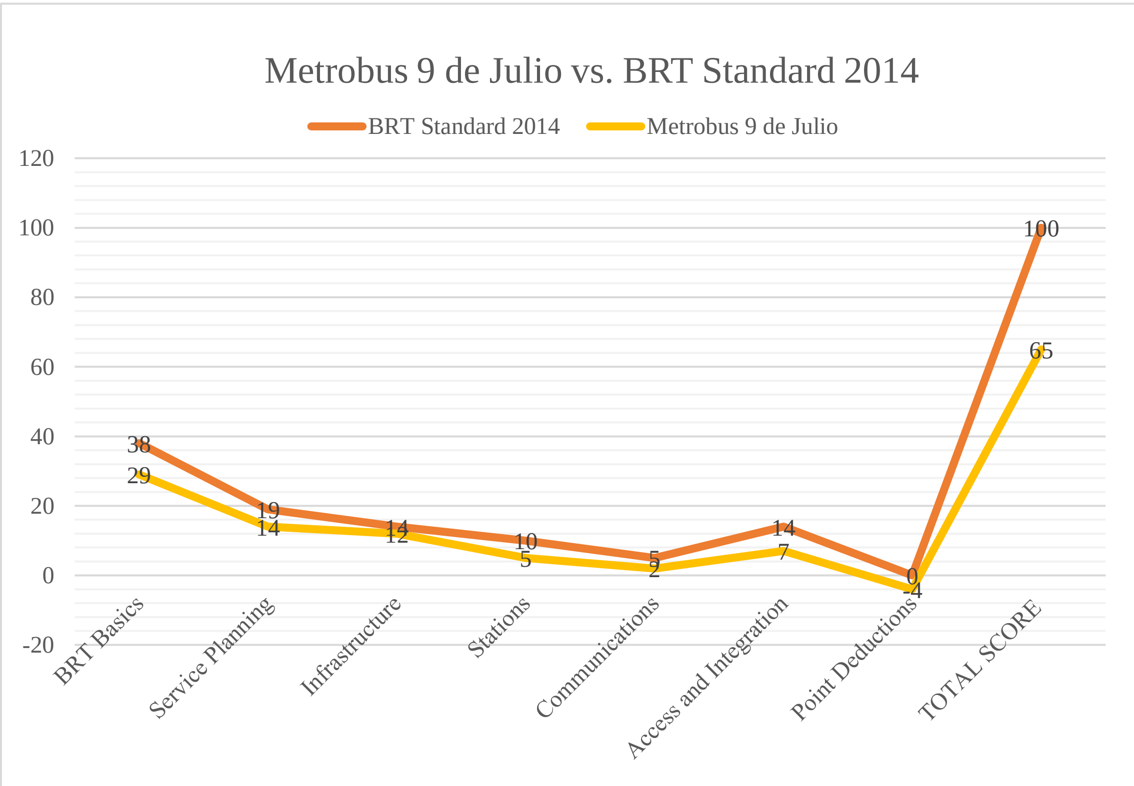
Fig. 29: Some signs of wear and potholes on the busway

4.2.3.8 BRT Standard 2014 Ranking of Metrobus 9 de Julio

Tab. 46 shows the Metrobus 9 de Julio scorecard. In total, it reached 65 points out of 100, and therefore, it is awarded a Bronze BRT according to The BRT Standard 2014. Graph 5 shows the comparison of the scoring of Metrobus 9 de Julio and The BRT Standard 2014.

Tab. 46: Metrobus 9 de Julio – Total score – Bronze BRT

METROBUS 9 DE JULIO		
CATEGORY	SCORE	
	MAX	REACHED
BRT Basics	38	29
Service Planning	19	14
Infrastructure	14	12
Stations	10	5
Communications	5	2
Access and Integration	14	7
TOTAL (without point deductions)	100	69
Point Deductions	-45	-4
TOTAL SCORE		**65**
BRT Standard Ranking	Gold, Silver, Bronze or Basic BRT	**BRONZE BRT**



Graph 5: Metrobus 9 de Julio vs. BRT Standard 2014 scoring

4.2.3.9 Conclusion and recommendation

We can say that **Metrobus 9 de Julio, as a Bronze BRT, rather meets the definition of BRT according to The BRT Standard 2014 and it is generally consistent with the international**

best practice. Still, there are some deficits which would be good to eliminate. From the results and findings it was concluded that **the highest loss of points is caused by:**

- **no provision of off-board fare collection** (loss of 8 points),
- **no provision of express and limited services** (loss of 3 points),
- **no possibility of boarding the bus through all doors** (loss of 3 points),
- **unsafe pedestrian access to some stations** (loss of 3 points).

Metrobus 9 de Julio loses 8 points by no provision of off-board fare collection. This feature belongs to the BRT Basics, which is a set of elements that are considered as essential when defining the corridor as BRT by the Technical Committee. This element, where passengers pass through turnstiles and the fare is deducted or verified, in a large scale minimize delays caused by passenger boarding. Metrobus 9 de Julio has the type of ticketing system when passengers buy the ticket directly from the driver. Therefore, **the boarding is possible only through the front door, which causes queues and delays.** There is another loss of 3 points connected with this problem – no possibility of boarding through all doors. **The corridor could gain 11 points by installing off-board fare collection and permitting boarding through all doors.**

The provision of express and limited services reduces the stopping of buses, and therefore, increases the operational speed and lowers travel time. **Metrobus 9 de Julio should introduce express services to transport passengers from one end of the corridor to the other without stopping, in order to speed up the journey for passengers who need to travel through the entire corridor.** This could be a low-cost improvement as no construction work has to be done.

Metrobus 9 de Julio also loses 3 points when evaluating Pedestrian Access. There were many deficits found along the corridor during personal investigation such as **damaged accesses to some pedestrian crossings, very narrow drop curbs, narrow and dangerous pedestrian crossings and some pedestrian crossings around the corridor were not well lighted. Tactile paving surfaces are often incorrectly used, sometimes having insufficient contrast with the adjacent pavement and not all curbs are well-defined.** These deficits and the wrong usage can cause serious problems or endanger blind and partially sighted people when they try to orientate themselves at crossings. Therefore, it is essential that mobility specialists and highway engineers work together for a successful tactile pavement implementation. There are little or no improvements in pedestrian access along the corridor, some of these accesses are in bad condition and need to be innovated.

Metrobus 9 de Julio loses 2 points due to:

- control center with insufficient services,
- buses with high amounts of tailpipe emissions which do not meet Euro VI and U.S.2010 emission standards,
- insufficient branding,
- slight vehicle-to-platform gap at some stations,
- some signs of wear and potholes on the busways.

Metrobus 9 de Julio loses 1 point due to:

- the lines that are not at the platform level – line number 126,
- small internal width, only partial protection from the weather and no security at the stations,
- no sliding doors at the stations,
- insufficient real-time passenger information such as “next bus” at the station or “next station” on the bus,
- absence of physical transfer points with other public transport that minimize walking between modes,
- no secure and weather-protected bicycle parking,

- absence of bicycle lanes at Estados Unidos, Independencia, Chile, México and Venezuela stations,
- lack of bicycle-sharing integration along the corridor.

All these elements should be improved in the future but the most important and urgent deficits which should be solved firstly are the ones described above.

4.2.4 Safety problem on Metrobus 9 de Julio

According to the previous evaluation and personal investigation, it was found that the biggest safety problem for pedestrians on Metrobus 9 de Julio is the **incorrect application of tactile ground surface indicators for blind pedestrians and sometimes also the incorrect usage of drop curbs for physically impaired pedestrians on pedestrian crossings along the 9 de Julio corridor.**

The most common deficits are:

- **dropped curb is not along the whole width of the pedestrian crossing,**
- **absence of the back edge of tactile paving (necessary at the controlled crossing),**
- **direction of rows of blister is not in the direction of the crossing,**
- **neither a dropped curb nor tactile paving are installed in a straight line perpendicular to the direction of crossing,**
- **sometimes, tactile paving does not have a distinctive pattern of blisters and does not contrast with the surrounding surface,**
- **sometimes, tactile paving is missing completely.**

Fig. 30: Damaged dropped curb with wrong usage of tactile paving, Back edge is missing

Fig. 31: Direction of the back edge and rows of blister is not in the direction of the crossing

Fig. 32: Damaged dropped curb without tactile paving

4.3 Metrobus San Martín

Metrobus San Martín was built as the sixth metrobus in Buenos Aires. The inauguration took place at 'Pappo Napolitano' station (named after a famous Argentinian singer) 27th April 2016. This Metrobus connects the north-west border with the heart of the city. Every day, more than 70 000 passengers, mostly workers and students who enter the city for different activities, benefit from this corridor (28).

4.3.1 Development of Metrobus San Martín

In the past, Avenida San Martín had 4 lanes for each direction with no preference for public transport. High number of buses were using this street and because they were mixed with other traffic their speed was low. The demand, on the other hand, was very high because Avenida San Martín connects Greater Buenos Aires with the center and it also connects important and crowded places such as El Libertador station of the Urquiza railway, the Faculty of Agriculture and Veterinary of the University of Buenos Aires, Roffo hospital and Metrobus Juan B. Justo (28).

The opening of a new tunnel on San Martín Avenue under the Urquiza railway was the first step for the inauguration of Metrobus San Martín. The tunnel, opened on 28th March 2016, is 370 meters long and 5.10 meters high and it has two lanes on each side (41).

Metrobus San Martín was inaugurated one month later – on 27th April 2016 with the presence of the city government officials. The opening ceremony took place at Norberto "Pappo" Napolitano station (near the intersection of Avenida San Martin and Juan B. Justo). There is also a further project to extend the metrobus network to the province of Buenos Aires (42).

Nowadays, there are 2 lanes used by cars for each direction and in the center of Avenida San Martín Metrobus which has one lane exclusive for buses for each direction and center split stations is working.

4.3.2 Facts and objectives

The basic facts about Metrobus San Martín are as follows:

- 5.8 km extension with 12 stations
- 70 000 passengers/day
- 11 bus lines: 24, 47, 57, 78, 87, 105, 109, 123, 135, 146 and 176
- ‘direct-service’ operation
- connection with the General Urquiza railroad at El Libertador station, Av. General Paz and Metrobus Juan B. Justo
- up to a 20 % reduction in travel time (from 48 to 38 minutes → 10 min/day/one way = 20 min/day/two ways = 5 days/year)
- busways from Av. Juan B. Justo to Av. General Paz
- costs of AR$ 70 million = US$ 5 million = CZK 113 million
- 6 neighbourhoods – Villa Crespo, Villa General Mitre, Paternal, Villa del Parque, Agronomía and Villa Devoto
- one tunnel under the General Urquiza railroad
- one bridge above the San Martín railroad (28)

The main objectives of Metrobus San Martín are similar as the objectives of Metrobus 9 de Julio:

- connect the north-west of the city with the center of Buenos Aires
- improve mobility in the city
- reduce travel time for passengers, more regularity
- improve the circulation on Av. San Martín
- help to reduce the number of private cars in the Central Area
- reduce accidents
- improve environmental quality in the Central Area (28)

4.3.3 Assessment of effectiveness and quality of Metrobus San Martín according to The BRT Standard 2014

The information for the assessment of effectiveness and quality of Metrobus San Martín is based on the personal research, design drawings provided by the Transport department, the Government of the City of Buenos Aires and the information available on the webpage of Metrobus in Buenos Aires.

4.3.3.1 BRT Basics

Metrobus San Martín has dedicated right-of-way almost on the entire length of the corridor. There are no special lanes for buses only ordinary lanes for mixed traffic in one part of the corridor – from the begging to the end of the tunnel under the General Urquiza railway – between the streets Pareja and Asuncion. Dedicated lanes start again after the tunnel and continue to Ladines station. Dedicated lanes have altogether 5.4 km, which means that they are applied on 93 % of the length of the corridor. A two-way median-aligned busway is implemented along the central verge of a two-way road. The cross-section is shown in Fig. 33. The fare collection in Metrobus San Martín is the same as in other Metrobuses in Buenos Aires – there are no off-board fare collection or proof-of-pavement fare collection and passengers pay directly to the driver while entering the bus.

Regarding intersection treatments, all turns are prohibited across the busway along the entire length of the corridor. There is also a signal priority in some parts of the corridor. The green light is first lighted for buses only and after a few seconds for the rest of the traffic in the parts where buses exit the corridor, join the lane for mixed traffic and continue their way outside the corridor.

All stations have platform-level boarding. The vertical gap is +/- 0 centimetres. There are no measures for reducing the gap between the station platform and the bus floor, and therefore, sometimes horizontal gaps occur when the bus drivers do not dock properly.

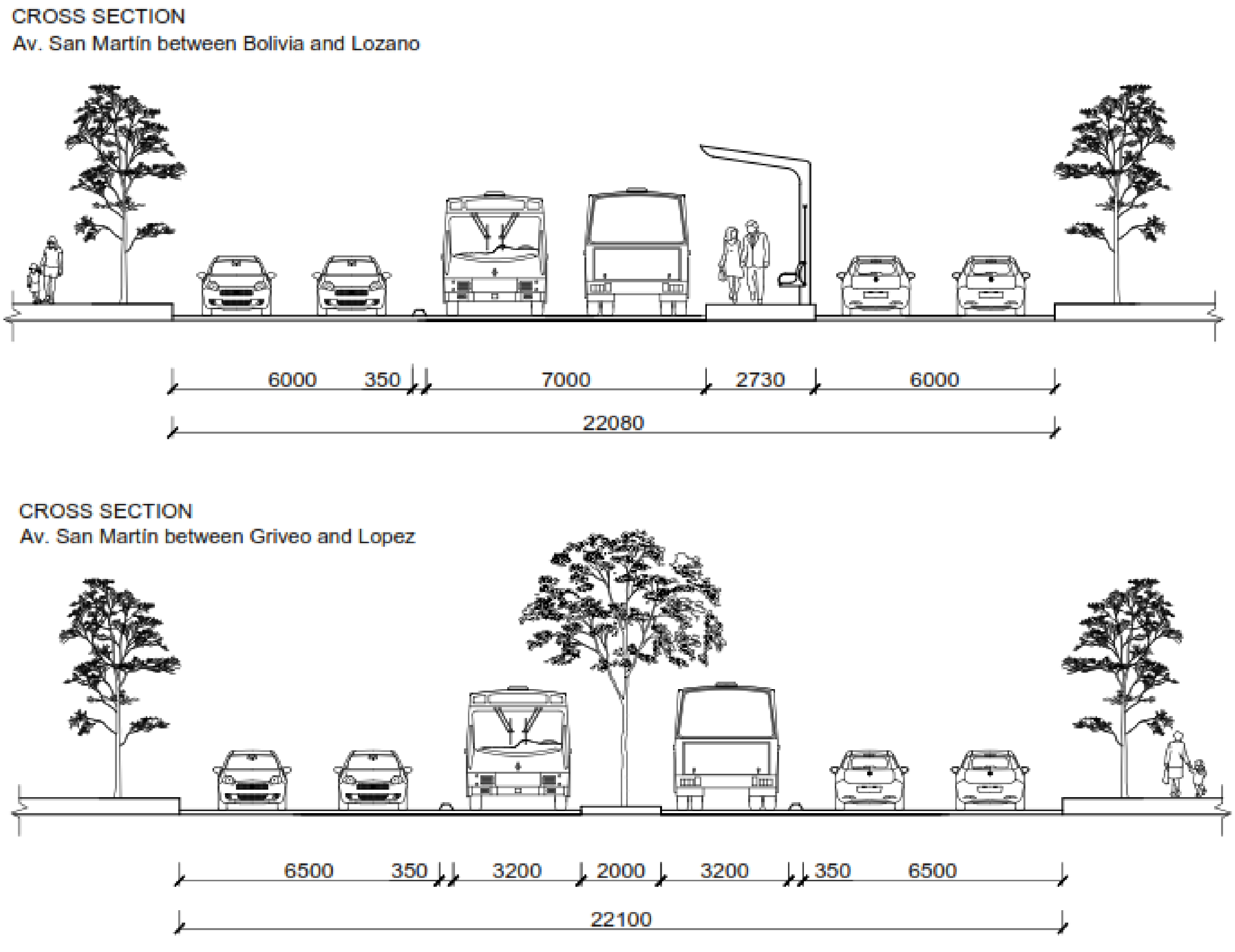


Fig. 33: Cross section of the busway with and without the station on Metrobus San Martín

The scorecard of BRT Basics of Metrobus San Martín is shown in Tab. 47:

Tab. 47: Metrobus San Martín – BRT Basics – score 27 / 38

BRT Basics	Score		
	Max	Reached	
Dedicated Right-of-Way	8	8	Maximum score
Busway Alignment	8	8	Maximum score
Off-board Fare Collection	8	0	Loss of 8 points out of 8!
Intersection Treatments	7	7	Maximum score
Platform-level Boarding	7	4	Loss of 3 point out of 7
Total	**38**	**27**	Loss of 11 points out of 38

Minimum requirements for a corridor to be considered BRT:

1	At least 3 km length with dedicated lanes	yes – 5.4 km length
2	Score 4 or more points in the dedicated right-of-way element	yes – 8 points
3	Score 4 or more points in the busway alignment element	yes – 8 points
4	Score 20 or more points across all five BRT Basics elements	yes – 27 points

Metrobus San Martín is considered BRT and it is possible to continue with the evaluation.

Fig. 34: Median-aligned busway with dedicated right-of-way

Fig. 35: Queue at the front door of the bus

4.3.3.2 Service Planning

Altogether, there are 11 lines which operate on the San Martín corridor: 24, 47, 57, 78, 87, 105, 109, 123, 135, 146 and 176. These lines are all local services stopping at each station of the corridor. However, there are some lines that do not use the corridor from the beginning to the end but only some part of it. There are no limited or express services on this corridor. As in the case of Metrobus 9 de Julio, there is no control center exclusive for metrobuses but a control center for public transport in general which is also responsible for Metrobus San Martín.

Even though Metrobus San Martín is not located along one of the top ten corridors, in terms of bus ridership, it gets points because this system was well chosen according to the highest demand on the road. The corridor also gets points for the highest demand segment – Danoto Álvarez that has a Tier 1 configuration (see 3.5.1.2).

Bus lines on Metrobus San Martín operate during the whole day and night, 7 days per week. Regarding the multi-corridor network, the San Martín corridor connects the existing corridor – Metrobus Juan B. Justo at the intersection of Av. Juan B. Justo and Av. San Martín (San Martín station of Metrobus Juan B. Justo and Pappo Napolitano station of Metrobus San Martín).

Tab. 48: Metrobus San Martín – Service Planning – score 14 / 19

Service Planning	Score		
	Max	Reached	
Multiple Routes	4	4	Maximum score
Express, Limited, and Local Services	3	0	Loss of 3 points out of 3!
Control Center	3	1	Loss of 2 points out of 3
Located In Top Ten Corridors	2	2	Maximum score
Demand Profile	3	3	Maximum score
Hours of Operations	2	2	Maximum score
Multi-corridor Network	2	2	Maximum score
Total	**19**	**14**	Loss of 5 points out of 19

4.3.3.3 Infrastructure

Metrobus San Martín does not have passing lanes at stations. Even though there are no express services on the corridor (for which passing lanes are necessary) it is useful to have passing lanes to accommodate high numbers of buses and to avoid buses backing up when they wait to enter the station. There is no possibility for a bus to pass another one on Metrobus San Martín and, sometimes, buses are backing up at the stations.

Mostly old buses which do not have catalytic converters operate on this corridor, as on Metrobus 9 de Julio. These old and not very well maintained buses are certified to Euro IV emission standards. Only one point is awarded because these vehicles give off twice as much PM as vehicles meeting U.S.2010 and Euro VI standards (10; 39).

According to The BRT Standard, stations should be located at minimum of 26 meters from intersections. This statement is not respected at each station of the corridor. Generally, stations are situated in a way that the stop line for buses is situated close to the intersection - in the distance of approximately 11 meters but the distance between the end of the bus and the far edge of the crosswalk is usually much longer – between 50 and 100 meters. If we consider both of these distances, 41 % of stations on the corridor are set 26 meters from intersections (*Design drawings of Metrobus San Martín*). The block length on the corridor San Martín is longer than on Metrobus 9 de Julio (130 – 150 meters) because Avenida San Martín runs across the ordinary system of blocks. Therefore, there is no exception due to the block length.

Metrobus San Martín does not have one central station which would serve both directions of service. Instead, it has centrally aligned stations separated for each direction – split stations. A physical connection between two directions is not provided, therefore, fewer points are awarded. The pavement along the corridor is made of asphalt and only stations are made of concrete pavement structures designed for a 30-year life span.

Tab. 49: Metrobus San Martín – Infrastructure – score 4 / 14

Infrastructure	Score		
	Max	Reached	
Passing Lanes at Stations	4	0	Loss of 4 points out of 4!
Minimizing Bus Emissions	3	1	Loss of 2 points out of 3
Stations Set Back From Intersections	3	1	Loss of 2 points out of 3
Center Stations	2	1	Loss of 1 point out of 2
Pavement Quality	2	1	Loss of 1 point out of 2
Total	**14**	**4**	Loss of 10 points out of 14

Fig. 36: Queues of buses at stations caused by the absence of passing lanes

4.3.3.4 Stations

The distances between stations should be between 0.3 and 0.8 kilometer. The station spacing along the San Martín corridor is 500 m, 610 m, 1010 m, 270 m, 320 m, 410 m, 340 m, 450 m, 790 m, 390 m and 430 m (*Design Drawings of Metrobus San Martín*). The stations are spaced, on average, between 0.3 km and 0.8 km apart, except the place where there is a 600-meter-long bridge across the San Martín railroad (in that part, the distance between stations is 1010 m).

Stations should be safe, wide, attractive and comfortable. The stations of Metrobus San Martín are attractive, partially protected from the weather and well-lighted. The total width of the stations is 3 meters but there is no internal width because the stations are not closed. There are no security guards or cameras.

Only regular (non-articulated) buses operate on this corridor. They usually have 3 doors, the front and the back doors are narrow and the middle one is wide. The front and the middle doors have level platforms but the back door has 3 stairs. Some buses only have 2 doors – the front and the middle one – both large. Boarding is possible only with the front door – no points awarded.

Metrobus San Martín has 12 stations along the corridor. There are no sub-stops used and the docking bay at each station is only one but it is long enough to accommodate up to 3 buses. Two to five different lines can stop at each station. Backing up of buses may occur at the stations of two lines but backing up of buses at the stations of five buses is very frequent. This problem is worse when three or even more buses of the same line arrive in a row. There are no sliding doors in stations.

Tab. 50: Metrobus San Martín – Stations – score 3 / 10

Stations	Score		
	Max	Reached	
Distances Between Stations	2	2	Maximum score
Safe and Comfortable Stations	3	1	Loss of 2 points out of 3
Number of Doors On the Bus	3	0	Loss of 3 points out of 3!
Docking Bays and Sub-stops	1	0	Loss of 1 point out of 1
Sliding Doors In BRT Stations	1	0	Loss of 1 point out of 1
Total	**10**	**3**	Loss of 7 points out of 10

4.3.3.5 Communications

As in the case of Metrobus 9 de Julio, all stations in the corridor follow the single unifying brand of the entire BRT system. However, the buses and lines are different – from different operators – and they are not unified.

In stations along the corridor, there is up-to-date static passenger information – maps of the corridor with the stations and names of the stops of each bus. There is no real-time passenger information along the entire corridor.

Tab. 51: Metrobus San Martín – Communications – score 2 / 5

Communications	Score		
	Max	Reached	
Branding	3	1	Loss of 2 points out of 3
Passenger Information	2	1	Loss of 1 point out of 2
Total	**5**	**2**	Loss of 2 points out of 5

In Fig. 37, there is a station of Metrobus San Martín. On the right side of the picture (right end of the station) there is static passenger information – a map of the corridor. In the picture, it is also visible that there is no provision of bicycle lanes along or parallel to the corridor and cyclists have to use lanes for cars.

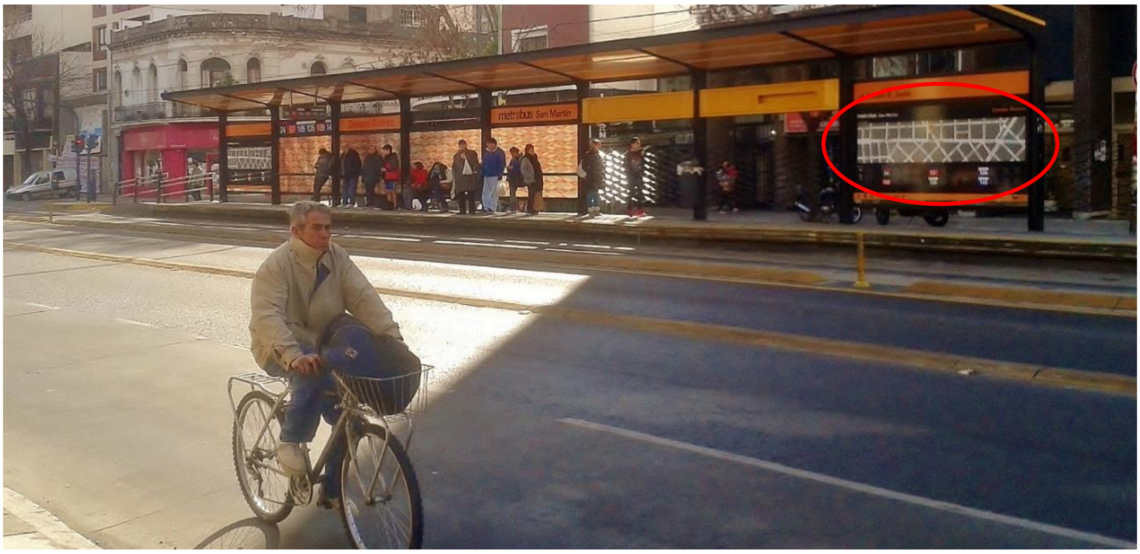


Fig. 37: Station of Metrobus San Martín

4.3.3.6 Access and Integration

Metrobus should be accessible to all special-needs customers. The corridor is accessible for wheelchairs, there are dropped curbs at all immediate intersections and tactile ground surface indicators which lead to all stations. There are also Braille readers on columns near the entrance to the bus at each station. Integration with other public transport is done only by fare payment. There are no physical transfer points along the corridor.

All crosswalks are signalized and well-lighted. The footpath remains levelled and is continuous. The same problem with tactile ground surface indicators appears again, as in the case of Metrobus 9 de Julio. Tactile indicators are not used or are used incorrectly on most of the crossings. There are modest pedestrian improvements along the corridor.

There is no bicycle integration on Metrobus San Martín. Secure bicycle parking is not provided, not even at the terminal stations and there are bicycle racks only near few stations on the corridor. There are no bicycle lanes on the corridor or parallel to it. Sometimes, it is possible to see the encroachment of bicycles on the corridor trying to overtake the line of cars. There is also no provision of bicycle-sharing integration along the corridor.

Tab. 52: Metrobus San Martín – Access and Integration – score 6 / 14

Access and Integration	Score		
	Max	Reached	
Universal Access	3	3	Maximum score
Integration with Other Public Transport	3	2	Loss of 1 point out of 3
Pedestrian Access	3	1	Loss of 2 points out of 3
Secure Bicycle Parking	2	0	Loss of 2 points out of 2
Bicycle Lanes	2	0	Loss of 2 points out of 2
Bicycle-Sharing Integration	1	0	Loss of 1 point out of 1
Total	**14**	**6**	Loss of 8 points out of 14

Fig. 38: Incorrectly installed dropped curb with tactile paving

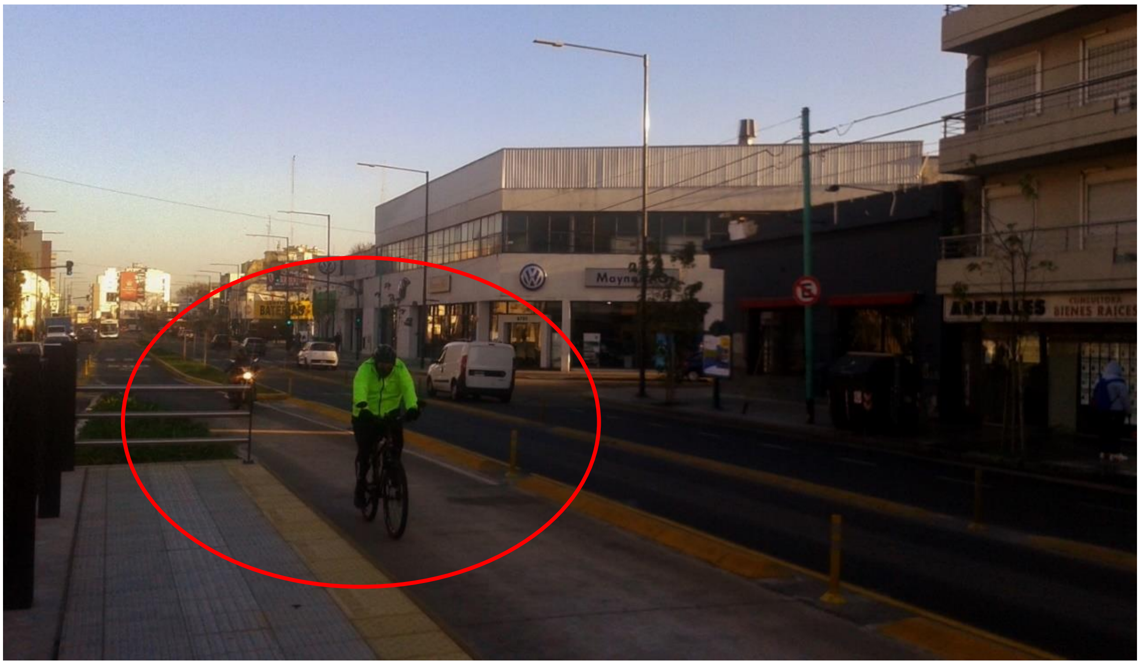


Fig. 39: Some encroachment of bicycles and motorbikes on the corridor

4.3.3.7 Point Deductions

The speed of buses is lower than in the case of Metrobus 9 de Julio. The average speed of buses on the San Martín corridor without counting stopping at stations (counting only the speed when the bus is moving) is around 20 km/h and the average speed of buses on the corridor, including stopping at stations (relationship between the distance and average time on the corridor) is around 10 km/h. The corridor is penalized -10 points due to the very low commercial speed. The daily demand is 70 000 passenger per day. The ridership on the corridor during peak hours is around 1 458 p/h/d – more than 1 000 p/h/d (28).

The physical enforcement of right-of-way is done by delineators, bollards or colorized pavement. Even though the segregation is done along the entire corridor, except the places where some buses have to leave the corridor, at some cross-sections and on the bridge and in the tunnel, there is some encroachment of other vehicles – motorbikes and very rarely bicycles or cars. By an on-site survey, it was found out that at some places motorbikes entered the busway very rarely or not at all. On the other hand, at some stations, such as Ángel Roffo or Empedrado, there was the encroachment from 10 to 15 motorbikes per hour. Therefore, 3 points will be deducted from the final core. At some stations, there is no gap between the bus floor and the station platform but at most stations a slight gap or even a large gap exist. The corridor is penalized -4 points for slight to large gaps at most of the stations.

Passenger density during the peak hour is less than 5 passengers per m^2 on buses, less than 3 passengers per m^2 at stations and there are no visible signs of overcrowding.

Busways and stations are very new (the works finished in April 2016) so there are no signs of wear, potholes or warping and they are in good condition. Buses are not new but they are in good condition, too.

From the traffic survey during the peak period (8:00 - 9:00 am):

- line *24* operates approximately 24 buses per hour
- line *47* operates approximately 18 buses per hour
- line *57* operates approximately 4 buses per hour
- line *78* operates approximately 28 buses per hour
- line *87* operates approximately 14 buses per hour
- line *105* operates approximately 18 buses per hour
- line *109* operates approximately 12 buses per hour
- line *123* operates approximately 12 buses per hour
- line *135* operates approximately 18 buses per hour
- line *146* operates approximately 24 buses per hour
- line *176* operates approximately 4 buses per hour

All lines, except lines 57 and 176, have more than 8 buses per hour during the peak hour. Line 57 and 176 are known as middle-distance buses because their route runs to the Province of Buenos Aires. They have some restriction in the city to speed up the journey, there are less of them and they run less often.

From the traffic survey during the off-peak period (12:00 - 13:00 pm):

- line *24* operates approximately 22 buses per hour
- line *47* operates approximately 11 buses per hour
- line *57* operates approximately 2 buses per hour
- line *78* operates approximately 18 buses per hour
- line *87* operates approximately 13 buses per hour
- line *105* operates approximately 14 buses per hour
- line *109* operates approximately 14 buses per hour
- line *123* operates approximately 12 buses per hour
- line *135* operates approximately 16 buses per hour
- line *146* operates approximately 20 buses per hour
- line *176* operates approximately 4 buses per hour

All lines, except line 57, have more than 4 buses per hour during the off-peak hour.

Tab. 53: Metrobus San Martín – Point Deductions – score -18 / -45

Point Deductions	Score		
	Max	Reached	
Commercial Speeds	-10	-10	Loss of -10 points out of -10!
Minimum PPHPD Below 1 000	-5	0	No penalty
Lack of Enforcement of Right-of-Way	-5	-3	Loss of -3 points out of -5!
Significant Gap Between the Bus Floor and the Station Platform	-5	-4	Loss of -4 points out of -5!
Overcrowding	-5	0	No penalty
Poorly Maintained Busways, Buses, Stations, and Technology Syst.	-10	0	No penalty
Low Peak Frequency	-3	-1	Loss of -1 point out of -3
Low Off-Peak Frequency	-2	0	No penalty
Total	**-45**	**-18**[7]	Loss of -18 points out of -45

Fig. 40: Some encroachment of motorbikes on the busway

[7]A new version of the BRT Standard, The BRT Standard 2016, was published at the end of June 2016. According to this new version, a corridor can be assessed by Design score (based only on design and services) or Full score (combination of Design score and Operation deductions). The full score can only be applied six months after a corridor has started commercial operations.

The evaluation of Metrobus San Martín was done only two months after its opening. Therefore, according to The BRT Standard 2016, this corridor should not be assessed by Full score but as all the evaluations are done according to The BRT Standard 2014, where this is not taken into account, this part also stays incorporated in Total score.

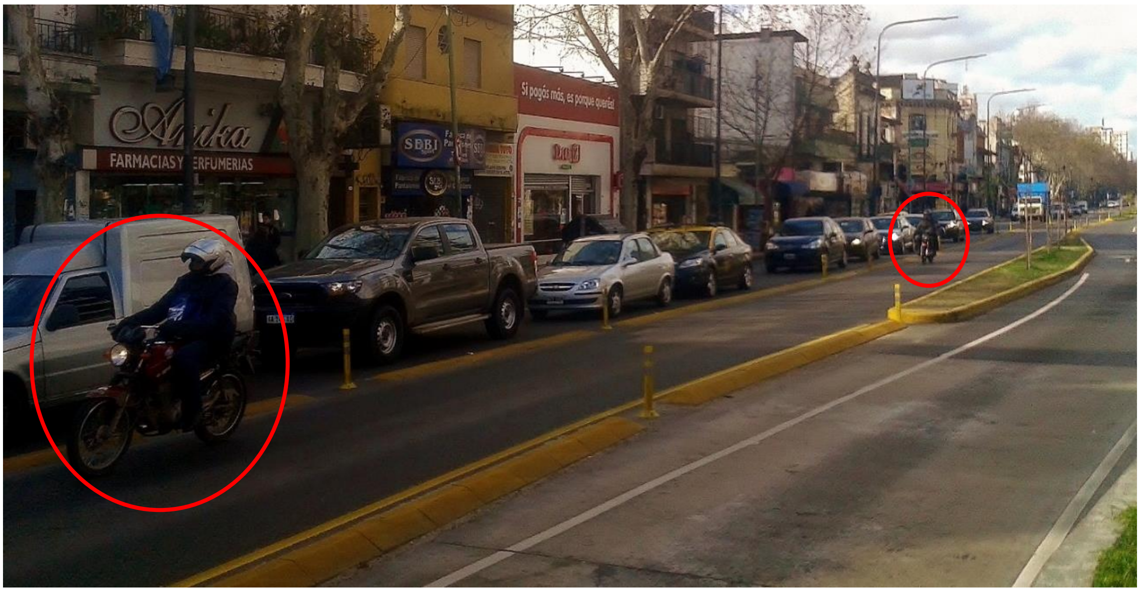


Fig. 41: Encroachment of motorbikes on the busway to overtake the queue of cars

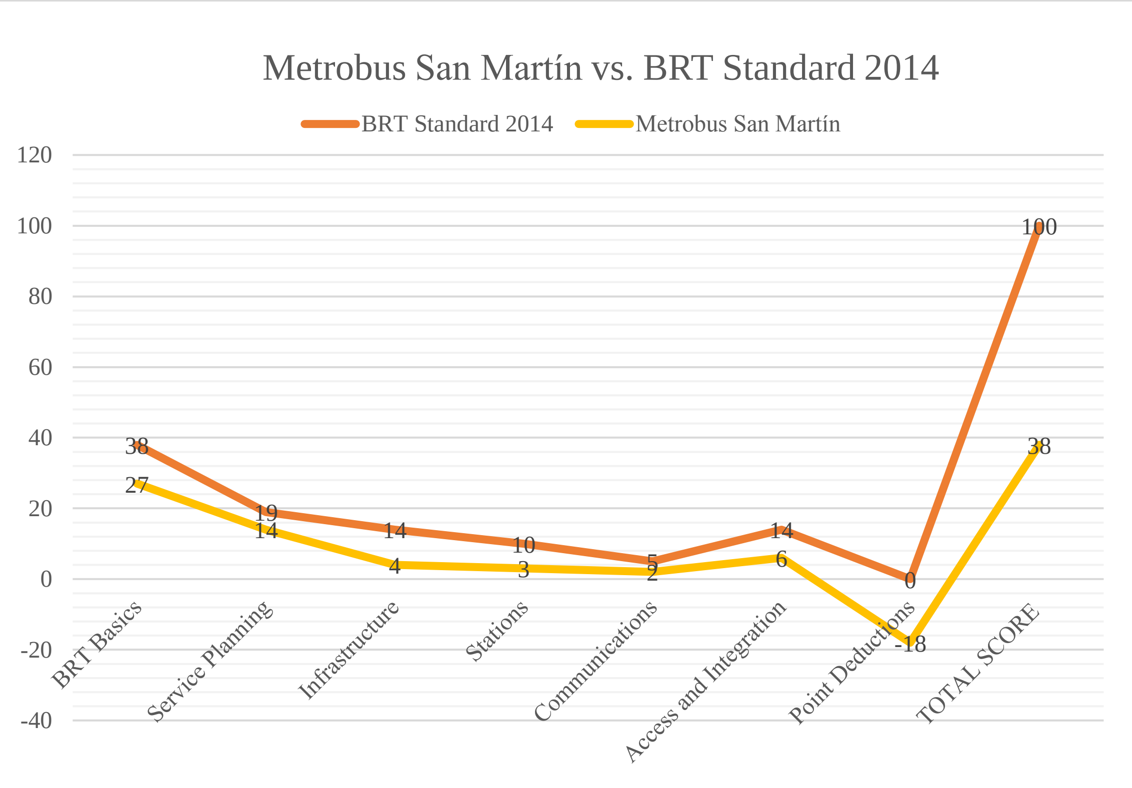
Fig. 42: Larger gap at some stations and the queue of buses at the station

4.3.3.8 BRT Standard 2014 Ranking of Metrobus San Martín

In Tab. 54, the Metrobus San Martín scorecard is shown. In total, it reached 38 points out of 100 and, therefore, it is considered Basic BRT according to The BRT Standard 2014. Graph 6 shows the comparison of scoring of Metrobus San Martín and The BRT Standard 2014.

Tab. 54: Metrobus San Martín – Total score – Basic BRT

METROBUS SAN MARTÍN		
CATEGORY	SCORE	
	MAX	REACHED
BRT Basics	38	27
Service Planning	19	14
Infrastructure	14	4
Stations	10	3
Communications	5	2
Access and Integration	14	6
TOTAL (without point deductions)	100	56
Point Deductions	-45	-18
TOTAL SCORE		**38**
BRT Standard Ranking	Gold, Silver, Bronze or Basic BRT	**BASIC BRT**



Graph 6: Metrobus San Martín vs. BRT Standard 2014 scoring

4.3.3.9 Conclusion and recommendation

Metrobus San Martín with its 38 points belongs to the category of Basic BRT. It has a core subset of elements which are essential to the definition of BRT according to The BRT Standard 2014 but yet, it did not reach the quality of the Bronze-standard BRT. From the results and findings, it was concluded that **the highest loss of points is caused by:**

- **very low commercial speed** (loss of 10 points),
- **no provision of off-board fare collection** (loss of 8 points),
- **no provision of passing lanes at stations** (loss of 4 points),

- **occurrence of slight to large gaps at most of the stations** (loss of 4 points),
- **no measures for reducing the gap in place** (loss of 3 points),
- **no provision of express and limited services** (loss of 3 points),
- **no possibility of boarding the bus through all doors** (loss of 3 points),
- **lack of enforcement of the busway** (loss of 3 points).

Metrobus San Martín loses 10 points due to a very low speed on the corridor which is around 10 km/h. This is due to the fact that **this corridor is a high-demand system which has too many buses that carry too many passengers and are concentrated into a single lane**. Sometimes, the bus speed is lower than the speed in mixed traffic.

Metrobus San Martín loses 8 points by **no provision of off-board fare collection, as in the case of Metrobus 9 de Julio.** This feature belongs to the BRT Basics and it is an essential element for reducing the boarding and alighting of passengers. The buses operating on Metrobus San Martín (as all buses throughout Buenos Aires) have a type of ticketing system where passengers pay directly to the driver. The boarding of passengers is possible only through the front door which often causes queues and the corridor loses another 3 points due to this deficit. **The implementation of SUBE readers (contactless cards used in Buenos Aires for transportation via bus, metro and rail) outside the vehicle at least at main stations could solve this problem.** For off-board fare collection, closed stations are necessary so that the passengers have to go through the readers to enter the station and so that the entrance to buses without paying does not occur.

There is only one bus lane for each direction along the corridor and passing lanes at stations are not provided. This element is quite important to accommodate high numbers of buses and to prevent the corridor from being congested with buses backed up waiting to enter the station. Sometimes, more than three buses come to the station and only the first one needs to stop (there are passengers who want to board or alight). The other buses could overtake this bus if there were passing lanes and continue on their way. On the San Martín corridor, this is not possible and the buses have to wait till the first one goes. **Even though there are no express services on the corridor, for which passing lanes are critical, it is useful to design passing lanes at the stations to allow the system growth.**

Another problem is the absence of measures for reducing the gap between the bus floor and the station platform at the station of Metrobus San Martín. Slight, but sometimes also large gaps occur at most of the stations along the corridor resulting in more problematic boarding and alighting for passengers, especially the handicapped, elderly or children. Therefore, **Metrobus San Martín should train drivers to eliminate the gap between the bus floor and the station platform or introduce some measures to narrow the gaps, such as installing Kassel curbs, alignment markers, platform edge bumper strips, guided wheel or boarding bridges.** Alignment markers or Kassel curbs would be one of the most cost effective and efficient solutions.

The absence of express and limited services is a deficit occurring in Metrobus San Martín as well as in Metrobus 9 de Julio. The difference is that **Metrobus 9 de Julio can implement express and limited services on its corridor but in the case of Metrobus San Martín it is not possible at the moment because of no passing lanes on the corridor where the buses of express services could overtake the buses of local services.** This deficit must be fixed firstly and then it will be possible to implement express and limited services on this corridor, too.

There is also a lack of right-of-way enforcement on the busway. Motorbikes are the most common vehicles encroaching the busway, even though it is not authorized. At some places, dozens of them can be found entering the busway within only one hour. **To avoid the problems, accidents and bus speed declination, it is necessary to increase the enforcement of the right-of-way by camera enforcement or regular policing with high fines.**

Metrobus San Martín loses 2 points due to:

- control center with insufficient services,
- buses with high amounts of tailpipe emissions which do not meet Euro VI and U.S.2010 emission standards,
- stations are not sufficiently set back from the intersections,
- only partial protection from the weather, no security at the stations and no internal width as all stations are opened,
- insufficient branding,
- deficit in pedestrian access – only modest improvements along the corridor,
- no provision of secure bicycle parking on the corridor,
- no provision of bicycle lanes along the corridor.

Metrobus San Martín loses 1 point due to:

- split central stations – one station for each direction,
- pavement structure designed for 30-year life only at stations,
- no sub-stops at stations and only one docking bay,
- no sliding doors at stations,
- no real-time passenger information,
- absence of physical transfer points with other public transport that minimize walking between modes,
- no provision of bicycle-sharing integration along the corridor.

As we can see from the findings, many deficits which occurred on Metrobus 9 de Julio occurred on Metrobus San Martín, too. The systems are similar, as both metrobuses are within one city, but Metrobus 9 de Julio has some better parameters. Metrobus San Martín lost more points in the section of BRT Basics, Infrastructure, Stations and Point Deductions.

4.3.4 Safety problem on Metrobus San Martín

On Metrobus San Martín, the same problems with incorrect application of tactile ground surface indicators for blind pedestrians were found, as well as incorrect usage of dropped curbs for physically impaired pedestrians, as in the case of Metrobus 9 de Julio. This problem is already described in chapter 4.2.4.

Recently, another big problem in pedestrian access to Metrobus San Martín stations has been discovered. **Five accidents of pedestrians – four adults and one child – happened on this corridor within the period of only two months, from the beginning of its functioning (the end of April 2016) until the end of June.** The reason is that **the access to the stations of San Martín corridor is possible only from one end of the stations.** On the other end of the stations, there is a railing and greenery which should prevent the passage of pedestrians through this side. However, **enforcement is not sufficient enough and many pedestrians enter the stations from the “wrong” end.** Sometimes, it is done on purpose, sometimes by mistake, not knowing the new situation or the fact that it is forbidden. Pedestrians also often cross the road in places with no pedestrian crossing. This happens more often in places where pedestrian crossings are far from each other.

By research during the peak-hour in four different places it was found out that:

- **in Danoto Álvarez station** and the surrounding area of 50 meters, **68 unauthorized entrances of pedestrians** into the busway or to the stations during the peak-hour were noticed (18:00 – 19:00)

- **in Ángel Roffo station** and the surrounding area of 50 meters, **52 unauthorized entrances of pedestrians** into the busway or to the stations during the peak-hour were noticed (08:00 – 09:00)
- in the final station of Metrobus, **Ladines,** and the surrounding area of 50 meters, **40 unauthorized entrances of pedestrians** into the busway or to the stations during the peak-hour were noticed (08:00 – 09:00)
- **in Empedrado station** and the surrounding area of 50 meters, **16 unauthorized entrances of pedestrians** into the busway or to the stations during the peak-hour were noticed (08:00 – 09:00)

The highest number of pedestrians who entered the road, busway or the station in other place than the pedestrian crossing, was in Danoto Álvarez station during the evening peak hour. The reason of such a high number of unauthorized entrances of pedestrians, in this case, could be explained by a longer distance (220 meters) between two pedestrian crossings. Research in this station was done between 18:00 and 19:00. At that time it was already dark and people who were entering the road or who were waiting in the central island to be able to finish the passage, were hardly visible. This makes it **very dangerous and should be repaired as soon as possible**.

This problem does not occur on Metrobus 9 de Julio because all stations are interconnected. Passengers can enter the station from both ends and can also walk from one station to the other without the necessity of using sidewalks (there are pedestrian crossings between the stations). It is also impossible to pass at any other place than the pedestrian crossing because the busways on the corridor are separated from the rest of the traffic by high concrete barriers.

Three low columns positioned perpendicular to the direction of crossing at pedestrian crossings which prevent easy and inattentive passage through the bus lanes are also used in Metrobus 9 de Julio. On Metrobus San Martín, these columns are not installed, which can negatively influence pedestrian safety, too. Lower price in this situation also lower security.

At the moment, the aim is to lower the unauthorized entering of pedestrians into the road where there is no pedestrian crossing and to induce pedestrians to enter the station only from the end designed to it. That means to **build concrete barriers and use greenery so that the place seems inapproachable. The central islands will be exalted so that the passage through them will be impossible or at least very uncomfortable. The usage of low columns on pedestrian crossings could also help to increase the safety, vigilance and attention of pedestrians at the entrance to pedestrian crossings.**

Fig. 43: Pedestrians entering the busway to cross the road

Fig. 44: Pedestrians entering the busway to enter the station

Fig. 45: Pedestrians waiting on the yellow curb separating a busway and a normal road to cross the road

Fig. 46: Unauthorized pedestrians' entering the road and busway on the corridor

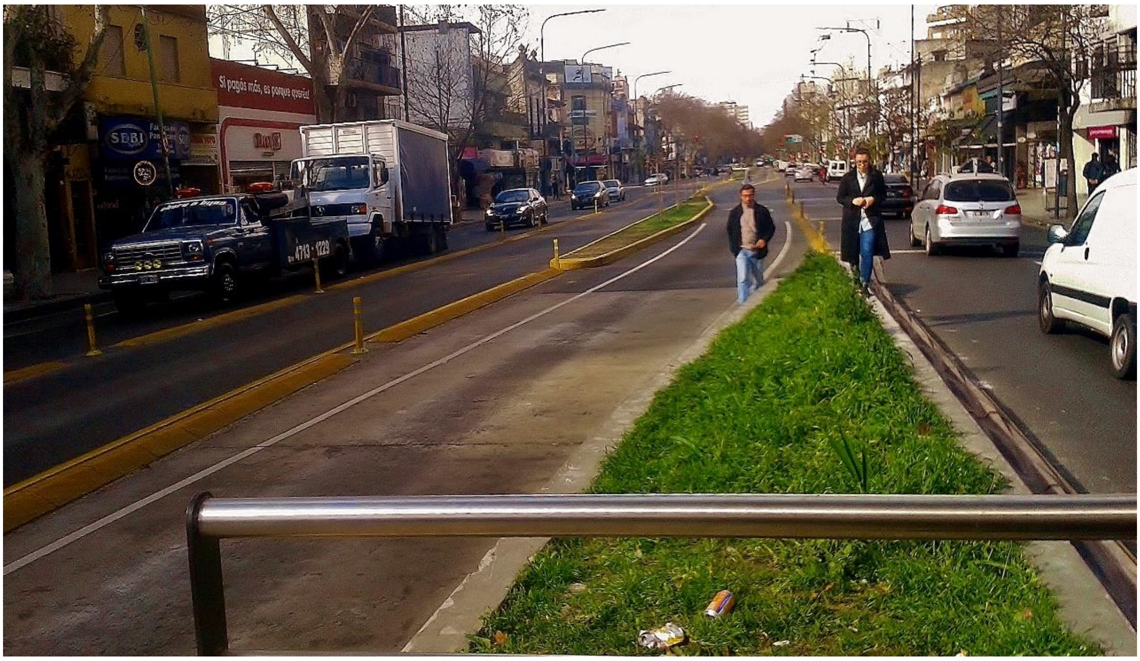


Fig. 47: Unauthorized entering the station from the "wrong" side

4.4 Comparison of Metrobus 9 de Julio and Metrobus San Martín and findings

From the previous evaluation, we can see that **there are many similarities in Metrobus 9 de Julio and Metrobus San Martín**, such as the Tier 1 configuration along the corridor, prohibition of turns of cars across the busways or station's platforms levelled with the bus floor. Both metrobuses have the same branding and very similar static passenger information.

We can also find **some deficits and mistakes which are the same for both Metrobus 9 de Julio and Metrobus San Martín**. No provision of off-board fare collection and no possibility of boarding the bus through all doors are two of them. Solving this problem can save many seconds or even minutes per station. No provision of express and limited services, usage of old non-articulated buses and no secure bicycle parking are other common deficits. A bigger problem which was found during the research on both corridors is unsafe pedestrian access for blind pedestrians. Tactile ground surface indicators at pedestrian crossings are often used incorrectly or they are completely missing at some places. This deficit should be fixed as soon as possible.

On the other hand, **there are some differences between these two metrobuses. One of the reasons of the differences between them is the cost of each corridor. Metrobus San Martín was more than half the price of Metrobus 9 de Julio even though its corridor is longer.** Metrobus 9 de Julio cost approximately AR$ 43 million/km = CZK 69 million/km but Metrobus San Martín was almost four times cheaper – AR$ 12 million/km = CZK 19 million/km. Metrobus 9 de Julio has some parameters which result in higher quality and also a higher award according to The BRT Standard.

Metrobus 9 de Julio has two dedicated lanes for each direction which are physically separated from other traffic with central stations serving both directions. On the other hand, Metrobus San Martín has only one bus lane for each direction along the corridor, no passing lanes at stations and the stations are centrally aligned but separated – split stations. This is caused by the width of Av. San Martín, which is much narrower than Av. 9 de Julio and it was not possible to build two lanes for each direction along the corridor or one wide central station used for both directions.

Metrobus 9 de Julio has special yellow curbs at stations which lead drivers to stop the bus not too far but also not too close to the station (in the past the drivers often hit the edge of the station by the side of the bus). On the contrary, Metrobus San Martín does not have any measures for reducing the gap. On Metrobus 9 de Julio, concrete pavement is used along the entire length of the corridor but on Metrobus San Martín concrete pavement is used only at stations and asphalt pavement is used along the rest of the corridor.

On both corridors, the stations are situated close to intersections. In the case of Metrobus 9 de Julio, it is due to the small length of the blocks but in the case of Metrobus San Martín, the block length is longer and, therefore, many stations could be situated further away from intersections. Even though there are still some deficits, the stations on Metrobus 9 de Julio have better parameters (partially closed stations, better protection from the weather, some real-time passenger information, etc.) than the stations on Metrobus San Martín. Metrobus 9 de Julio has sub-stops with two docking bays but Metrobus San Martín does not have sub-stops and at each station there is only one docking bay. This docking bay can accommodate up to three buses but sometimes backing up of buses occurs at some stations.

Metrobus 9 de Julio has bicycle lanes parallel to the corridor (however, not along the whole length), on the other hand, Metrobus San Martín does not have any bicycle lanes close to the corridor and any bicycle integration either. Last but not least, both corridors could have better physical enforcement of right-of-way but it is especially Metrobus San Martín that should focus on this parameter because the encroachment of motorbikes (or cars) is much more frequent than on Metrobus 9 de Julio. The frequency of buses on Metrobus 9 de Julio is always more than 8 buses per hour but during the research on Metrobus San Martín it was found that two bus lines are not that frequent with only 4 buses passing the station per peak-hour.

4.5 New parameter to The BRT Standard

One more problem not included in The BRT Standard, was found on Metrobus San Martín. This problem – **unauthorized pedestrians' entering the road, busway and stations** – is a serious one because it occurs at many places of the corridor. In only two months, five accidents of pedestrians occurred on this corridor because of this deficit and during the research it was found that there were up to 68 encroachments of pedestrians into the busway or to the stations noticed only in one peak hour at one station and its surrounding area of 50 meters**.**

On Metrobus 9 de Julio, this problem does not occur due to better parameters – the possibility to enter the station from both ends and the impossibility to enter the station and pass the road at any other place than the pedestrian crossing.

This criterion – encroachment of pedestrians into the road, busway and stations – is not mentioned in The BRT Standard even though, as we can see from the real practice, it can be very dangerous for pedestrians and can cause problems. The necessity of adding this parameter to the new publication of The BRT Standard, either as a penalty to the section of Point Deductions or as a new design metric to the section of Access and Integration, can be the subject of further work.

5 BRT IN RIO DE JANEIRO

5.1 Transportation system in Rio de Janeiro

Rio de Janeiro belongs to one of the most visited cities in the Southern Hemisphere. The population of Rio de Janeiro is 6 093 472 inhabitants, which makes this city the second most populated municipality in Brazil and the sixth most populated on the American continent (43). The city is located on the south-eastern coast of Brazil and part of it was recognized as a World Heritage Site with the name "Rio de Janeiro: Carioca Landscapes between the Mountain and the Sea" by UNESCO in 2012 (44).

The roads in Rio de Janeiro do not have a strictly square or rectangular pattern, as in the case of Buenos Aires. The city was growing gradually and, therefore, it does not have a symmetric network of streets. Most roads are one-way roads.

5.1.1 Local public transport

Local public transport in Rio de Janeiro consists of underground and urban trains, BRT and regular buses and trams and taxis, while buses are the main form of public transportation. Until now, the public transport was insufficient and it was not easy to travel in the city. Deficient subway lines and buses mixed with traffic turned transportation into chaos. In order to increase the capacity and to reduce the traffic congestion, the transportation policy is moving towards trains, subways and especially BRT. Thanks to sport events, such as the FIFA World Cup in 2014 and the Summer Olympic Games in 2016, public transport in Rio de Janeiro has improved a lot (45).

The underground in Rio de Janeiro, called ‘Metrô Rio’, was first opened in 1979. The system is rather small consisting of three lines – Orange Line 1 that connects some main touristic points of the city, Green Line 2 with Maracanã station – the stadium where both big sport events took place and recently, the third line – Yellow Line 4 – has been opened. It was completed on 30th of July 2016 and in August it began to operate for athletes and the public going to the Olympic Games. The population of Rio de Janeiro has access to the subway from September 2016. All lines together have 58 kilometers with 41 stations (45; 46).

The Brazilian train operator – SuperVia Trens Urbanos – was founded in Rio de Janeiro in November 1998. The rail network of Rio de Janeiro consists of eight lines – Deodoro, Santa Cruz, Japeri, Paracambi, Belford Roxo, Saracuruna, Vila Inhomirim and Guapimirim. The system length is 270 kilometers and 201 trains transport approximately 700 000 passengers every day (47).

The first corridor of Bus Rapid Transit in Rio de Janeiro – Transoeste – was inaugurated on 6th June 2012. At the moment, there are three corridors – Transoeste, Transcarioca and Transolímpica. The fourth corridor, Transbrasil, is under construction (48).

There are 831 public bus lines in Rio de Janeiro that go to all parts of the city. Buses are the easiest and cheapest possibility to get around Rio. They do not have a fixed schedule but depending on the line and the time of the day they run every 10 to 15 minutes during the day and 30 to 60 minutes during the night (49).

In Rio de Janeiro, there is one historic tram line called Santa Teresa Tram (Bonde de Santa Teresa). This tram was opened in 1877 and became electric in 1896. Santa Teresa Tram with its length of 6 kilometers connects the city center with the residential neighbourhood Santa Teresa (50).

The Rio de Janeiro tram system was in decline from the 1950s. By the end of the 1950s, most of the tram routes had been closed. Recently (5th June 2016), a new light rail transit system – the VLC (Vehicle on Light Tracks) – was inaugurated in Rio de Janeiro. This project was a pivotal piece for the revitalization of Porto Maravilha and the preparation for the Olympic Games 2016. There are 32 trams operating on a 28 kilometer-long track with 31 stations (50; 51; 52).

5.1.2 BRT in Rio de Janeiro

Transoeste was the first BRT corridor in Rio de Janeiro that was inaugurated on 6th June 2012. This BRT runs from Jardim Oceânico to Santa Cruz, with a branch to Campo Grande. Nowadays, it has 56 kilometers with 66 stations and 120 000 passengers benefit from the reduction of almost one hour of travel time between Barra de Tijuca and Santa Cruz/Campo Grande. This corridor is connected with the Santa Cruz railway at stations Campo Grande, Santa Eugênia and Santa Cruz, with BRT Transcarioca at Terminal Alvorada station, with BRT Transolímpica at Recreio/Salvador Allende station and with the fourth metro line at Jardim Oceânico station (53).

The second corridor with exclusive lanes – BRT Transcarioca – was inaugurated on 2nd June 2014. This corridor with an extension of 39 kilometers and 47 stations allows passengers to save up to 60 % in travel time (54). More about BRT Transcarioca is written in chapter 5.2.

The third BRT, Transolímpica (officially named Corridor President Tancredo Neves), has been opened recently – the inauguration was on 9th July 2016. The aim was to improve public transport in the city for the Olympic Games 2016 (Transolímpica runs through the neighbourhoods where most of the competitions took place). This corridor connects Barra da Tijuca and Recreio with Magalhães Bastos and Diodorus. The extension is 26 kilometers and it has 18 stations with three terminals. It is estimated that approximately 70 000 passengers will benefit from the reduction in travel time between Deodoro and Recreio by 60 % (55; 56).

The fourth corridor – BRT Transbrasil – is under construction. This corridor will run on 32-kilometer-long busways and it will connect Santos Dumont airport with Diodorus in the western part of the city. It is expected that this corridor will carry most passengers of all BRT corridors not only in Rio de Janeiro but in whole Brazil – around 900 000 passengers per day. BRT Transbrasil should be finished by the end of 2017 (57).

Fig. 48: Map of BRTs in Rio de Janeiro (finished and future ones) (58)

5.2 BRT Transcarioca

BRT Transcarioca was the second corridor built in Rio de Janeiro (after BRT Transoeste), inaugurated on 2nd June 2014. This 39-kilomenter-long corridor connects three main railroads in Rio de Janeiro, the subway and BRT Transoeste. High number of passengers benefit from this corridor (approximately 230 000 passengers) (54).

5.2.1 Facts and objectives

The basic facts about BRT Transcarioca are as follows:

- 39 km extension with 47 stations (5 terminal stations)
- 230 000 passengers/day
- 8 bus lines: 3 local services, 3 express services, 2 semi-direct services
- 'trunk-feeder' operation
- connection with the metro line 2 at Vicente de Carvalho station, with the Saracuruna railway at Olaria and Penha stations and with Belford Roxo and Japeri railways at Madureira station, with BRT Transoeste at Terminal Alvorada station, with BRT Transolímpica at Recreio/Salvador Allende station and with future BRT Transbrasil in Avenida Brasil
- connection between Galeao international airport and residential and commercial areas in Barra da Tijuca
- up to 60 % reduction in travel time
- 38 % reduction in O_2 emissions
- two bridges
- four viaducts (54; 59)

The main objectives of BRT Transcarioca are:

- connect the northern and southern part of the city and connect the international airport with residential area
- improve mobility in the city
- reduce travel time for passengers, more regularity
- help to reduce O_2 emissions
- reduce accidents

5.2.2 Assessment of effectiveness and quality of BRT Transcarioca according to The BRT Standard

The information for the assessment of effectiveness and quality of BRT Transcarioca is based only on the personal research and the information available from the webpage of BRT in Rio de Janeiro.

5.2.2.1 BRT Basics

BRT Transcarioca has dedicated right-of-way and physical segregation along the entire length of 39 kilometers. The Tier 1 configuration – two-way median-aligned busways that are in the central verge of a two-way road or bus-only corridors with fully exclusive right-of-way and no parallel mixed traffic with one bus lane for each direction is used along the entire corridor. Buses drive in their dedicated lanes in the same direction as mixed traffic.

Regarding ticket payments, 100 % of the stations on the corridor have turnstile-controlled off-board-fare collection and, therefore, the corridor is getting maximum points. Turns are prohibited across the busway along almost the whole length of the corridor.

All bus-station platforms have the same level as the bus floor. The vertical gap is almost zero centimetres but the horizontal gap is not minimized by any measures for reducing the gap in place.

Tab. 55: BRT Transcarioca – BRT Basics – score 34 / 38

BRT Basics	Score		
	Max	Reached	
Dedicated Right-of-Way	8	8	Maximum score
Busway Alignment	8	8	Maximum score
Off-board Fare Collection	8	8	Maximum score
Intersection Treatments	7	6	Loss of 1 point out of 7
Platform-level Boarding	7	4	Loss of 3 points out of 7!
Total	**38**	**34**	Loss of 4 points out of 38

Minimum requirements for a corridor to be considered BRT:

5 At least 3 km length with dedicated lanes — yes – 39 km length
6 Score 4 or more points in the dedicated right-of-way element — yes – 8 points
7 Score 4 or more points in the busway alignment element — yes – 8 points
8 Score 20 or more points across all five BRT Basics elements — yes – 34 points

BRT Transcarioca is considered BRT and it is possible to continue with evaluation.

Fig. 49: Dedicated right-of-way (54)

Fig. 50: Platform-level boarding and sliding doors at each station (54)

5.2.2.2 Service Planning

BRT Transcarioca has multiple routes which operate on this corridor. There are three local services – Alvorada x Madureira, Madureira x Fundao and Alvorada x Fundao; three express services – Alvorada x Madureira, Penha x Santa Efigenia and Alvorada x Fundao and two semi-direct services – Alvorada x Vicente de Carvalho and Alvorada x Galeao. There is a special control center for the BRT system in Rio de Janeiro at Terminal Alvorada station.

BRT Transcarioca is located along one of the top ten corridors with its peak load of 11 000 passengers/hour/direction (2). The corridor also includes the highest demand segment, which has the Tier 1 trunk corridor configuration (see 3.5.1.2).

This BRT works during the whole day and night, 7 days a week. BRT Transcarioca connects to an existing BRT Transoeste at Terminal Alvorada station.

Tab. 56: BRT Transcarioca – Service Planning – score 19 / 19

Service Planning	Score		
	Max	Reached	
Multiple Routes	4	4	Maximum score
Express, Limited, and Local Services	3	3	Maximum score
Control Center	3	3	Maximum score
Located In Top Ten Corridors	2	2	Maximum score
Demand Profile	3	3	Maximum score
Hours of Operations	2	2	Maximum score
Multi-corridor Network	2	2	Maximum score
Total	**19**	**19**	Loss of 0 points out of 19

5.2.2.3 Infrastructure

BRT Transcarioca has physically dedicated passing lanes at all stations. Buses can easily overtake other buses standing at the station. Brazil, as well as Argentina, has adopted vehicle emission standards that are equivalent to Euro IV and above. This BRT reduces emissions of CO_2 by 65 500 tons and 1.2 tons of particulate matter every year. BRT Transcarioca uses new buses that are certified to Euro IV with PM traps (39; 59).

According to The BRT Standard, stations should be located at minimum 26 meters from the intersection. Most of the stations on BRT Transcarioca are located more than 40 meters from intersections and full points can be assigned.

This corridor has center stations which serve both directions of service along the entire corridor. Stations, as well as running ways, are made of concrete. This structure is designed for a 30-year life span.

Tab. 57: BRT Transcarioca – Infrastructure – score 13 / 14

Infrastructure	Score		
	Max	Reached	
Passing Lanes at Stations	4	4	Maximum score
Minimizing Bus Emissions	3	2	Loss of 1 point out of 3
Stations Set Back From Intersections	3	3	Maximum score
Center Stations	2	2	Maximum score
Pavement Quality	2	2	Maximum score
Total	**14**	**13**	Loss of 1 points out of 14

Fig. 51: Center station serving both directions, Passing lanes at the stations (59)

5.2.2.4 Stations

The station spacing at BRT Transcarioca is, on average, 0.83 km (calculated by using the corridor length and the number of stations) – more than 0.8 kilometer.

Stations should be safe, wide, attractive and comfortable. The stations of BRT Transcarioca are attractive, completely closed, well protected from the weather and well-lighted. The internal width of the stations is approximately 4 meters. There are security guards at main stations.

Only articulated buses operate on this corridor. They have four doors, all of them are wide and they are at the same level as the station platforms. Boarding is possible through all doors (depending on the size of the station and the number of slide doors at the station).

There are two docking bays, two sub-stops or both in the highest demand stations, such as Terminal Alvorada, Madureira, Vicente de Carvalho or Terminal Fundao. There are sliding doors at each station.

Tab. 58: BRT Transcarioca – Stations – score 8 / 10

Stations	Score		
	Max	Reached	
Distances Between Stations	2	0	Loss of 2 points out of 2
Safe and Comfortable Stations	3	3	Maximum score
Number of Doors On the Bus	3	3	Maximum score
Docking Bays and Sub-stops	1	1	Maximum score
Sliding Doors In BRT Stations	1	1	Maximum score
Total	**10**	**8**	Loss of 2 points out of 10

Fig. 52: Station of BRT Transcarioca (54)

Fig. 53: Inside the station, at the top of the picture there is static and real-time passenger information (54)

5.2.2.5 Communications

All buses, routes and stations on the corridor follow the single unifying brand of the entire BRT system.

Inside the stations, there is up-to-date static passenger information and also real-time passenger information such as time and date and information of “next bus” at the station or “next stop” on the bus.

Tab. 59: BRT Transcarioca – Communications – score 5 / 5

Communications	Score		
	Max	Reached	
Branding	3	3	Maximum score
Passenger Information	2	2	Maximum score
Total	**5**	**5**	Loss of 0 points out of 5

5.2.2.6 Access and Integration

Both the stations and the vehicles on the corridor have to be accessible for all special-needs customers and wheelchairs. The corridor has dropped curbs at all immediate intersections, Braille readers at all stations and Tactile ground surface indicators leading to the stations.

Integration with other public transport is done by fare payment (RioCard) as well as by physical transfer points (bridges, ramps, etc.).

In the section of Pedestrian Access, the corridor gets 2 points. Pedestrian access is good and safe and there are many improvements along the corridor. There is no secure bicycle parking along the corridor and there are standard bicycle racks only near few stations. There are no bicycle lanes parallel to the corridor. There is no possibility of bicycle-sharing on BRT Transcarioca.

Tab. 60: BRT Transcarioca – Access and Integration – score 8 / 14

Access and Integration	Score		
	Max	Reached	
Universal Access	3	3	Maximum score
Integration with Other Public Transport	3	3	Maximum score
Pedestrian Access	3	2	Loss of 1 point out of 3
Secure Bicycle Parking	2	0	Loss of 2 points out of 2
Bicycle Lanes	2	0	Loss of 2 points out of 2
Bicycle-Sharing Integration	1	0	Loss of 1 point out of 1
Total	**14**	**8**	Loss of 6 points out of 14

Fig. 54: Universal access to stations (54)

5.2.2.7 Point Deductions

The speed of buses varies depending on whether it is local or express service. The speed limit is 70 km/h. The average commercial speed of express buses is around 30 km/h and the average commercial speed of local buses is approximately 25 km/h. BRT Transcarioca has 11 000 passengers/hour/direction in peak hours (2).

Along the entire corridor, there is physical enforcement of right-of-way that prevents encroachment from other vehicles. The on-site observation confirmed that there is no encroachment along the corridor. There are no measures for reducing the gap between the bus floor and the station platform and drivers sometimes do not dock properly. The corridor is penalized -2 points for slight gaps at some stations.

Passenger density during the peak hour is more than 5 passengers per m^2 on buses. There are visible signs of overcrowding (such as problems with closing the bus doors) on semi-direct lines, as well as on local lines and sometimes also on express lines.

BRT Transcarioca is quite new and, therefore, busways, buses, stations and technology systems are in good conditions.

From the traffic survey during peak period (17:00 - 18:00 am):

- local line Alvorada x Madureira operates 8 buses per hour
- local line Madureira x Fundao operates 8 buses per hour
- local line Alvorada x Fundao operates 8 buses per hour
- express line Alvorada x Madureira operates 8 buses per hour
- express line Penha x Santa Efigenia operates 8 buses per hour
- express line Alvorada x Fundao operates 8 buses per hour
- semi-direct line Alvorada x Vicente de Carvalho operates 6 buses per hour
- semi-direct line Alvorada x Galeao operates 6 buses per hour

Most of the lines have 8 buses per hour during the peak hour but both of the semi-direct lines have only 6 buses/hour.

From the traffic survey during the off-peak period (12:00 - 13:00 pm):

- local line Alvorada x Madureira operates 8 buses per hour

- local line Madureira x Fundao operates 8 buses per hour
- local line Alvorada x Fundao operates 8 buses per hour
- express line Alvorada x Madureira operates 8 buses per hour
- express line Penha x Santa Efigenia operates 8 buses per hour
- express line Alvorada x Fundao operates 8 buses per hour
- semi-direct line Alvorada x Vicente de Carvalho operates 2 buses per hour
- semi-direct line Alvorada x Galeao operates 2 buses per hour

All lines have more than 4 buses per hour during the off-peak hour but both of the semi-direct lines have only 2 buses/hour.

Tab. 61: BRT Transcarioca – Point Deductions – score -9 / -45

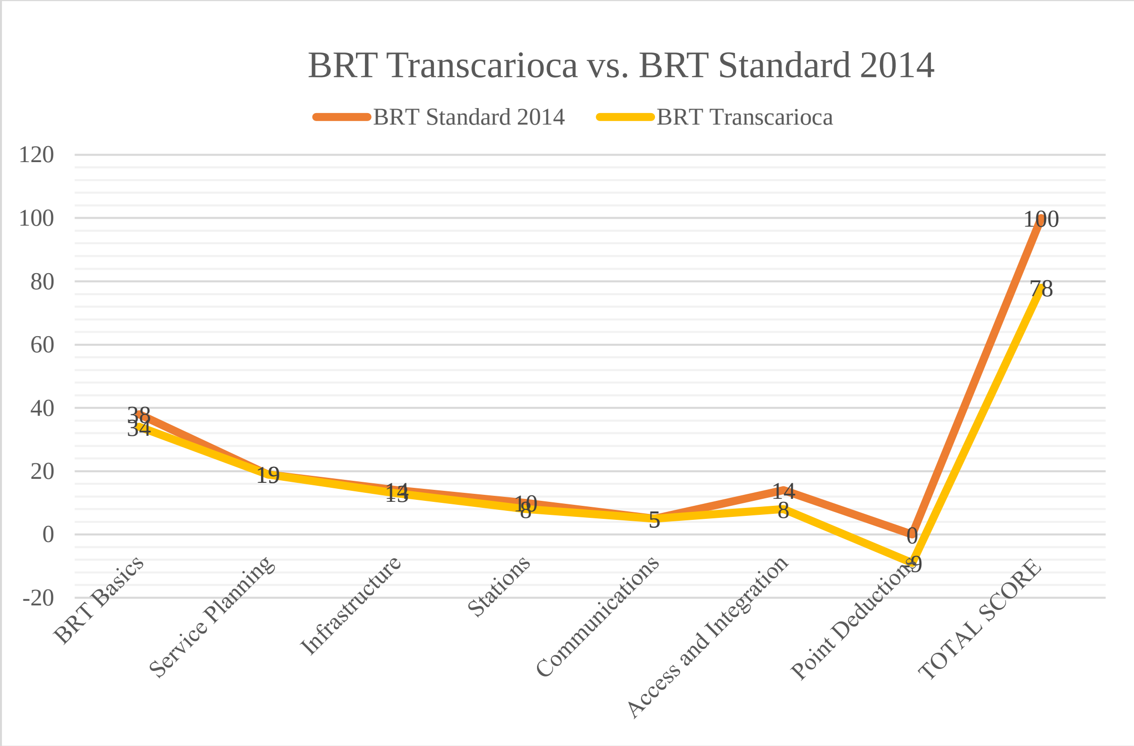
Point Deductions	Score		
	Max	Reached	
Commercial Speed	-10	0	No penalty
Minimum PPHPD Below 1 000	-5	0	No penalty
Lack of Enforcement of Right-of-Way	-5	0	No penalty
Significant Gap Between the Bus Floor and the Station Platform	-5	-2	Loss of -2 points out of -5
Overcrowding	-5	-5	Loss of -5 points out of -5!
Poorly Maintained Busways, Buses, Stations, and Technology Syst.	-10	0	No penalty
Low Peak Frequency	-3	-1	Loss of -1 point out of -3
Low Off-Peak Frequency	-2	-1	Loss of -1 point out of -2
Total	**-45**	**-9**	Loss of -9 points out of -45

5.2.2.8 BRT Standard 2014 Ranking of BRT Transcarioca

In Tab. 62, the BRT Transcarioca scorecard is shown. In total, it reached 78 points out of 100 and, therefore, it is awarded Silver BRT according to The BRT Standard 2014. Graph 7 shows the comparison of scoring of BRT Transcarioca and The BRT Standard 2014.

Tab. 62: BRT Transcarioca – Total score – Silver BRT

BRT TRANSCARIOCA		
CATEGORY	SCORE	
	MAX	REACHED
BRT Basics	38	34
Service Planning	19	19
Infrastructure	14	13
Stations	10	8
Communications	5	5
Access and Integration	14	8
TOTAL (without point deductions)	100	87
Point Deductions	-45	-9
TOTAL SCORE		**78**
BRT Standard Ranking	Gold, Silver, Bronze or Basic BRT	**SILVER BRT**



Graph 7: BRT Transcarioca vs. BRT Standard 2014 scoring

5.2.2.9 Conclusion and recommendation

BRT Transcarioca with its title of Silver BRT, includes most of the features of international best practice and achieves high quality of service and operational performance. From the results and findings, it was concluded that **the highest loss of points is caused by:**

- **occurrence of overcrowding** (loss of 5 points),
- **no measures for reducing the gap in place** (loss of 3 points).

There are only two main deficits on BRT Transcarioca that cause a bigger loss of points. The first problem is overcrowding. Local and express services run every 7.5 minutes and semi-direct services run only every 10 minutes during peak hours and every 20 or 30 minutes during off-peak hours (loss of -1 and -1 point in the section of point deductions). **Local and semi-direct services are often full and sometimes it happens that not all passengers waiting at the station can enter the bus. Express services are sometimes full, too but it is not that frequent.** Even though only articulated buses with higher capacity are used on BRT Transcarioca, there are many passengers that use the BRT system and the supply does not satisfy the demand. **Semi-direct lines, as well as local lines, should operate more often to reduce the problems with overcrowding.**

The second bigger problem is the absence of measures for reducing the gap between the bus floor and the station platform at the stations of BRT Transcarioca. **Mostly, drivers dock the bus close to the station platform but sometimes a slight gap occurs** (loss of -2 points in the section of point deductions). It results in more problematic boarding and alighting for some passengers. **BRT Transcarioca should introduce some measures to lower the gaps, such as installing Kassel curbs, alignment markers, platform edge bumper strips, guided wheel or boarding bridges.**

BRT Transcarioca loses 2 points due to:

- bigger distance between stations than recommended,
- no provision of secure bicycle parking,
- no provision of bicycle lanes,
- slight gap between the station platform and the bus floor.

BRT Transcarioca loses 1 point due to:

- no prohibition of car turns through the busway at every cross section,
- bus emissions that do not meet Euro VI or US 2010,
- no provision of good and safe pedestrian access for a 500-meter catchment area surrounding the corridor,
- no provision of bicycle-share integration,
- low peak and off-peak frequency of semi-direct lines.

In general, BRT Transcarioca should provide more lines on the corridor, introduce some measures for reducing the gap in place and implement bicycle lanes and parking as well as bicycle-share integration.

6 METROBUS IN PRAGUE

6.1 Transportation system in Prague

Prague is the capital of the Czech Republic and with its population of 1 267 449 residents (population of a larger urban zone is 2 204 730), it is also the most populated city, the second most populated region in the Czech Republic and 15th largest city in the European Union. Prague is located in Central Europe and it is its political, cultural and economic center (60; 61). Prague has belonged to UNESCO World Heritage Sites since 1992. Every year more than six million tourists come to visit the Czech metropolis (in 2015, there were over 6 573 000 tourists visiting Prague) (62).

Prague is a historical city, it is the center and the biggest crossroad of most traffic in the Czech Republic and, therefore, it has an extend transport infrastructure. The main flow of traffic goes through the city center and through the inner and outer circle roads.

The Inner Circle road (the City Circle, in Czech: 'Městský okruh') surrounds the wider part of the city center. Part of the Inner Circle road is the newly constructed Blanka Tunnel Complex. The construction began in 2007 and it was officially opened, with a few years of delay caused by several problems, on 19th September 2015. This tunnel complex is the longest one in the Czech Republic and it is also the longest city tunnel in Europe. Blanka is one of the largest, most complex and also most expensive projects that has been implemented in the capital city of Prague. It consists of three single tunnels – Bubenečský, Dejvický and Brusnický with a total length of 5.5 kilometers and it is located in the north-west part of the Inner Circle road. This tunnel complex was built to relieve the historic center of Prague of heavy car traffic (63). The section of the Inner Circle road from Troja, through the Blanka Tunnel Complex, Strahov Tunnel, Mrázovka Tunnel, the bridge in Barrandov and Jižní spojka has been already built. There is a plan to interconnect the Inner Circle road in the north-east between the years 2014 – 2019. The total planned length of the City Circle should be 32.1 km. After its completion, the whole Inner Circle road will be part of the radial-circular system and it will provide a bypass along the city center to reduce the traffic and to prioritize public transport in the center (64).

The Outer Circle road (the Prague Circle, in Czech: 'Pražský okruh', 'Dálnice D0') will provide a connection between all major motorways and speedways that enter the Prague region. It will ensure faster transit without the necessity to travel through the city and it will thereby contribute to increasing the safety of road transport and to improving the environment in the city.

According to original plans, it was supposed to be finished in 2008 but eight years later, in 2016, there is less than half of the 82-kilometer-long circle around Prague in operation (65).

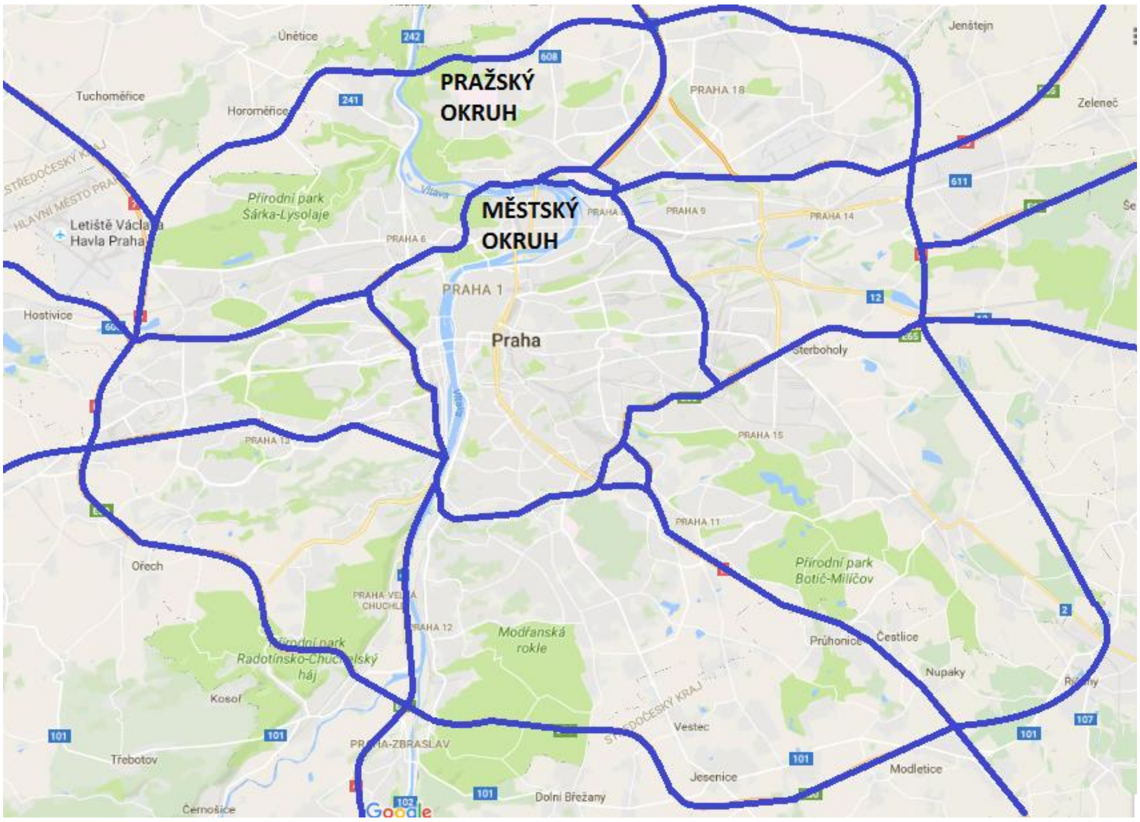


Fig. 55: Inner Circle road ('Městský okruh') and Outer Circle road ('Pražský okruh')

6.1.1 Local public transport

Prague's public transport consists of rail, metro, trams, buses, funiculars and ferries. Public transport in Prague is largely used and it is integrated into a complex system. Prague Integrated Transport (in Czech: 'Pražská integrovaná doprava', PID) is an integrated transport system in Prague and the nearby Central region coordinated by ROPID (in Czech: 'Regionální organizátor Pražské integrované dopravy'). Prague integrated transport is being built in order to offer a high quality public transport service that will be a competitive alternative to individual transport. The aim is to introduce a single fare and tickets for all public transport modes, united regulations, integrated route plan, information system and improvement in transfer facilities. Its objectives, plans and procedures are published in the Regional Plan of Prague Integrated Transport for the Year 2015 with an outlook for the period of 2016-2019 published by ROPID (66).

The system of public transport is conceived so that the rail transport is the backbone of public transport in Prague. Primarily, it is a metro system complemented with the tram network. In suburbs of the city and larger housing estates, the transport service is provided by buses.

Metro in Prague was founded in 1974 and nowadays, it has three lines – A (green, 17 stations, 17 km), B (yellow, 24 stations, 26 km) and C (red, 20 stations, 22 km). Since 7th April 2015, the total length has been 65.1 kilometers with a total of 61 stations. All three lines meet in the city center at three interchange stations. Metro runs daily between 5 am and midnight. The frequency during the morning and afternoon peak hour is 2 to 3 minutes. The frequency in the evening and during the weekend is lower, between 4 to 10 minutes. The total number of passengers transported by metro in 2015 was 456 820 000 and approximately 1 566 000 people use metro lines daily. There is a plan to build the fourth line that will connect the city center with the southern part of the city (67; 68; 69).

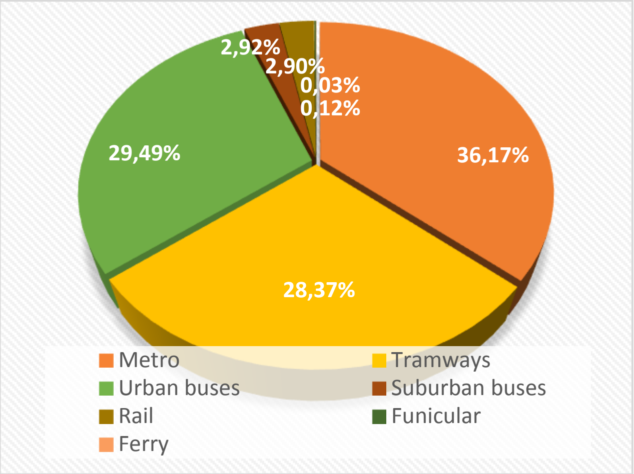
The tram service in Prague is provided by an extensive network of day (21 lines) and night (9 lines) trams. They have diametric, radial or tangential function and their length is 142.7 kilometers in total. Within the metropolitan public transport network, the most important backbone tram lines are: line number 3 (Kobylisy – Sídliště Modřany), line number 9 (Sídliště Řepy – Spojovací), line number 17 (Vozovna Kobylisy – Sídliště Modřany) and line number 22 (Bílá Hora – Nádraží Hostivař). These backbone tram lines have intervals of 4-5 minutes during the working days and 7-10 minutes during the evening and on weekends. There are also other tram lines that are less frequent. Within one working day, 6 200 trams transport 1 188 000 passengers and during the whole year of 2015, there were altogether 358 284 000 passengers transported by the tram service in Prague (69).

The first Prague's bus line from Malostranské náměstí to Pohořelec started to operate in 1908 (67). Within PID, there is an urban and suburban bus service that operates in Prague. The urban bus service creates a complementary network to the metro and trams and provides many important tangential connections and services of certain areas, especially in the outer part of the city. The bus network in Prague operates three types of buses: metrobus lines, standard lines and midibus lines. Metrobuses are often operated by articulated buses and they have priority on traffic lights. Midibus lines are smaller and they have lower capacity. These lines operate in less populated and less accessible neighbourhoods and they help to improve the travel conditions especially for passengers with mobility problems – all midibus lines are wheelchair accessible. There are 149 urban bus lines. The suburban bus service connects the city with surrounding regions. The total length of the bus network is 818 km, where there are 1 161 000 passengers transported every day (66; 69).

Rail transport within PID has been developed since 1992. Since 2007, suburban train lines have started to be labelled by letters S and R and they have focused on regular operation. In the last period, fast passage of rail lines through Prague is expanding. Nineteen train lines carry around 117 000 passengers on a 160-km-long track every day (69).

The funicular is part of PID, too and it provides the connection between Újezd, Nebozízek and Petřín. In 2015, it carried a total number of 1 480 000 passengers (daily average of 4 055 passengers). Ferries operating across the Vltava River became a part of public transport in 2005. They are used for recreational trips but increasingly more also as normal public transport. Six ferries that carried around 403 000 passengers have been in operation in 2015 (69).

Mode of transport	Passengers/year	%
Metro	456 820 000	36.17
Tramways	358 284 000	28.37
Urban buses	372 435 000	29.49
Suburban buses	36 855 000	2.92
Rail	36 669 000	2.90
Funicular	1 480 000	0.12
Ferry	402 700	0.03
Total	**1 262 945 700**	**100.00**



Graph 8: Number of transported passengers within PID in Prague for 2015 (69)

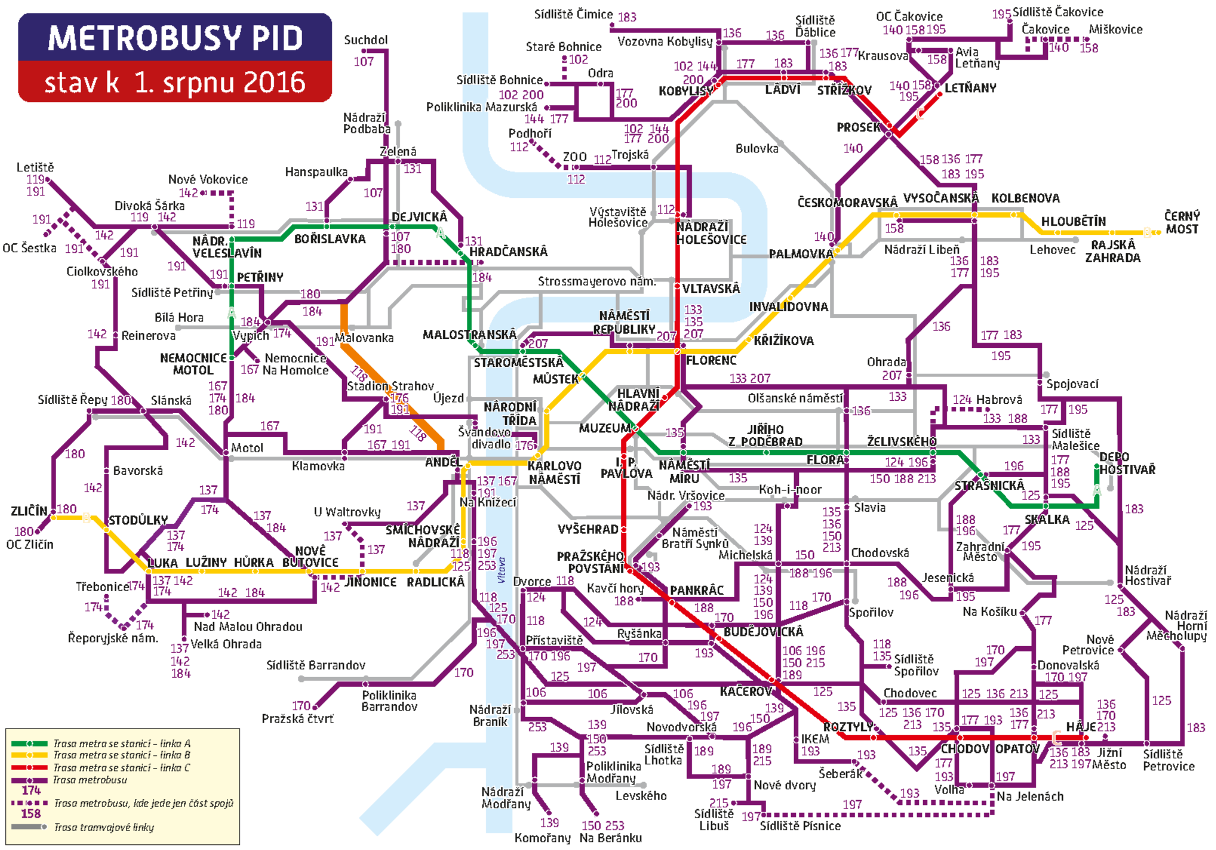


Fig. 56: Map of public transport in Prague, routes of metrobuses are in purple colour (66)

6.1.2 Metrobus in Prague

Metrobuses in Prague, also called the Metropolitan Network of Bus Lines, started to operate in 2012. Prague took an example of the successful implementation of metrobuses in German cities (Hamburg, Munich and Berlin) where the largest increase in passengers was recorded on tangential lines. These lines connect the outskirts of the city and enable passengers to get faster to their destination providing transport not through the city center but around it. There is a growing demand for long tangential directions in Prague, too. These lines also help to lighten some busy parts of the metro or trams in the center that are on the limit of their capacity (metro C from Kačerov to I.P.Pavlova). Last but not least, the aim of metrobuses was also to unify bus network, increase its attractiveness and effectiveness, increase the level of priority and offer public transport to passengers in places where rail public transport with higher capacity was missing completely (Prague 4, Prague 10). A survey among passengers in Prague showed that approximately 70 % of passengers prefer to use links with short intervals even at the cost of transfers rather than wait for a straight line with a longer interval (66; 70).

The introduction of metrobuses in Prague, as a new bus network, was more a political and marketing move to approximate to the western countries where the implementation of buses with a high level of service was successful and attracted many new passengers. In Prague, the existing backbone bus lines were renamed to metrobuses and other metrobuses were created by merging multiple standard lines. The improvements, such as priority of buses on light controlled intersections, implementations of bus lanes, usage of articulated buses, etc. had been implemented already several years before the introduction of metrobuses. However, since 2009, when the preparation of the new metrobus system started, these measures have increased rapidly and they have been applied primarily on the routes of future metrobus lines.

In Annex 10.2, there are graphs showing the development of reserved bus lanes and tram rail shared with buses in Prague. The first large set of preferential measures was implemented in 2009 when the length of reserved lanes increased by more than 100 % (8 065 meters of new reserved bus lanes and 870 meters of tram rail newly shared with buses). In 2012, another 4 130 meters of new reserved bus lanes and 990 meters of tram rail shared with buses were put in use. Furthermore, preference for buses at light controlled intersections was introduced at 23 intersections. The vast majority of these measures was focused on the main axes of the metropolitan bus network, which runs on roads with high-intensity individual automobile transport – in critical sections of roads in terms of the quality of operation of metrobus lines (71).

Fig. 57: Dedicated bus lanes (Opatovská Street) and tram rail shared with buses (Plzeňská Street) (71)

There are altogether 38 lines of metrobuses in Prague as of March 2016 (Note: The stations in brackets are not operated by part of the lines):

- **102** KOBYLISY – Dunajecká – SÍDLIŠTĚ BOHNICE – (STARÉ BOHNICE)
- **106** NÁDRAŽÍ BRANÍK – Na Lysinách – Novodvorská – KAČEROV
- **107** DEJVICKÁ – Zemědělská univerzita – SUCHDOL
- **112** NÁDRAŽÍ HOLEŠOVICE – Trojská – ZOOLOGICKÁ ZAHRADA – (PODHOŘÍ)
- **118** SÍDLIŠTĚ SPOŘILOV – Budějovická – Dvorce – SMÍCHOVSKÉ NÁDRAŽÍ
- **119** NÁDRAŽÍ VELESLAVÍN – Divoká Šárka – Dědina – LETIŠTĚ
- **124** DVORCE – Zemanka – Budějovická – Kloboučnická – ŽELIVSKÉHO – (HABROVÁ)
- **125** SMÍCHOVSKÉ NÁDRAŽÍ – Háje – Sídliště Petrovice – Nádraží Hostivař – SKALKA
- **131** HRADČANSKÁ – Zelená – Juliska – Hanspaulka – BOŘISLAVKA
- **133** FLORENC – Ohrada – Třebešín – SÍDLIŠTĚ MALEŠICE
- **135** FLORENC – Náměstí Míru – Slavia – Spořilov – CHODOV
- **136** VOZOVNA KOBYLISY – Prosek – Vysočanská – Ohrada – Flora – Slavia – Spořilov – Opatov – Háje – JIŽNÍ MĚSTO
- **137** NA KNÍŽECÍ – Malvazinky – U WALTROVKY – (Nové Butovice – VELKÁ OHRADA)
- **139** ŽELIVSKÉHO – Na Míčánkách – Kloboučnická – Kačerov – Lhotka – KOMOŘANY
- **140** PALMOVKA – Prosek – Letňany – Tupolevova – Ke Stadionu – ČAKOVICE
- **142** NOVÉ BUTOVICE – Velká Ohrada – Luka – Stodůlky – Slánská – Sídliště Na Dědině – NÁDRAŽÍ VELESLAVÍN – (NOVÉ VOKOVICE)

- **144** KOBYLISY – Dunajecká – POLIKLINIKA MAZURSKÁ
- **150** (ŽELIVSKÉHO – Slavia – Michelská) – KAČEROV – Lhotka – NA BERÁNKU
- **158** (ČESKOMORAVSKÁ – Vysočanská – Prosek) – LETŇANY – Staré Letňany – AVIA LETŇANY / KRAUSOVA – (OC Čakovice – MIŠKOVICE)
- **167** NA KNÍŽECÍ – Anděl – Kotlářka – Nemocnice Motol – NEMOCNICE NA HOMOLCE
- **170** JIŽNÍ MĚSTO – Háje – Brechtova – Spořilov – Budějovická – Branické náměstí – Přístaviště – Poliklinika Barrandov – PRAŽSKÁ ČTVRŤ
- **176** KARLOVO NÁMĚSTÍ – Švandovo divadlo – STADION STRAHOV
- **177** CHODOV – Opatov – Na Košíku – Skalka – Sídliště Malešice – Spojovací – Vysočanská – Prosek – Kobylisy – Podhajská pole – POLIKLINIKA MAZURSKÁ
- **180** DEJVICKÁ – Vypich – Nemocnice Motol – Sídliště Řepy – (ZLIČÍN) – OBCHODNÍ CENTRUM ZLIČÍN
- **183** HÁJE – Sídliště Petrovice – Janovská – Nádraží Hostivař – Perlit – Spojovací – Vysočanská – Prosek – Kobylisy – Vozovna Kobylisy – SÍDLIŠTĚ ČIMICE
- **184** (HRADČANSKÁ) – KUKULOVA / VYPICH – Nemocnice Motol – Nové Butovice – VELKÁ OHRADA
- **188** ŽELIVSKÉHO – Sídliště Malešice – Strašnická – Jesenická – Michelská – Pankrác – KAVČÍ HORY
- **189** KAČEROV – Nemocnice Krč – Tempo – SÍDLIŠTĚ LHOTKA
- **191** NA KNÍŽECÍ – Klamovka – Stadion Strahov – Vypich – Petřiny – CIOLKOVSKÉHO – (OC ŠESTKA – LETIŠTĚ)
- **193** NÁDRAŽÍ VRŠOVICE – Náměstí Bratří Synků – Pankrác – Krčský hřbitov – Poliklinika Budějovická – Nemocnice Krč – ŠEBERÁK – (Na Proutcích) – VOLHA – CHODOV
- **195** SÍDLIŠTĚ ČAKOVICE – Tupolevova – Letňany – Prosek – Vysočanská – Spojovací – Sídliště Malešice – Skalka – JESENICKÁ
- **196** SMÍCHOVSKÉ NÁDRAŽÍ – Přístaviště – Novodvorská – KAČEROV (– Michelská – NAD VINNÝM POTOKEM)
- **197** SMÍCHOVSKÉ NÁDRAŽÍ – Přístaviště – Novodvorská – Sídliště Lhotka – Pavlíkova – SÍDLIŠTĚ PÍSNICE – (Na Proutcích) – NA JELENÁCH – Chodov – Benkova – HÁJE
- **200** KOBYLISY – Podhajská pole – Odra – SÍDLIŠTĚ BOHNICE
- **207** STAROMĚSTSKÁ – Náměstí Republiky – Florenc – OHRADA
- **213** ŽELIVSKÉHO – Slavia – Spořilov – Opatov – Háje – JIŽNÍ MĚSTO
- **215** KAČEROV – Nemocnice Krč – Tempo – Pavlíkova – SÍDLIŠTĚ LIBUŠ
- **253** SMÍCHOVSKÉ NÁDRAŽÍ – Pobřežní cesta – Zátišská – NA BERÁNKU

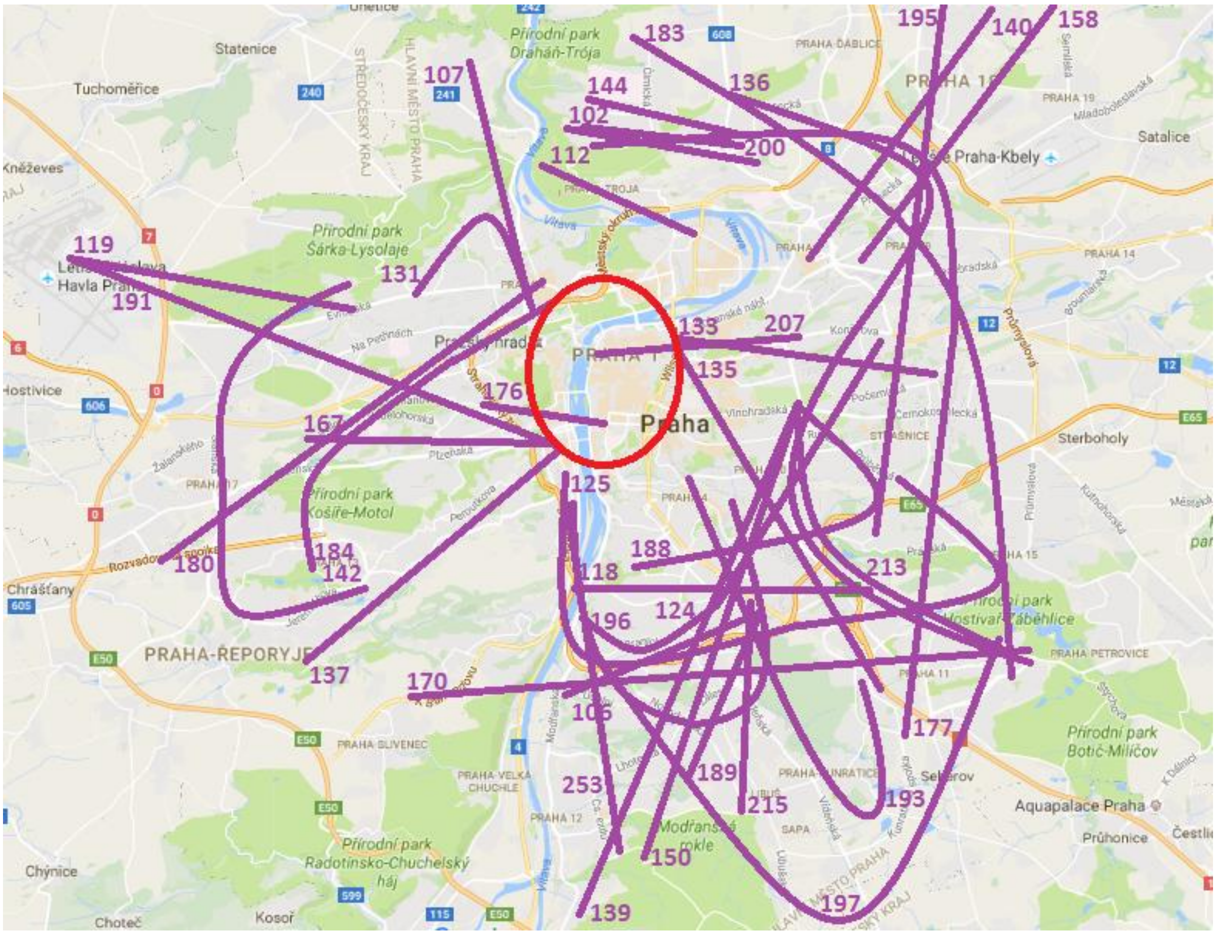


Fig. 58: Scheme of thirty-eight metrobuses in Prague with the city center marked in red

Metrobuses in Prague have some improved parameters which ROPID defined as:

- provision of important connections, operation during the whole day and the whole week,
- direct routes with minimum of detours,
- less lines with shorter intervals (6-8 min. during peak hours, 12-15 min. during off-peak hours),
- articulated buses being used,
- different kinds of priority being used on their routes (66).

Prague's metrobuses have a special designation at stops as well as on vehicles. At the bus stop, the number of the metrobus line is marked in a frame and it has purple colour. On the bus, unlike regular buses, the number of the Metrobus line is written in a frame (66).

The motivation and objectives for metrobuses in Prague:

- increase the punctuality and speed,
- provide a response to the lack of public transport capacity in some corridors (where the rail public transport is missing),
- economic reasons (13).

6.2 Problems of Prague's metrobuses

Recently, 4 years after the implementation of metrobuses in Prague, the management in ROPID has changed the head director and there is a plan to invest more in rail transportation rather than in the metrobus system. Therefore, now, there is a question, whether it is better to cancel all metrobuses and rename them back to the backbone lines, or to select metrobus lines with the highest demand on which to promote preferential measures, increase the overall quality of these lines and significantly distinguish them from the regular bus system.

There are some problems on the existing metrobus network in Prague:

- **no basic concept of the metrobus network with future development,**
- **metrobuses are not a superior system to regular bus lines – lack of hierarchy,**
- **minimum or no differences between metrobuses and regular bus lines,**
- **very high number of metrobus lines,**
- **not all parameters defined for metrobuses in Prague are complied with,**
- **the routes of lines often change.**

Prague has an extensive rail network that creates the backbone of the public transportation system. Buses were always complementary transport vehicles in areas where there was no rail transport or where it was not sufficient. **Metrobuses were supposed to bring some level of hierarchization to the bus network with dedicated and unique features and strong identification.**

In Prague, the concept of hierarchization of the bus network was prepared (metrobuses/regular buses/midibuses). However, the hierarchy between metrobuses and regular buses is not visible. Some metrobus lines were renamed from backbone lines, some metrobus lines were formed by combination of more lines into one and some of them were chosen according to the current needs. **From all these lines, a metrobus network lacking logic was created. Since the beginning, there has been no basic concept of what this metrobus network should look like and how it is going to develop in the future.**

Another problem is, that there is almost no difference between metrobuses and regular buses. **The effort is to give the metrobus lines some privileges, such as higher-capacity vehicles, dedicated bus lanes, priority at light intersections or more comfortable stations. However, these measures are observed on regular bus lines as well.** Moreover, it is possible to observe that there are some metrobus lines that are operated by non-articulated buses (such as lines 102, 106, 124, 131, 133, 207, etc.) with no reserved bus lanes on their route (such as metrobus lines 131, 176 or 207) and with no tram rail shared with buses (line 131). On the other hand, there are some regular bus lines that use articulated buses and their routes go through the stretches of dedicated bus lanes (such as regular bus lines 152, 232 or 261). **These facts cause confusion of what is and what is not a metrobus** and, in some cases, it may seem that the only difference between regular buses and metrobuses is the purple frame with the number of the metrobus line on the station.

There are only a few metrobus or BRT lines/corridors introduced in huge cities that were described in previous chapters (Buenos Aires has six corridors and Rio de Janeiro only four). They started with the implementation of one metrobus line/corridor, after that they implemented another one and little by little it was growing into a bigger metrobus/BRT network. **What happened in Prague was that in 2012, thirty-eight metrobus lines were implemented at once without any plans of their future growth. Now, it is difficult to give all the priority, quality and comfort required from metrobus to all these lines.**

Not all parameters of metrobuses established in the beginning are complied with. For example, **many lines do not satisfy the criterion of direct routes with minimum detours** (for example, metrobus lines 124, 137, 142, 158, 170, 193, 197, etc.). **The routes of some lines did not change by the implementation of metrobuses and the routes of other lines have changed but not in order to straighten the route but according to the current necessity.** Direct routes are not possible to do everywhere because they depend on the local transport network, however, in many cases, there is a possibility to optimize the route in order to speed up buses. Direct routes with minimum detours provide higher speeds and most passengers prefer faster travel at the expense of longer walking distances to the station. **Not all lines satisfy the interval of 12-15 min. during off-peak hours.** The intervals in the evening are usually longer – 20 min. (lines 140, 142, 144, 150, etc.). As already said in the paragraph above, **not all the lines use articulated buses and not all of them have priority measures used on their routes**.

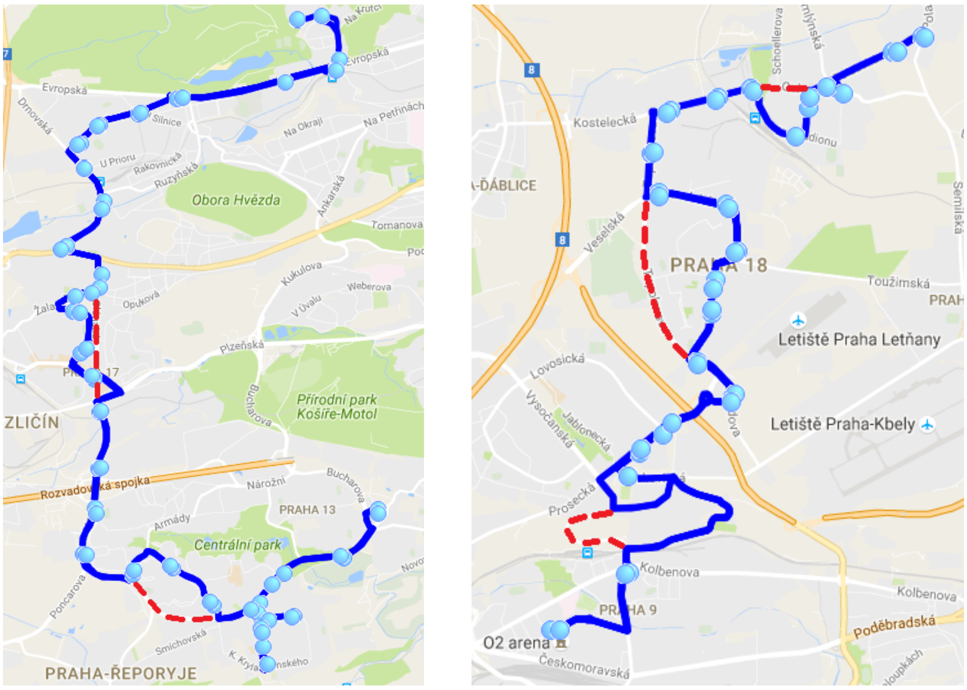


Fig. 59: Examples of metrobus lines (line 142 on the right and line 158 on the left) that do not have direct routes with possible route marked in red (72)

Last but not least, **the routes of some metrobus lines are changing very often, which makes them unstable and unreliable for passengers**. Several changes in the routes of metrobus lines have been made since the implementation of metrobuses in Prague. In 2012, route or station modifications were made on many bus lines so that they could become metrobus lines: 102, 106, 118, 124, 125, 135, 136, 137, 139, 150, 170, 176, 180, 183, 191, 193, 196, and 197. **The aim was to reduce the number of bus lines** (73).

In 2013, it was necessary to make corrections of the routes of some metrobus lines:

- line 106 was shortened to the route Kačerov – Roztyly, in the section Nádraží Braník – Psohlavců it newly went through Černý kůň, Na Lysinách and Jitřní station;
- line 135 was shortened by the section Chodov – Koleje Jižní Město (replaced by line 197);
- line 170 newly went through Donovalská, Benkova and Brodského station in the section Brechtova – Chodovec;
- line 193 was extended (only some lines) by the section Šeberák – Volha – Chodov;
- line 197 went through new stations Na Jelenách, Chodov, Brodského, Donovalská and Brechtova to Háje station (74).

In 2014, there were some changes of the routes of metrobus lines, too:

- line 112 in the direction of Nádraží Holešovice newly went over Troja bridge;
- line 176 was shortened to the route Karlovo Náměstí – Stadion Strahov;
- line 180 was extended to the station Obchodní centrum Zličín (75; 76).

In 2015, other changes followed:

- line 119 was shortened to Nádraží Veleslavín metro station;
- line 131 was diverted from Hanspaulka station to the new Bořislavka metro station;
- line 137 was diverted from Bucharova to Bavorská station;
- line 142 and 184 were newly created;
- line 191 was extended by the section Sídliště Petřiny – Divoká Šárka – Ciolkovského – OC Šestka – Letiště (77).

Finally, the year 2016 brings another series of big transformations. In October 2016, many metrobus lines will change their routes again. **The aim of these bus changes is to have more lines with fewer transfers.**

- Line 102 – some of the buses will be extended from Kobylisy station through Poliklinika Čumpelíkova to the final station Šimůnkova;
- Line 124 – in the direction to Dvorce the line will go through Poliklinika Budějovická station
- Line 136 – in the direction to Jižní Město the line will be diverted from Prosek station to Letňany, Tupolevova, Nádraží Čakovice and Sídliště Čakovice stations;
- Line 140 – some of the buses will be extended by the section Čakovice – Miškovice;
- Line 158 – the route will be shortened by the section Českomoravská – Letňany and from Čakovice it will be diverted to Třeboradice;
- Line 183 – in the northern part it will be diverted to the area of Žernosecká street (Třebenická – Sídliště Ďáblice – Vozovna Kobylisy);
- Line 193 – in the direction from Nádraží Vršovice it will be shortened to Šeberák station;
- Line 195 – in the southern part it will be diverted from Tupolevova street to Staré Letňany station – Avia Letňany / Krausova;
- Line 196 – will be shortened and diverted from Michelská to Kloboučnická station (78; 79).

From the previous, it is visible that every year there were changes of the routes of some metrobus lines while bigger changes were made in 2013 and 2015 and the biggest one since 2012 will come this year, in 2016. **One of the goals of the implementation of metrobuses in 2012 was to reduce the number of bus lines because there were too many of them and the bus network was not synoptic. However, in 2016, there is another goal – to increase the number of bus lines back again and to reduce transfers. This disunity causes confusion. It is necessary to have an elementary concept of the metrobus network with its goals and a plan for the future development.**

6.3 Surveys and real facts of Prague's metrobuses

In Prague, it is not possible to use The BRT Standard for evaluating Prague's metrobuses because they do not meet the most basic parameter of this Standard. There is no metrobus line in Prague whose route could be named as a corridor – at least a 3-kilometer-long route with dedicated lanes – and, thus, the other evaluation according to The BRT Standard cannot be done. Therefore, Prague's metrobuses are assessed according to the obtained surveys and data.

The facts and surveys of thirty-eight Prague's metrobus lines are summarized in this chapter. They are divided into three subchapters – transport demand surveys, preference and other criteria. The data were obtained from the Prague's transport organizations – ROPID, DPP and TSK. All data are recorded on the attached CD.

6.3.1 Summary of metrobuses according to transport demand surveys

Tab. 63 shows on a summary of the demand for metrobuses in Prague from available surveys.

Tab. 63: The number of passengers per day

		Number of passengers per day (6:00 a.m. to 8:00 p.m.) according to surveys							
Num.	**Total length [km]**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**P/Km/ Day**
102	8.50	9 378	-	9 138	-	6 155	-	-	724
106	15.15	12 543	-	-	11 461	-	-	9 205	608
107	11.95	-	23 764	-	-	22 329	-	-	1 869
112	7.15	7 380	-	6 056	-	8 165	-	-	1 142
118	21.8	9 438	-	-	13 179	-	14 951	-	686
119	17.50	-	12 494	-	-	14 132	-	-	808
124	22.10	16 730	-	-	18 252	-	-	19 693	891
125	48.10	-	5 310	-	30 915	-	29 861	-	621
131	11.30	-	12 700	-	-	12 133	-	-	1 074
133	12.85	22 265	-	11 290	-	-	-	-	879
135	26.10	21 452	-	-	28 276	-	-	22 471	861
136	46.45	37 669	-	36 642	37 942	35 923	-	37 905	816
137	24.40	-	11 368	-	10 591	11 950	13 328	-	546
139	30.50	21 865	-	-	19 254	-	-	19 639	644
140	20.70	14 476	-	13 368	-	11 586	-	-	560
142	33.60	-	547	-	-	-	-	-	16
144	6.95	8 017	-	7 592	-	7 610	-	-	1 095
150	28.55	9 073	-	-	16 347	-	-	17 272	605
158	24.00	-	-	11 116	-	11 396	-	-	475
167	15.35	-	18 199	-	14 751	14 187	-	-	924
170	39.70	8 700	-	-	16 452	-	17 313	-	436
176	9.15	-	7 477	-	6 031	8 457	6 178	-	675
177	55.70	41 679	-	40 079	43 457	-	-	42 967	771
180	29.30	-	9 543	-	13 375	12 219	15 788	-	539
183	54.20	20 813	-	21 538	24 628	-	-	27 758	512
184	25.35	-	3 448	-	-	-	-	-	136
188	27.30	30 359	-	27 727	24 594	-	-	24 111	883
189	8.75	12 261	-	-	10 493	-	-	9 552	1 092
191	40.95	-	6 101	-	5 402	8 659	-	-	211
193	34.75	17 434	-	-	22 168	-	-	26 005	748
195	36.55	25 539	-	-	25 605	-	-	24 611	673
196	35.35	5 260	6 058	-	21 158	-	17 898	-	506
197	45.45	15 677	14 099	-	22 839	-	23 373	-	514
200	8.20	16 237	-	15 316	-	15 563	-	-	1 898
207	10.75	-	-	11 703	-	-	-	14 440	1 343
213	21.25	16 224	-	-	15 579	-	-	14 242	670
215	9.40	10 292	-	-	14 665	-	-	9 671	1 029
253	18.90	11 434	9 952	-	10 960	-	9 687	-	513

The lines marked in grey are the lines whose routes have changed and after the change there was no survey done and, therefore, it is impossible to make any conclusions from the surveys of these lines. The lines marked in yellow – 125, 136 and 177 – are long tangential lines with the highest demand along their route. The lines marked in green – 107, 200 and 207 – are very short local or radial lines with the highest demand in terms of passengers per kilometer per day.

Unfortunately, it is hard to make good conclusions from these surveys. Firstly, because they were done by people (mostly students) and people are fallible. It is easy to make mistakes in calculations, especially if the demand is high. Another important point is that these surveys were done only during one day of a year. There were no observations from more days that could be averaged in order to achieve more accurate results. However, this should be changed soon and students will be replaced by sensors fixed into the frame of the bus door. These sensors will count passengers entering and exiting the bus with a much higher or absolute accuracy and more often. Secondly, it is hard to make conclusions from these surveys because the routes of some lines have changed during the years. Some of them were shortened, some of them were extended and some lines changed part of their route completely. Therefore, it is difficult to make some realistic evaluation of such metrobus lines. However, there are no other data available and therefore, it is calculated with these demand surveys. In lines without changes of the route, we can see if the demand has an increasing or decreasing tendency and whether the introduction of metrobuses was effective. Greater accuracy would be achieved by long-term monitoring (more than three years from the implementation).

Tab. 64: The change of routes on metrobus lines in Prague

102	In 2012 the route was shortened to Kobylisy station
106	In 2012 the route was changed, in 2013 it was shortened to Kačerov and newly continued to Hodkovičky
107	Since 1978 the route has been without changes
112	In 2014 the route in the direction to Nádraží Holešovice was diverted over Troja bridge
118	In 2012 the route was changed
119	In 2015 the route was shortened to Nádraží Veleslavín
124	In 2012 the locations of some stations were changed
125	The line was introduced in 2010; in 2012 the route was extended to Skalka station
131	In 2015 the route was changed to Bořislavka metro station
133	In 2011 the route was shortened from Florenc to Sídliště Malešice
135	In 2013 the route was shortened to Chodov
136	In 2012 the route was changed to Jižní město
137	In 2012 the route was extended to Nové Butovice, in 2015 the route was partly changed
139	In 2012 the route was changed to Modřany and Komořany
140	Since 2008 the route has been without changes (only from May 2014 to May 2015 the route was diverted to Českomoravská due to a long-term lock-out)
142	In 2011 the line was cancelled; in 2015 it was renewed again
144	Since 2004 the route has been without changes
150	In 2012 the route was extended to Baba and Na Beránku
158	Since 2009 the route has been without changes
167	Since 1993 the route has been without changes
170	In 2012 the route was extended and diverted to Pražká čtvrť; in 2013 it was diverted back to Chodovec
176	In 2012 the route was extended to Nové Butovice; in 2014 it was shortened back to Stadion Strahov
177	Since 1995 the route has been without changes
180	In 2012 the route was extended to Zličín; in 2014 it was extended to Obchodní centrum Zličín

183	In 2012 the route was extended to Háje
184	In 2015 the route changed from Velká Ohrada through Motol to Hradčanská
188	Since 1987 the route has been without changes
189	In 2012 line 182 was cancelled and now only strengthened line 189 is in operation
191	In 2015 the route was extended and the intervals were shortened
193	In 2012 the route was extended to Šeberák; in 2013 another extension to Chodov
195	Since 2008 the route has been without changes
196	In 2012 the route was extended from Kačerov to Strašnická
197	In 2012 a concurrent line 198 was cancelled; in 2013 the route was extended to Háje
200	Since 2004 the route has been without changes
207	In 2008 the line was cancelled; in 2011 it started to operate again
213	Since 2005 the route has been without changes
215	In 2012 line 117 with a similar route was cancelled
253	Since 1988 the route has been without changes

From Tab. 64, it can be observed that there has been **no change of the route of metrobus lines 107, 140, 144, 158, 167, 177, 188, 195, 200, 213 and 253 during the last 6 years (at least since 2009)**. If we compare these lines with Tab. 63 *shows on a summary of the demand for metrobuses in Prague from available surveys.*

Tab. 63, we can observe how the demand changed before and after the implementation of metrobuses, in 2012. **Lines 144, 158, 195, 200 and 253 almost did not change the demand and those that did changed very little or not at all** and it is necessary to take into account the deviation from measurements. **A slight decrease in the demand can be seen in lines number 107 and 213, a bigger decrease in the demand is observable in lines 140, 167 and 188**. The only line where it is possible to observe **a very slight increase in demand is line 177**.

These results are not very satisfactory because the demand for most bus lines after the implementation of metrobuses remained unchanged or even decreased. This can be due to the fact that some other newly created lines dragged the demand for those lines. However, it is still necessary to take into account that these surveys were done by people and it is not possible to state how credible the results are.

From the surveys of other lines it is not possible to make conclusions whether the metrobuses are efficient or not because their routes have changed during and/or after the implementation of metrobuses and there are not enough surveys after the year 2012 (at least two of them in different years while the route of lines would remain unchanged) to make some true inferences.

6.3.2 Summary of metrobuses according to the amount of preference

The measure of preference or priority of buses is important for labelling the buses as metrobuses or BRT. These features influence the speed of the lines. Tab. 65 is divided into four parts. The first part informs about the total length (round trip) of the route of the line and the type of route (urban, local, radial, tangential, circular, etc.). The other two parts describe two main types of preferences – the length of the reserved bus lanes (partly shared with taxis and cyclists) together with the tram rail shared with buses and the priority at controlled intersections – for each Prague's metrobus line. This information was found out from tables of locations of reserved lanes and tables and maps of locations of controlled intersections with and without priority obtained from ROPID and DPP. The last column informs about the speed of each line (the commercial speed calculated as the average speed of the speeds from all periods of the day).

Tab. 65: The measures of priority of metrobuses in Prague

Num.	Total length [km]	Total length of reserved bus lanes [km]	Total length of tram rail shared with buses [km]	Reserved lanes length/ Route length [%]	Controlled intersec. with priority	Total num. of control. intersec.	Controlled inter. with priority/ Total num. of controlled inter. [%]	Speed [km/h]
102	8.50	0.350	0.000	**4.1**	13	13	**100.0**	27.5
106	15.15	1.130	0.000	**7.5**	6	10	**60.0**	23.0
107	11.95	1.100	0.120	**10.2**	6	8	**75.0**	29.8
112	7.15	0.125	0.320	**6.2**	3	10	**30.0**	24.7
118	21.8	0.765	0.000	**3.5**	21	44	**47.7**	25.7
119	17.50	1.650	0.000	**9.4**	2	22	**9.1**	29.9
124	22.10	0.490	0.580	**4.8**	35	42	**83.3**	19.2
125	48.10	4.295	0.000	**8.9**	17	38	**44.7**	32.2
131	11.30	0.000	0.000	**0.0**	6	10	**60.0**	21.4
133	12.85	0.130	0.000	**1.0**	10	24	**41.7**	21.4
135	26.10	0.890	1.820	**10.4**	31	64	**48.4**	20.6
136	46.45	4.375	1.005	**11.6**	65	96	**67.7**	22.6
137	24.40	0.300	0.000	**1.2**	4	34	**11.8**	23.1
139	30.50	2.525	0.990	**11.5**	43	66	**65.2**	22.0
140	20.70	1.430	0.000	**6.9**	15	20	**75.0**	25.0
142	33.60	0.450	0.000	**1.3**	6	46	**13.0**	23.5
144	6.95	0.350	0.000	**5.0**	13	13	**100.0**	31.4
150	28.55	3.450	0.990	**15.6**	47	60	**78.3**	23.5
158	24.00	0.825	0.000	**3.4**	20	23	**87.0**	25.6
167	15.35	0.745	0.490	**8.0**	2	34	**5.9**	24.5
170	39.70	2.300	0.000	**5.8**	24	59	**40.7**	23.3
176	9.15	0.000	0.520	**5.7**	4	18	**22.2**	21.6
177	55.70	2.160	0.300	**4.4**	85	108	**78.7**	24.2
180	29.30	0.360	2.030	**8.2**	11	52	**21.2**	23.3
183	54.20	2.920	0.000	**5.4**	60	86	**69.8**	26.6
184	25.35	0.660	1.930	**10.2**	14	59	**23.7**	26.2
188	27.30	0.705	0.780	**5.4**	34	53	**64.2**	23.1
189	8.75	0.810	0.000	**9.3**	2	14	**14.3**	23.3
191	40.95	1.205	1.170	**5.8**	4	40	**10.0**	24.6
193	34.75	1.015	0.975	**5.7**	16	51	**31.4**	23.9
195	36.55	2.485	0.300	**7.6**	46	54	**85.2**	23.2
196	35.35	2.205	0.410	**7.4**	39	48	**81.3**	24.7
197	45.45	1.050	0.000	**2.3**	19	42	**45.2**	27.5
200	8.20	0.350	0.000	**4.3**	15	15	**100.0**	27.0
207	10.75	0.000	1.875	**17.4**	14	32	**43.8**	16.7
213	21.25	4.625	0.855	**25.8**	28	48	**58.3**	23.5
215	9.40	0.640	0.000	**6.8**	2	14	**14.3**	23.0
253	18.90	1.150	0.000	**6,1**	11	28	**39.3**	29.1

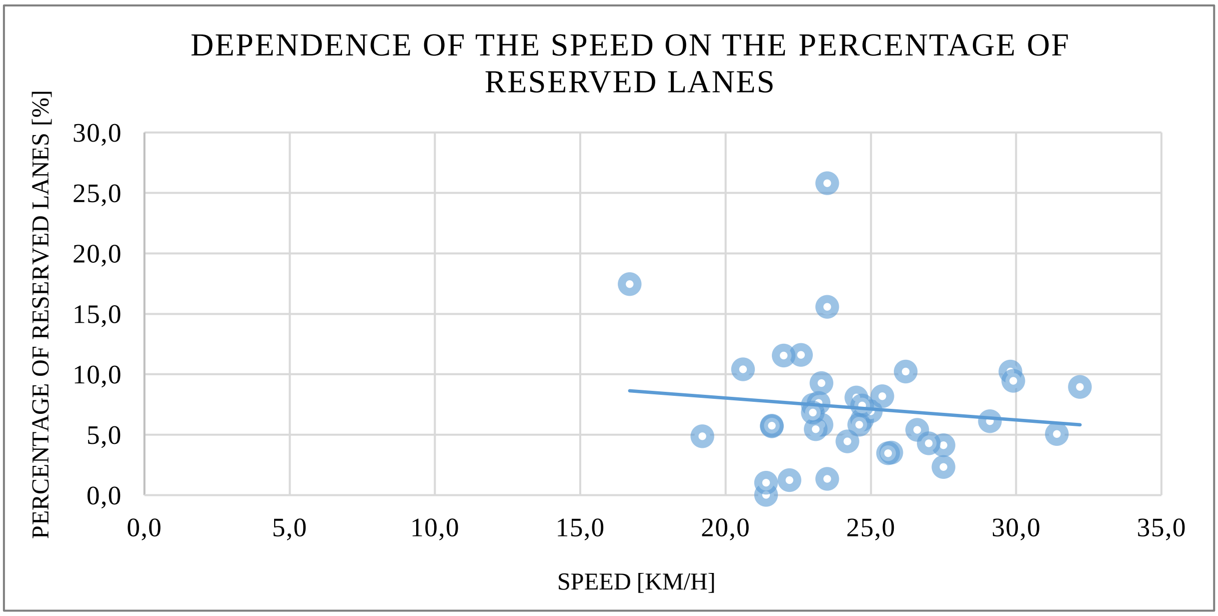
The green colour is used for the top three cases of the highest percentage of the length with reserved lanes (both cases included – reserved bus lanes and tram rail shared with buses), controlled intersections with priority and for the highest speed. The yellow colour is used for other top 5 to 10 cases. The grey colour is used for the worst cases.

From the results of the section – **The length of reserved bus lanes (partly shared with taxis and cyclists) and tram rail shared with buses** – in Tab. 65, it can be observed that the highest percentage of reserved lanes is found on metrobus lines:

- **213 – with 25.8 % of its route on reserved lanes,**
- **207 – with 17.4 % of its route on reserved lanes,**
- **150 – with 15.6 % of its route on reserved lanes.**

Lines 107, 135, 136, 139 and 184 also have quite high percentages of bus lanes in comparison with other lines – between 10 to 12 % of their route is operated on reserved lanes. Comparing these results with the speed of metrobuses we find out that the speed is not much affected by the total length of reserved lanes. For example, line 213 with the highest percentage of reserved bus lanes has quite a low speed (in comparison with other lines). Line 207 with the second highest percentage of reserved lanes has the lowest speed – 16.7 km/h. On the other hand, the metrobus line with the highest speed, line 125, does not belong to the top seven lines with the greatest length of reserved bus lanes, however, it belongs to a better average.

From Graph 9, it is visible that there is **no dependence of the speed of metrobuses on the percentage of reserved lanes (reserved bus lanes shared with taxis and cyclists and tram rail shared with buses). A higher percentage of reserved lanes does not result in higher speeds. In fact, the tendency is reversed. From the trend line in the graph, it is possible to observe that the higher the percentage of reserved lanes, the lower the speeds.** The length of the segments with reserved lanes is, in Prague, usually too short to influence the speed in a larger scale.



Graph 9: Dependence of the commercial speed on the percentage of reserved lanes

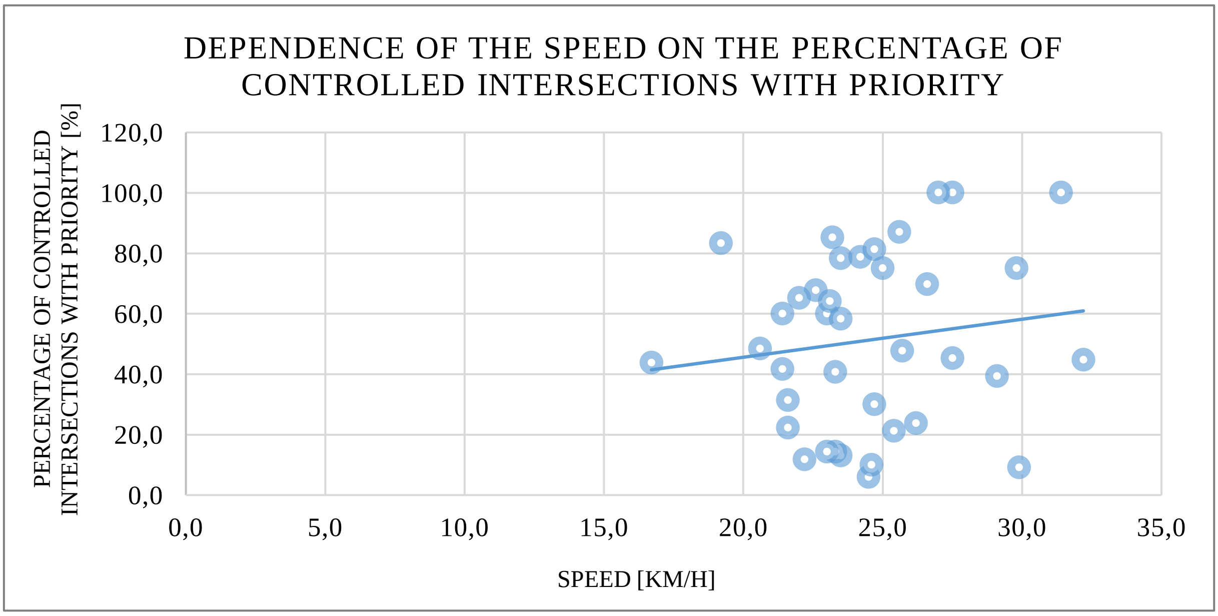
From the results of the section – **Priority at controlled intersections** – in Tab. 65, it can be observed that the highest ratio between controlled intersections with bus priority and the total number of controlled intersections along the route is found out on metrobus lines:

- **102 – 100 % of controlled intersections along the route are with bus priority,**
- **144 – 100 % of controlled intersections along the route are with bus priority,**

- **200 – 100 % of controlled intersections along the route are with bus priority.**

Lines 107, 124, 140, 150, 158, 177, 195 and 196 also have a high number of controlled intersections with bus priority – between 75-90 % from the total number of controlled intersections along the route. From Tab. 65, it can be observed that, generally, **the percentage of controlled intersections with bus priority does not affect the speed of the metrobus line, similarly as in the case of reserved bus lanes.** For example, line 125 with the highest speed belongs, in terms of the percentage of controlled intersections with bus priority, to a lower average – only 44.7 % of controlled intersections with bus priority from the total number of controlled intersection along the route. Another example, line 119 with the third highest speed has the second lowest percentage of controlled intersections with priority along the route. On the other hand, all three lines with the highest percentage of controlled intersections with bus priority along the route (line 102, 144 and 200) have a high speed, too.

From Graph 10, it is visible that there is **no dependence of the speed on the percentage of controlled intersections with priority. A higher percentage of controlled intersections with priority does not always result in higher speeds. However, from the trend line in the graph, it is visible that the tendency is slightly growing.**



Graph 10: Dependence of speed on the number of controlled intersections with priority

Reserved bus lanes together with priority at controlled intersections should yield higher speeds. Nevertheless, if we compare the results from both types of preference measures with the final commercial speed we find out that this statement is not true.

For example, line 150 have both preference parameters among the highest but its speed ranks it as a lower average. On the other hand, line 125 with the highest speed is characterized neither by a very high percentage of reserved bus lanes nor by a high percentage of controlled intersections with bus priority.

From such results it is possible to say that the speed of Prague's metrobuses does not depend that much on the level of priority but on many more other factors. These factors include, for example:

- **density of other traffic,**
- **spacing between stations,**
- **number of intersections (both, with or without priority) along the way,**
- **whether the routes are direct or whether there are many detours.**

6.3.3 Summary of metrobuses according to other criteria

This section describes Prague's metrobuses according to other criteria – such as the type of route, type of vehicle, stop spacing, frequency and integration.

Tab. 66: Other criteria of Prague's metrobuses

Num.	Type of the route	P/Km /Day	Type of vehicle	Low-floor [%]	Num. of stops	Stop spacing [km]	Frequency [min]		Integra - tion with metro
							Peak hour	Off-peak hour	
102	local	724	standard	52.8	10	0.505	6 / 7,5	15 / 20	C
106	local	608	standard	77.8	15	0.477	6 / 7-8	15 / 20	C
107	radial	1869	articulated	24.4	11	0.559	2-6 / 2-7	3-6 / 20	A
112	local	1142	art./stand.	100.0	8	0.513	7,5 / 5-10	6-10 / 15-20	C
118	tangential	686	art./stand.	72.0	18	0.614	6 / 7,5	15 / 20	B, C
119	radial	808	articulated	90.1	10	0.840	5-6 / 6-7,5	6-10 / 10	A
124	tangential	891	standard	71.1	29	0.455	6 / 7,5	15 / 20	A, C
125	tangential	621	articulated	73.6	29	0.834	4-5 / 6	12 / 20	A, B, C
131	local	1074	standard	74.9	11	0.518	4-5 / 6	10-12 / 15	A
133	radial	879	standard	49.7	14	0.457	6 / 6	10 / 20	B, C
135	radial	861	articulated	82.3	24	0.546	6 / 7,5	12 / 20	A, B, C
136	tangential	816	articulated	81.1	40	0.610	6 / 7,5	10 / 20	A, B, C
137	radial	546	standard	86.8	26	0.475	4 / 4	7,5 / 10-20	B
139	tangential	644	articulated	62.1	30	0.502	6 / 6	10 / 20	A, C
140	radial	560	articulated	75.0	19	0.558	6 / 6	10 / 20	B, C
142	tangential	16	standard	44.4	34	0.521	6 / 7,5	10 / 20	A, B
144	local	1095	art./stand.	79.9	6	0.550	6 / 7-8	15 / 20	C
150	tangential	605	articulated	64.9	25	0.584	6 / 7,5	15 / 20	A, C
158	radial	475	standard	56.0	20	0.628	2-8 / 3-7,5	15 / 20	B, C
167	radial	924	articulated	85.9	12	0.638	6 / 7,5	10 / 20	A, B
170	tangential	436	standard	75.5	38	0.528	6 / 7,5	15 / 20	C
176	radial	675	standard	100.0	9	0.483	6 / 7,5	10 / 20	B
177	tangential	771	articulated	66.0	43	0.651	6 / 7,5	15 / 20	A, B, C
180	tangential	539	articulated	58.6	20	0.755	6 / 7,5	15 / 20	A, B
183	tangential	512	standard	55.2	41	0.680	6-8 / 7-8	15 / 12-20	B, C
184	radial	136	standard	51.1	20	0.645	6-8 / 7-8	15 / 10-20	A, B
188	tangential	883	articulated	70.8	29	0.509	6-8 / 7-8	15 / 10-20	A, C
189	local	1092	articulated	59.5	9	0.478	6-12 / 7-8	15 / 7-20	C
191	radial	211	art./stand.	61.2	35	0.579	5-10 / 7-15	10 / 15	B
193	radial	748	art./stand.	92.0	31	0.561	6-8 / 7-8	15 / 10-15	C
195	tangential	673	articulated	96.9	30	0.630	6-8 / 7-8	15 / 12-20	A, B, C
196	circular	506	art./stand.	75.7	20	0.620	6-8 / 7-8	15 / 10-20	A, B, C
197	tangential	514	articulated	64.3	33	0.689	6-8 / 7-8	15 / 10-20	B, C
200	local	1898	articulated	84.8	8	0.525	3-4 / 3-4	7-8 / 4-20	C
207	radial	1343	standard	59.5	13	0.423	6 / 7-8	10-12 / 10-20	B, C
213	tangential	670	standard	84.0	19	0.566	6 / 7-8	11-12 / 20	A, C
215	local	1029	articulated	55.9	9	0.511	5-6 / 6	15 / 7-20	C
253	radial	513	articulated	52.1	15	0.640	5-6 / 7,5-10	15 / 15-20	B

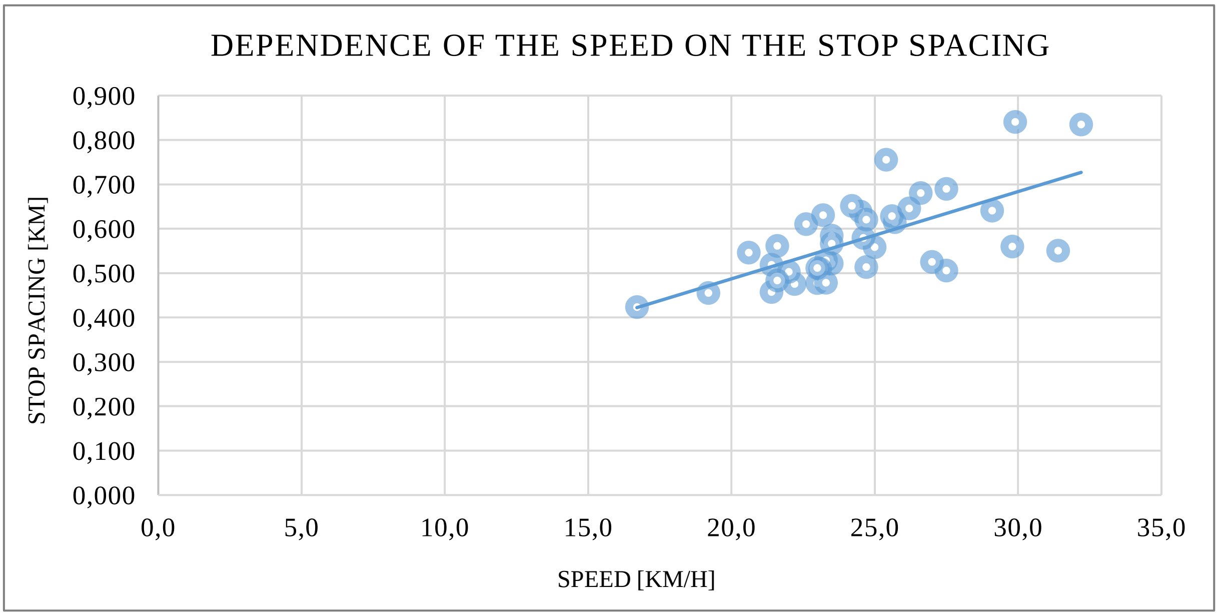
The demand – the number of passengers per kilometer per day – and the type of vehicle (whether it is low-floor or not), was found out from demand surveys. The stop spacing was calculated as the length (only one way) divided by the number of stops. The frequency and integration with metro was found out from general information about metrobuses.

Tab. 66 shows that **some metrobuses do not use articulated buses but only standard buses. Sometimes, it is due to the low demand but, in some cases, it can be also due to the lack of street space.** For example, line 207 uses standard vehicles even though the demand per kilometer is the third highest from all the lines – 1 343 passengers/km/day. This line goes through the city center and in some places the radius of curves is small and the space is not sufficient enough for articulated buses. Some of the lines use both types, while articulated vehicles are usually used for peak hours and week days and standard vehicles for off-peak hours and for weekends when the demand is lower.

Lines 112 and 176 have 100 % of the vehicles with low floors and line 195 has 96.9 % of its vehicles without barriers. However, **not all metrobus lines use low-floor vehicles during the whole day.** The lines marked in yellow use between 75-90 % low-floor vehicles. Three lines marked in grey, line 107, 133 and 142, use less than 50 % of low-floor vehicles on their routes during week days. **If we compare this with the number of passengers per kilometer per day, it is, again, not possible to observe any relationship.** The line with the second highest demand, line 107, has the lowest percentage of low-floor vehicles along the route. On the other hand, line 176 with 100 % of vehicles without barriers has only an average demand.

The frequency of Prague's metrobus lines is usually 6-8 minutes in the morning and the afternoon peak hours (it can be also shorter – 3-4 minutes or longer – 7-15 minutes), **10-15 minutes in off-peak hours in the midday and 15-20 minutes in the evenings. All metrobuses are integrated at least with one metro line, up to all three metro lines.**

The ideal station spacing according to The BRT Standard is 0.45 km but the distance of 0.3 – 0.8 kilometers is convenient, too. The lines marked in yellow in Tab. 66 have an ideal average distance between the stops (close to 0.45 – 0.5 km). Two lines marked in grey – 119 and 125 – have a bit larger distance between the stops than this limit (0.840 m and 0.834 m). The rest of the lines have a convenient stop spacing. From Graph 11, it is visible that there is **a linear dependence of the speed on the stop spacing. The larger the distances between the stops are, the higher the speed is.**



Graph 11: Dependence of the speed on the stop spacing

Other criteria that take into account comfort and quality can be added in this section. Some of those are:

- **Hours in operation**

All metrobuses run during the whole day (usually from 4 or 5 a.m. to midnight), 7 days per week.

- **Comfortable vehicles**

Prague's metrobuses use articulated buses that have four to five wide doors and non-articulated buses with three to four wide doors. Not all of them are accessible for wheelchairs, vehicles usually use low-floor and high-floor access, too.

Fig. 60: Articulated low-floor bus with five wide doors operating on line 177

- **Minimizing bus emissions**

Around fifty new articulated buses that currently meet the strictest Euro VI emission standards are used on metrobus lines. Line 119 preferentially uses vehicles that meet Euro VI emission standards and that have a special larger interior with luggage space. All types of buses operate on the other lines (from Euro II to Euro VI emission standards). Vehicles with lower emissions meeting Euro V and Euro VI (with lower diesel consumption) are primarily deployed during working days for longer performances and during weekends in the vast majority of performances. Older cars with higher emissions are deployed mainly as additional buses during the rush hours on working days (80; 81).

- **Type of fare collection**

Prague's metrobus lines use the proof-of-payment system of fare collection. Passengers buy a single ticket in kiosks or in a ticket vending machine and after entering the bus they mark this ticket in small boxes placed in the bus. It is also possible to buy the ticket by sending a text message through the mobile phone and the message with the valid code comes in a minute. Passengers can buy a season ticket (for a month, three months, year...), too. Occasional control by an inspector checks the validity of all types of tickets.

- **Comfortable stations/stops**

The stops along metrobus routes have transparent shelters that are partly weather-protected with seats for sitting. Some shelters are bigger, some of them are smaller but, in general, in case of bad weather, there is not enough space to accommodate higher numbers of passengers. Ticket vending machines can be found at main stops.

Fig. 61: Stop with a bigger shelter partly weather – protected; on the left side of the picture there is static passenger information

- **Passenger information**

There is static passenger information at each stop with the numbers of metrobus lines and their timetables. At many stations, there is also other information, such as the map of the public transport of Prague, types of fares with prices, etc. Usually there is no real-time passenger information, such as "next bus" at the station (only in some cases when the metrobus line stops at the station for trams). However, in each bus, there is real-time information about the line number, the next stop, the direction and the time.

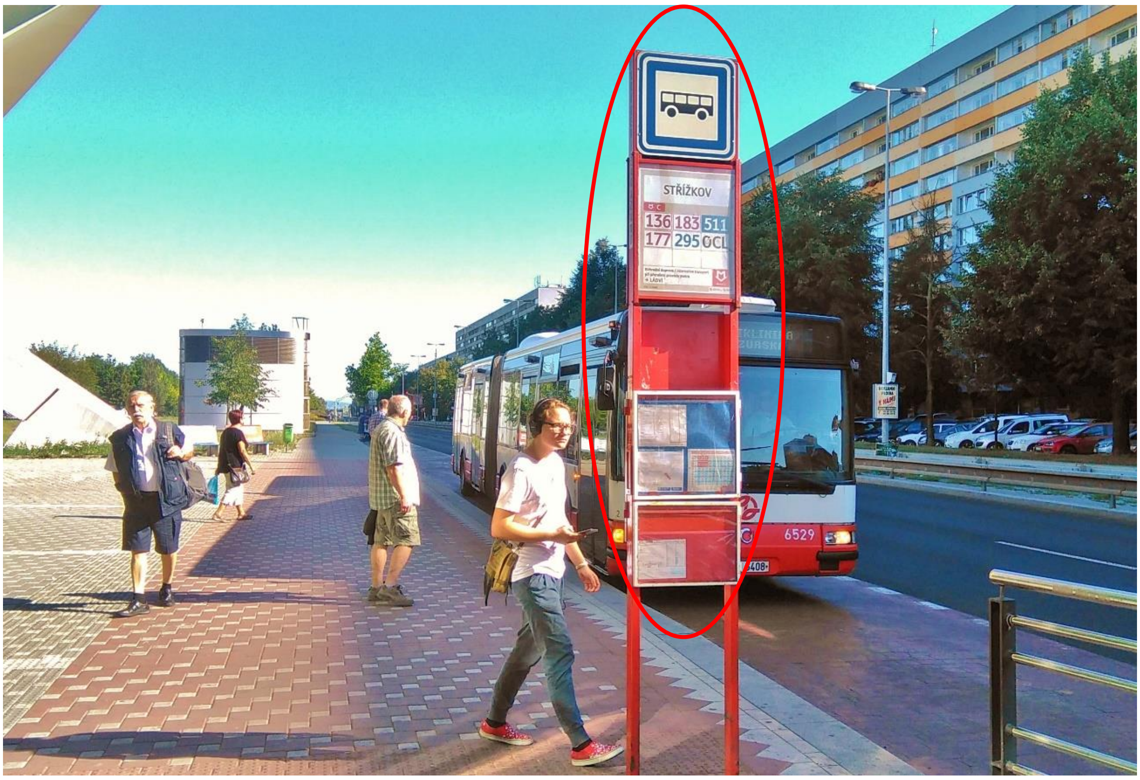


Fig. 62: Static passenger information at each station – number of lines (metrobus lines in purple colour – 136, 177, 183), timetables, information about types of fare

- **Universal access**

Not all stops are accessible for all special-need customers. Not all immediate intersections have dropped curbs and there are no Braille readers at stops. Not all stop platforms are at the same level as the bus floor. Even though most metrobuses are low-floor, there is a small vertical gap between the stop platform and the bus floor remaining. There are also no measures for reducing the horizontal gap (like Kassel curbs, alignment markers or guided wheels) and, therefore, sometimes smaller or larger gaps between the bus floor and the stop platform occur.

Fig. 63: Larger gap between the bus floor and the stop platform – more difficult boarding and alighting for elderly passengers; in the back of the picture, there is an entrance to the metro station (integration with metro line C)

- **ITS application**

There is real-time passenger information in the buses, including voice information in most of them. At some stops there is real-time passenger information and voice information on request for blind passengers. All buses use GPS and they have priority at some controlled intersections. Door and rear cameras can be found in the new vehicles. Automated passenger counters are not part of the vehicles yet, however soon, they should be installed in some of them.

- **Integration with other public transport**

Integration with other public transport is done by fare payment. A single transfer ticket allows passengers to complete all the journey using only one ticket, regardless of the number of transfers or the chosen means of transport. Prague's integrated transport includes urban trains, metro, trams, buses, funicular and ferries. The integration, at some places, is also done by physical transfer points (for example, when the bus stops at the tram station or next to the metro station, etc.).

- **Bicycle integration**

Bicycle lanes, secure bicycle parking and bicycle-sharing integration is necessary for passengers who wish to use bicycles as feeders to the metrobus system. Metrobus lines often share their reserved bus lanes with bicycles and taxis and, in some places, there are also other bicycle lanes next to mixed traffic, however, none of these cases are as safe as in the case of only cyclist paths separated from traffic. There are very few secure bicycle parking places in Prague and bicycle-sharing integration is quite new and, therefore, it has been spread, so far, mainly in the city center. It is quite easy to get to the most of the places in Prague by bike and, thus, if somebody is using a bicycle in Prague, usually it is used as a means of transport and not only as a feeder.

- **Branding**

Metrobuses in Prague are very poorly promoted. They do not have any unique brand and identity. Buses, routes and stations have the same brand as regular buses and the only difference is that the number of the metrobus line is written in a small frame on the buses, in purple colour in the frame at the stations and in timetables there is written 'metrobus' before the line number.

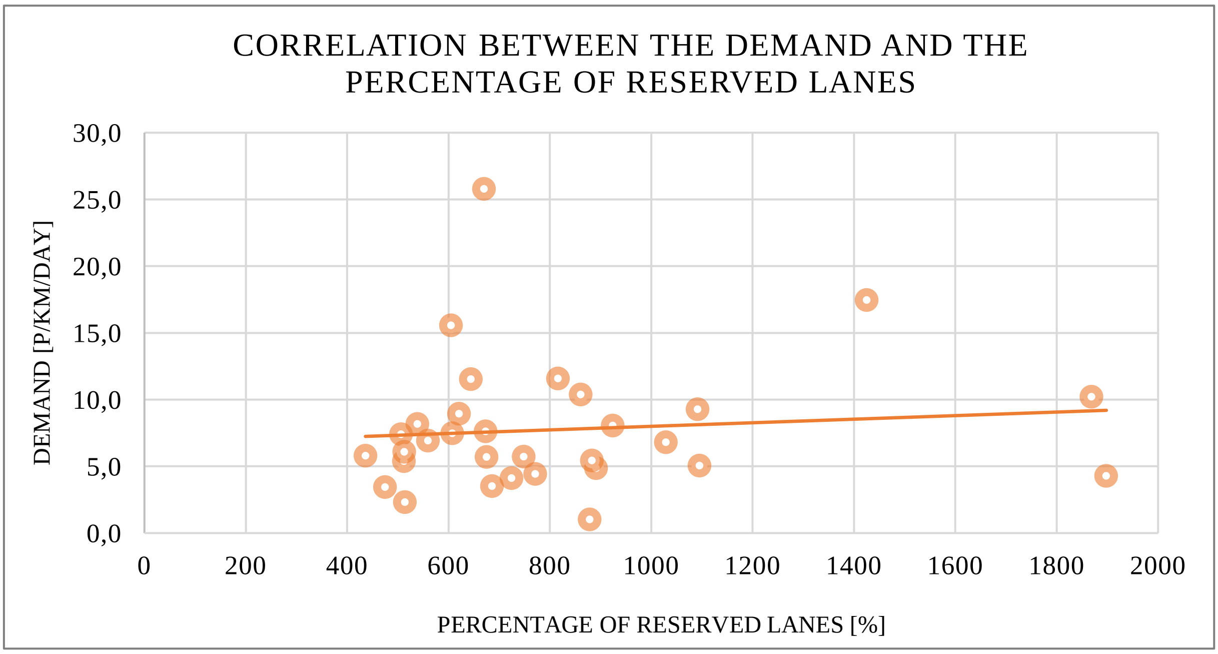
6.4 Conclusions and possible future development of Prague's metrobuses

In this chapter, the correlations between the demand and selected criteria, conclusions and findings from previous sections and a possible development of Prague's metrobuses in the future are described.

6.4.1 Correlations between the demand and selected criteria from previous chapters

A demand is a good factor for evaluating whether metrobuses are or are not efficient. This section describes the relationship between the demand and different comparable criteria of metrobuses in Prague. However, it is necessary to count with some deviations in the results because the outcomes from the demand surveys (chapter 6.3.1) are not 100% foolproof.

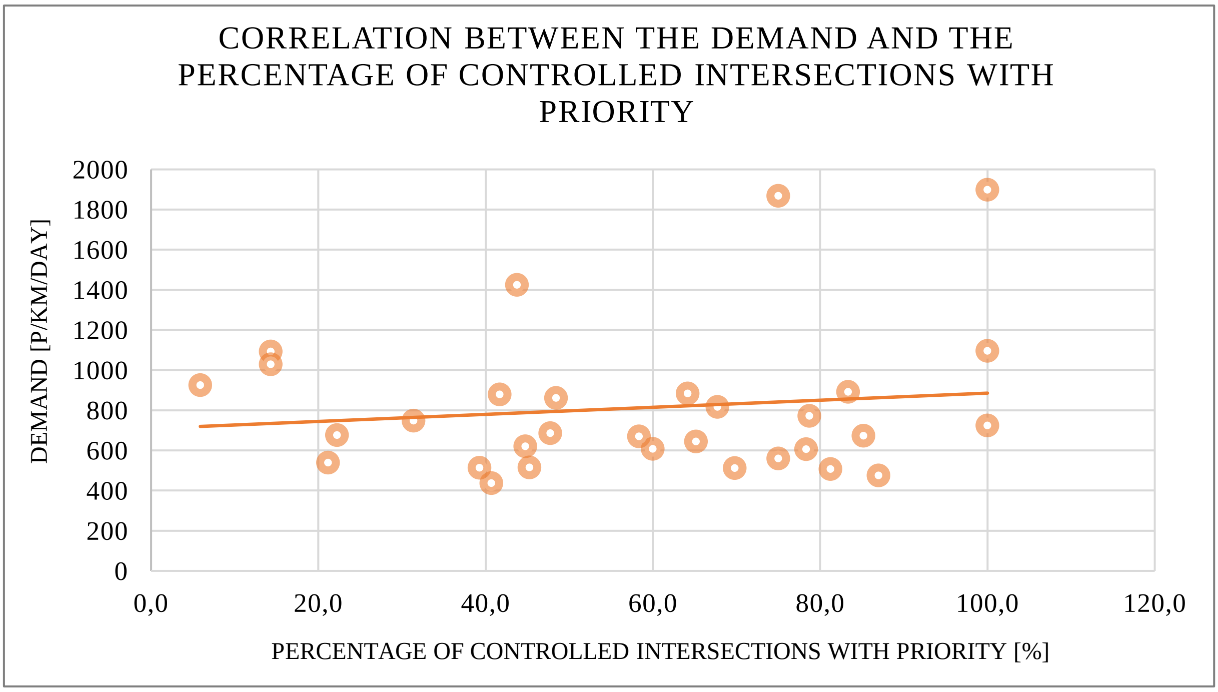
Only the metrobus lines that have at least one survey available after the last change of their route or the location of the stops are taken into account (not lines 112, 119, 131, 137, 142, 184, and 191). For these lines, the data from their last survey were used.



Graph 12: Correlation between the demand and the percentage of reserved lanes

In Graph 12, it is possible to observe that there is **no correlation between the demand and the percentage of reserved lanes (reserved bus lanes, bus lanes shared with taxis and cyclists and tram rail shared with buses)**. **A higher demand does not always result in a higher percentage of reserved lanes. However, from the trend line in the graph, it is visible that the**

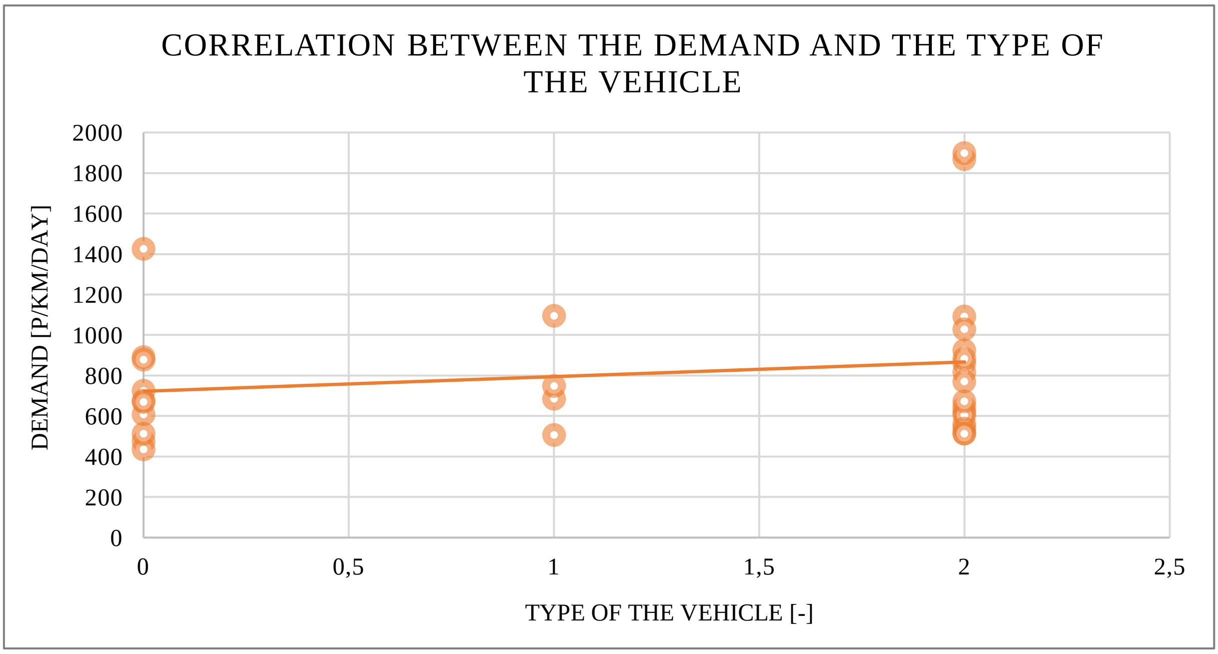
tendency is slightly growing. The percentage of reserved lanes also does not affect the speed (from Graph 9).



Graph 13: Correlation between the demand and the number of controlled intersections with priority

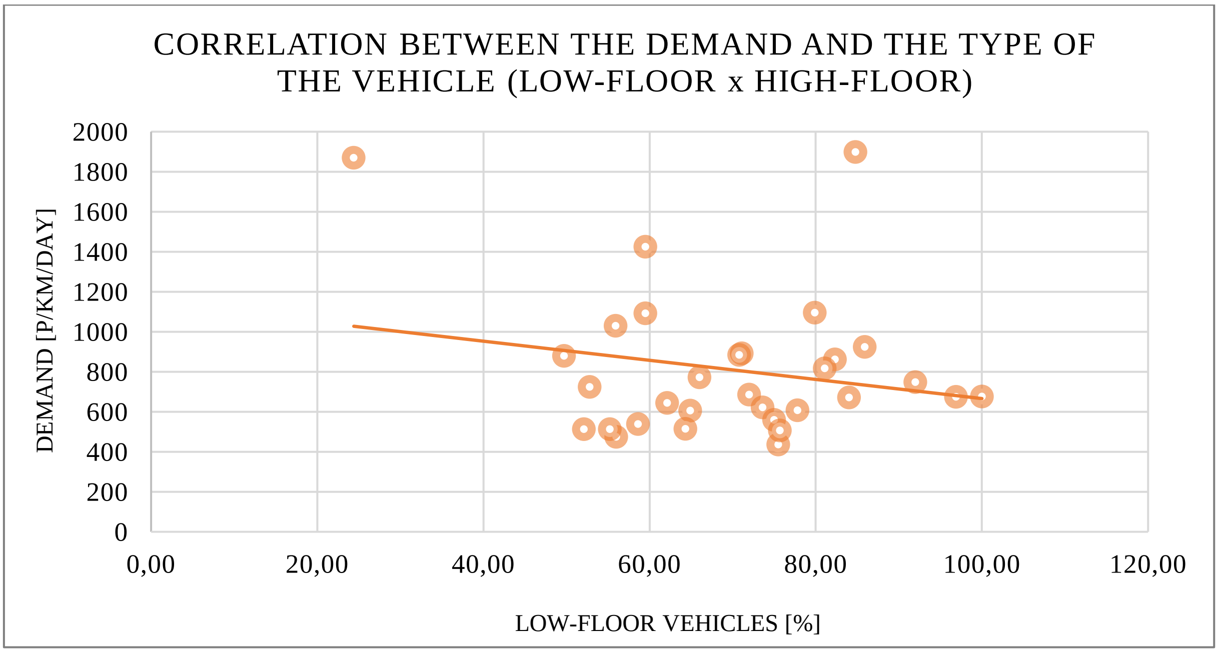
In Graph 13, it is possible to observe that there is **no correlation between the demand and the percentage of controlled intersections with priority**. **A higher demand does not always result in a higher percentage of controlled intersections with priority. However, from the trend line in the graph, it is visible that the tendency is slightly growing.** The percentage of controlled intersections with priority also does not affect the speed (from Graph 10).

From both graphs, we can make a conclusion that there is **no correlation between the demand and the level of preference of metrobuses in Prague**.



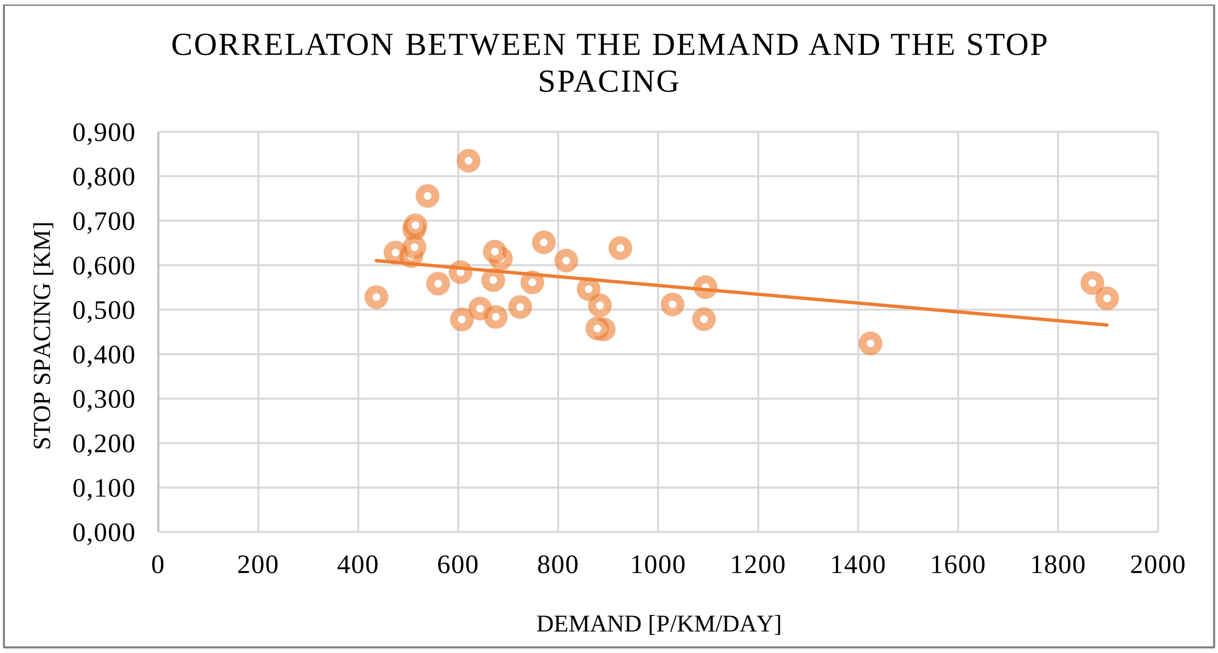
Graph 14: Correlation between the demand and the type of vehicle

In Graph 14, there is the correlation between the demand and the type of vehicle. On the x-axis, there are numbers 0, 1 and 2 chosen for types of vehicles as follows: 0 = standard bus, 1 = articulated/standard bus, 2 = articulated bus. From the result, we can observe that **there is a slight correlation and an increasing tendency – the lines with the higher demand use more articulated buses (number 2 on the x-axis) and the lines with the lower demand use more standard buses (number 0 on the x-axis), however, there are some exceptions**.



Graph 15: Correlation between the demand and the type of vehicle (low-floor x high-floor)

In Graph 15, there is the correlation between the demand and the type of vehicle, in terms of whether it is low-floor or high-floor. We can observe that there is **no correlation and, therefore, the demand does not affect the percentage of barrier-free buses and vice versa. Moreover, the trend line in the graph shows that the tendency is decreasing** (the higher the demand, the lower the percentage of low-floor vehicles).



Graph 16: Correlation between the demand and the stop spacing

Graph 16 shows the correlation between the demand and the stop spacing. In chapter 6.3.3, it was found out that **the distance between the stops influences the speed of the lines – the longer the distance between the stops is, the higher the speed is.** The correlation between the stop spacing and the demand is not that clear but, **apart from some exceptions, it is possible to say that the shorter the distance between the stops, the higher the demand is**. This is caused because lines with shorter distance between stops serve a higher number of passengers.

Most of the other criteria of Prague's metrobuses are the same for all lines, and therefore, it is not possible to draw any conclusions from such criteria.

6.4.2 Results and conclusions

The results of Prague's metrobuses from chapters 6.3.1, 6.3.2, 6.3.3 and 6.4.1 are summarized in this section and compared with the basic features of BHLS and BRT which are:

- reserved bus lanes,
- priority at signalized intersections,
- comfortable vehicles with higher quality and capacity,
- improved stops and terminals,
- passenger information, journey planners,
- lines with frequent and reliable service during the whole day,
- distinctive image and branding.

The preference of metrobuses over other traffic, as one of the most important features and a basic element of BHLS and BRT, should yield higher speeds. However, in Prague, there is **no correlation between the preferential features and the speed** (Graph 9 and Graph 10) **and, therefore, it does not apply that the higher the number of preferential features, the higher the speed**. In the case of reserved lanes, it may be due to the fact that the length of reserved lanes is, in most cases, too short to affect the speed in a larger scale. There are also many other factors that influence the speed of metrobus lines, such as the density of other traffic, stop spacing, number of intersections or direct routes/detours. One of the important factors that influence the demand may be the land use.

Preferential parameters should be applied, at most, on lines with the highest demand so that a significant proportion of passengers benefits from these improvements. This statement is not true either because preferential measures **are not applied preferably on metrobus routes with the highest demand** (Graph 12 and Graph 13) **but there where the local space and conditions allow it.**

The type of vehicle – whether it is articulated or standard – is, more or less, with exceptions, influenced by the demand. **The higher the demand is, the more articulated buses are used** (Graph 14). However, the parameter of accessibility for the disabled, elderly, children or people with strollers – whether the vehicle is low-floor or high-floor – is not, in the case of Prague's metrobuses, influenced by the demand. **It does not apply that the higher the demand is, the bigger the number of low-floor vehicles** (Graph 15). **This feature not only facilitates the boarding and alighting of special-need passengers but it also increases the speed of boarding and alighting and, therefore, it reduces the time spent at the stop.**

The stops are comfortable with shelters with seats and static passenger information. This feature is the same for all types of buses – it does not matter if it is a metrobus or a normal bus.

The stop spacing parameter is, in most cases, within the ideal range (according to The BRT Standard) of 0.3 and 0.8 kilometers, except two lines. **The stop spacing influences the speed and it applies that the higher the distance between the stops, the higher the speed** (Graph 11), **however, the lower the demand** (Graph 16). **The distance beyond this limit is not very**

convenient because the passengers have to walk too long to the stops and the distance below this limit is not very convenient, either because the bus speed is reduced a lot.

Metrobuses operate every day from the early morning hours till midnight. **The frequency, in most cases, meets the requirement of the minimum of 8 buses per hour in peak hours and the minimum of 4 buses per hour in off-peak hours (according to The BRT Standard).** However, there are some exceptions and, especially in the evening, the frequency of metrobuses is lower – usually 3 buses per hour (Tab. 66).

The level of branding is very low. The buses, routes and stations do not follow any unifying brand of the metrobus network. The only common feature is marking the number of the metrobus line in the frame on the bus and in the frame in purple colour at the stops.

From these results it is possible to summarize Prague's metrobus system into the following conclusions:

- **metrobuses in Prague do not meet some of the main requirements that should differ them from regular buses,**
- **the preferential parameters are not used sufficiently to affect, in a positive way, the speed,**
- **the preferential parameters are not located according to the highest demand,**
- **some of the other criteria relating to the comfort of the stations and the vehicles are met but they are not specific for the metrobus system but they are a current standard for both metrobuses and regular buses, too,**
- **the branding of the Prague's metrobus system is very poor and there is almost no distinction from the regular buses.**

Overall, we can to say that the plan of Prague's metrobuses was not very well prepared and also not very successful. There has been neither an increase in the number of passengers on the lines chosen as metrobuses nor a significant change in the quality of these lines. The metrobus lines were not well chosen because of the fact that many of them do not meet the requirements necessary to be labelled as metrobuses.

6.4.3 Future possible development of metrobuses in Prague

As mentioned in previous chapters, the selection of Prague's metrobuses was not very sophisticated. There are thirty-eight metrobus lines, which is too many to give them all the preference, quality and comfort required from metrobuses and to distinguish them from regular buses.

There are two possible ways of the future development of metrobuses in Prague. It is feasible to:

1) **significantly reduce the number of lines that will be called metrobuses on which all possible BHLS and BRT parameters will be applied,** or
2) **choose important stretches of road that have the potential to satisfy the most of the BHLS and BRT parameters and create a metrobus corridor that more bus lines will use.**

The first case requires **selecting only a few lines which connect important places in terms of land use that have a high demand so that a significant number of passengers benefit from these features and on which it is possible to successfully apply preferential measures. This case is analysed below.**

The second case requires **finding out the sections of road that have the highest potential to meet the most of the elementary BRT and BHLS features. Especially, finding out places**

where there is enough space for long compact segments of reserved bus lanes and where the rail transport is missing. This case may be the subject of further work.

In general, metro in Prague is a diametric system that makes up the backbone of the transportation network with a complementary tram system that also serves mainly diametric and radial directions. Both systems are systems with high capacity and speed with which most buses in Prague cannot compete. However, there is no metro and only few tram lines in tangential directions. Moreover, some metro and tram segments are very busy and, sometimes, above the point of track capacity and the transmission does not allow further strengthening of operation. The busiest stretch of metro has line C between the stations IP Pavlova and Kačerov.

Therefore, the **metrobus lines could lighten these sections by offering tangential lines to transfer the passengers travelling to the other part of the city, without the need to go through the city center. The radial and diametric system will be freer for those passengers who really need to enter the city center. However, it is necessary to offer alternative transport that will be good, comfortable and quick as well.**

In Fig. 64, there is the scheme of the types of routes. It is visible that tangential routes provide a shorter route to important places without the necessity to enter the city center.

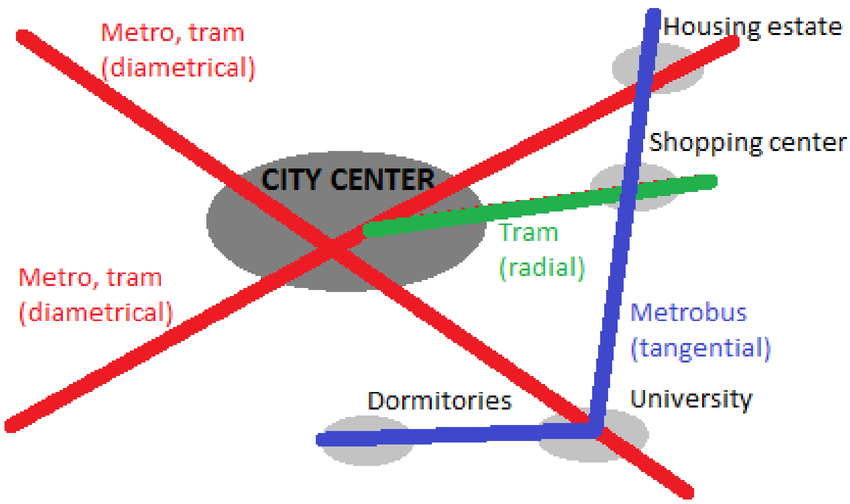


Fig. 64: The scheme of the types of routes – diametrical, radial, tangential

In Fig. 65, there is a section of a map of Prague showing the land use. All highlighted areas are listed in Annex 10.3. Furthermore, in the map, **the routes of selected lines that would be, according to the results and conclusions, appropriate to choose as metrobus lines – line 177, 136, 125, 150 and 193 are marked.** These lines are long tangential lines, except line 193 which is radial. Most of them are the busiest lines and they connect important places. The other reasons why these lines were chosen are described below.

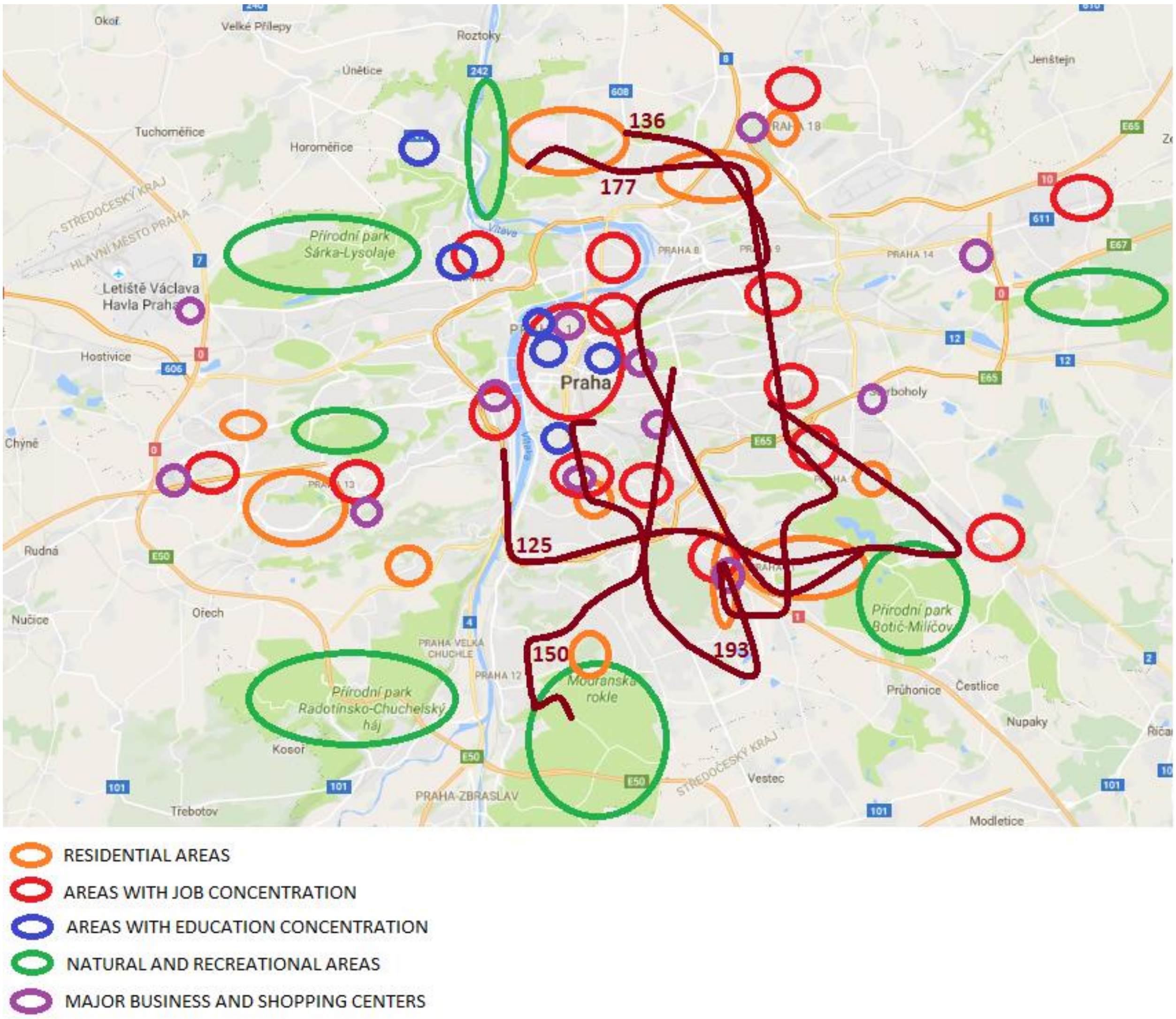


Fig. 65: Scheme of chosen metrobus lines on a land use map

Line 177:

- has the highest demand from all the lines along its route – **42 967 passengers/day**
- runs from the northern part of the city to the south-east
- connects housing estates Severní město and Jižní město, four important areas with job concentration – Vysočany, Malešice, Hostivař/Štěrbohly and Chodov and a big shopping center Chodov
- **connects all three metro lines – A (Skalka), B (Vysočanská) and C (Chodov, Opatov, Kobylisy – Prosek)**
- **lines 102, 144, 183, 195 and 200 partly use the same route as line 177 – other lines will benefit from improvements on line 177**
- has 4.4 % of reserved bus lanes and 78.7 % of controlled intersections with bus priority along its route
- uses articulated buses, 66 % of them are low-floor
- the frequency is 6 – 7.5 min. in peak hours, 15 – 20 min. in off-peak hours

Line 136:

- has the second highest demand from all the lines – **37 905 passengers/day**
- runs from the west part of the city to the east

- connects the housing estate Severní město, two important areas with job concentration – Karlín and Chodov, two shopping centers – Flora and Eden Vršovice and the housing estate Jižní město
- **connects all three metro lines – A (Flora), B (Vysočanská) and C (Opatov, Háje, Střížkov – Prosek)**
- **lines 125, 135, 170, 183, 195 and 213 partly use the same route as line 136 – other lines will benefit from improvements on line 136**
- **has 11.6 % of reserved bus lanes and 67.7 % of controlled intersections with bus priority along its route**
- uses articulated buses, 81.1 % of them are low-floor
- the frequency is 6 – 7.5 min. in peak hours, 10 – 20 min. in off-peak hours

Line 125:

- **the fast line with the highest speed – 32.2 km/h** (part of the route goes through 'Jižní spojka'), has the third highest demand from all the lines – **29 861 passengers/day**
- runs from the northern part of the city to the south
- connects housing estates Jižní město and Horněcholupská, three important areas with job concentration – Malešice, Hostivař/Štěrbohly and Chodov and the natural park Botič – Milíčov
- **connects all three metro lines – A (Skalka), B (Smíchovské nádraží) and C (Háje)**
- **lines 170, 183 and 213 partly use the same route as line 125 – other lines will benefit from improvements on line 125**
- has 8.9 % of reserved bus lanes and 44.7 % of controlled intersections with bus priority along its route
- uses articulated buses, 66 % of them are low-floor
- the frequency is 4 – 6 min. in peak hours, 12 – 20 min. in off-peak hours

Line 150:

- has an average demand along its route – **17 272 passengers/day**
- runs from the southern part of the city to the center
- connects the housing estate Modřany, an important area with job concentration – Pankrác, a shopping center Eden Vršovice and the natural park Modřanská rokle
- **connects two metro lines – A (Želivského) and C (Kačerov)**
- **lines 124, 139, 196, 213 and 253 partly use the same route as line 150 – other lines will benefit from improvements on line 150**
- **has a high percentage of reserved bus lanes – 15.6 % and 78.3 % of controlled intersections is with bus priority**
- uses articulated buses, 64.9 % of them are low-floor
- the frequency is 6 – 7.5 min. in peak hours, 15 – 20 min. in off-peak hours

Line 193:

- **has high demand along its route with a growing tendency – 26 005 passengers/day**
- runs from the south-east part of the city to the center
- connects housing estates Jižní město and Pankrác, three important areas with job concentration – Chodov, Michle and Nové Město, two shopping centers Chodov and Arkády Pankrác and some of the faculties of Charles University

- **is integrated with one metro line – C (Pražského povstání, Pankrác, Budějovická, Chodov) – relieves very congested metro stations**
- has 5.7 % of reserved bus lanes and 31.4 % of controlled intersections with bus priority along its route
- uses articulated and standard buses, 92.0 % of them are low-floor
- the frequency is 6 – 8 min. in peak hours, 10 – 15 min. in off-peak hours

It would be useful if preferential and quality parameters were applied primarily on these lines in a much larger scale than until now. The features to improve are, for example:

- to increase the amount of reserved bus lanes and to create coherent and uniform sections rather than many short segments
- to segregate and enforce the sections with reserved bus lanes from the road for mixed traffic, for example, by colorized pavement or delineators
- to increase the number of controlled intersections with priority where possible
- to use a good-quality pavement along the routes that is designed for 30-year life span
- all the vehicles should be low-floor for easier and faster boarding and alighting
- to use some measures for reducing the gap between the bus floor and the station platform – for example, the usage of Kessel curbs
- the stops should be comfortable – bigger shelters with more seats for sitting
- improved passenger information – not only static but also dynamic passenger information (“next bus” at the station, in the case of delay information about the real arrival of the bus, the time) should be used on each stop along the metrobus line
- all vehicles, stops and close intersections along the route of metrobus lines should have universal access for all special-need costumers (blind pedestrians, wheelchairs,…)
- the routes should be straightened as much as possible without detours
- integration with bicycles along metrobus lines – bicycle lanes, bicycle racks and secure bicycle parking at terminal stations and shared bicycles
- to improve the branding and the metrobus identity by the use of an unique brand name, logo and designated colors for buses, stops and routes

7 CONCLUSION

The main requirements and parameters of BRT are summarized in this work. From the evolution of the BRT systems, it is visible that nowadays, forty years after the first introduction of BRT in Brazil, the system has spread into the whole world and the vast majority of these systems have been built in the last 15 years. There is a bit different approach between the BRT in America and BHLS in Europe, which is not only due to different sizes of the cities and their populations, but also due to the street space – wide roads in America and, on the other hand, narrow streets in the historical cities in Europe. However, eventually, both systems strive for a higher quality and faster public transit system which will be superior to the regular bus system.

In the past, there was no common definition of BRT, which caused confusion about its concept. There was no control and, therefore, many modest bus system improvements were incorrectly named as BRT. The evaluation document, The BRT Standard, not only gives a common definition of BRT but it also sets a scoring system to evaluate BRT all around the world.

From the evaluation of two metrobuses in Buenos Aires it was found out that even though they have been built within one city, there are big differences between each other. The difference is not only due to the street space but also due to the financial investment in the corridors. The corridor Metrobus 9 de Julio, which was more than three times more expensive, has obviously much better features than the corridor San Martín. However, both corridors also have parameters in common.

The BRT corridor Transcarioca in Rio de Janeiro was evaluated according to The BRT Standard, too. This corridor has very high quality, capacity and speed and in The BRT Standard ranking it reached the second highest score – the Silver BRT. The corridors in Curitiba are not included in this work because there was not enough information available and not enough time for a proper research into these corridors.

It was not possible to evaluate the metrobus system in Prague according to The BRT Standard. Firstly, because it is not always feasible to apply all the parameters defined in The BRT Standard to European conditions where the space is limited. Secondly, because there are thirty-eight metrobus lines in Prague which do not meet many of the important parameters of BRT and BHLS and, therefore, none of them could be defined as the BRT corridor in order to evaluate such systems according to The BRT Standard.

Metrobuses in Prague were summarized according to the surveys available. It was found out that the main parameters which distinguish metrobuses from regular buses are not met. The preferential features in Prague do not yield higher speeds. One of the reasons could be that the reserved bus lanes are too short and not compact to affect the speed. There is also no correlation between the preferential features and the demand, which means that the preferential parameters are not applied primarily on the lines with the highest demand. Other criteria related to comfort are met but they are the same for both metrobuses and regular buses, too.

All in all, it was found out that the Prague's metrobus lines were not very well chosen because there are too many of them to give them all the priority, capacity and comfort required for BRT and BHLS. Many of them do not meet the requirements necessary to be labelled as metrobuses and, in fact, some of them are not really different from other regular bus lines. Therefore, in the last part of this work, a possible future development of Prague's metrobuses is outlined. One radial and four tangential lines were chosen according to the demand, preferential parameters and the land use. It would be useful to apply all possible improvements and features of BRT and BHLS in order to increase the comfort, the quality and the speed on these lines and to form some hierarchization of the bus system with dedicated and unique features.

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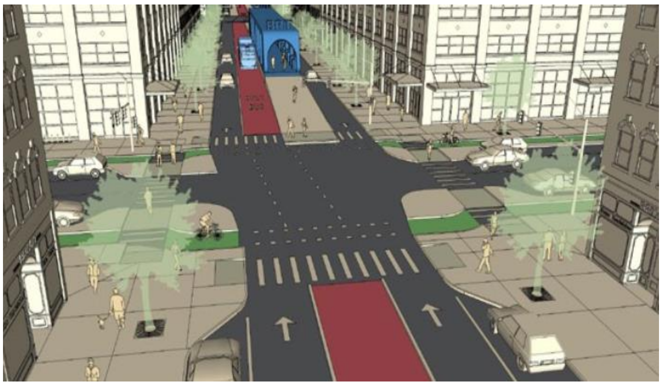
10 ANNEX

10.1 Examples of Busway Configuration

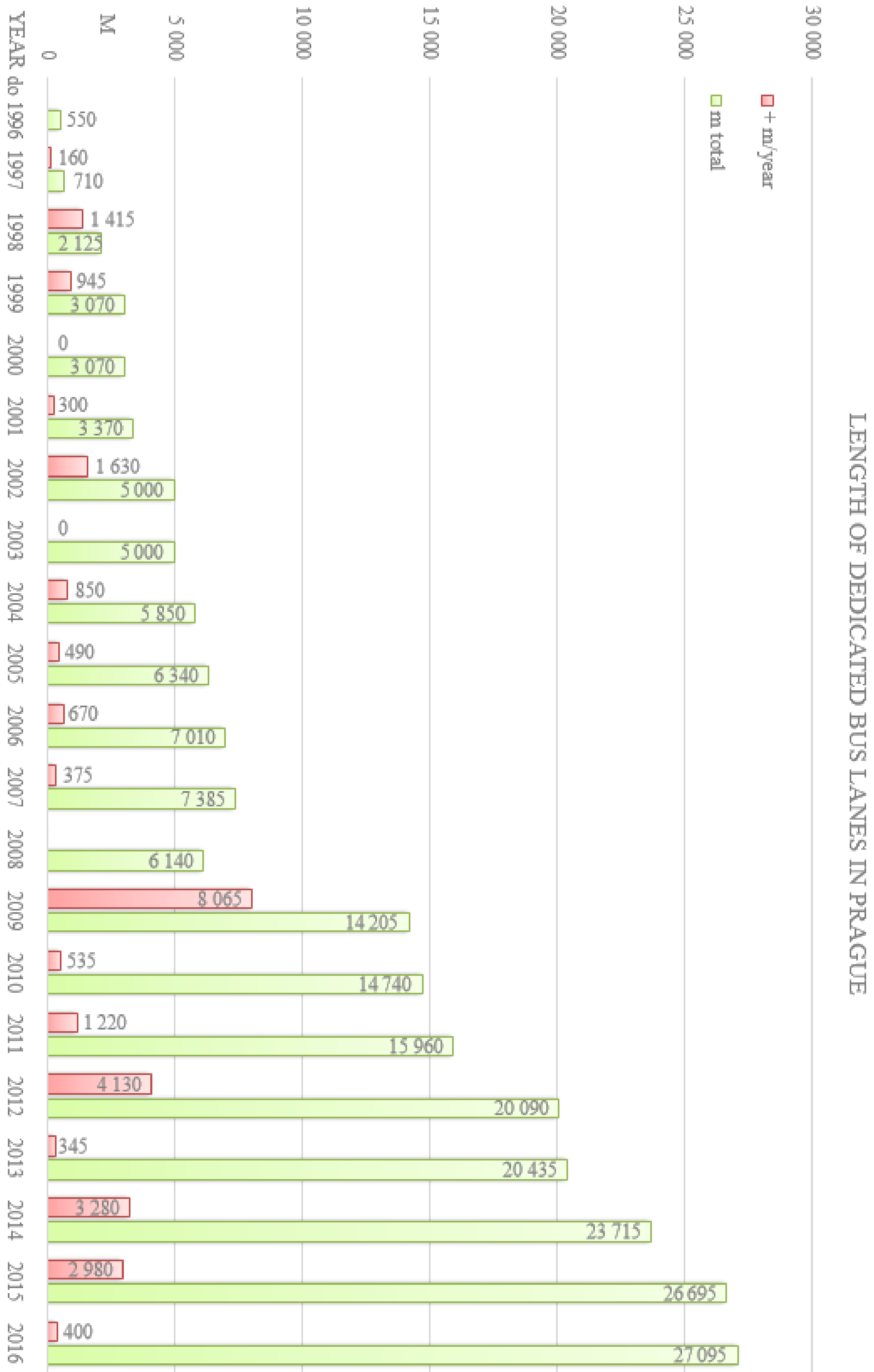
a) *b)*



c) *d)*

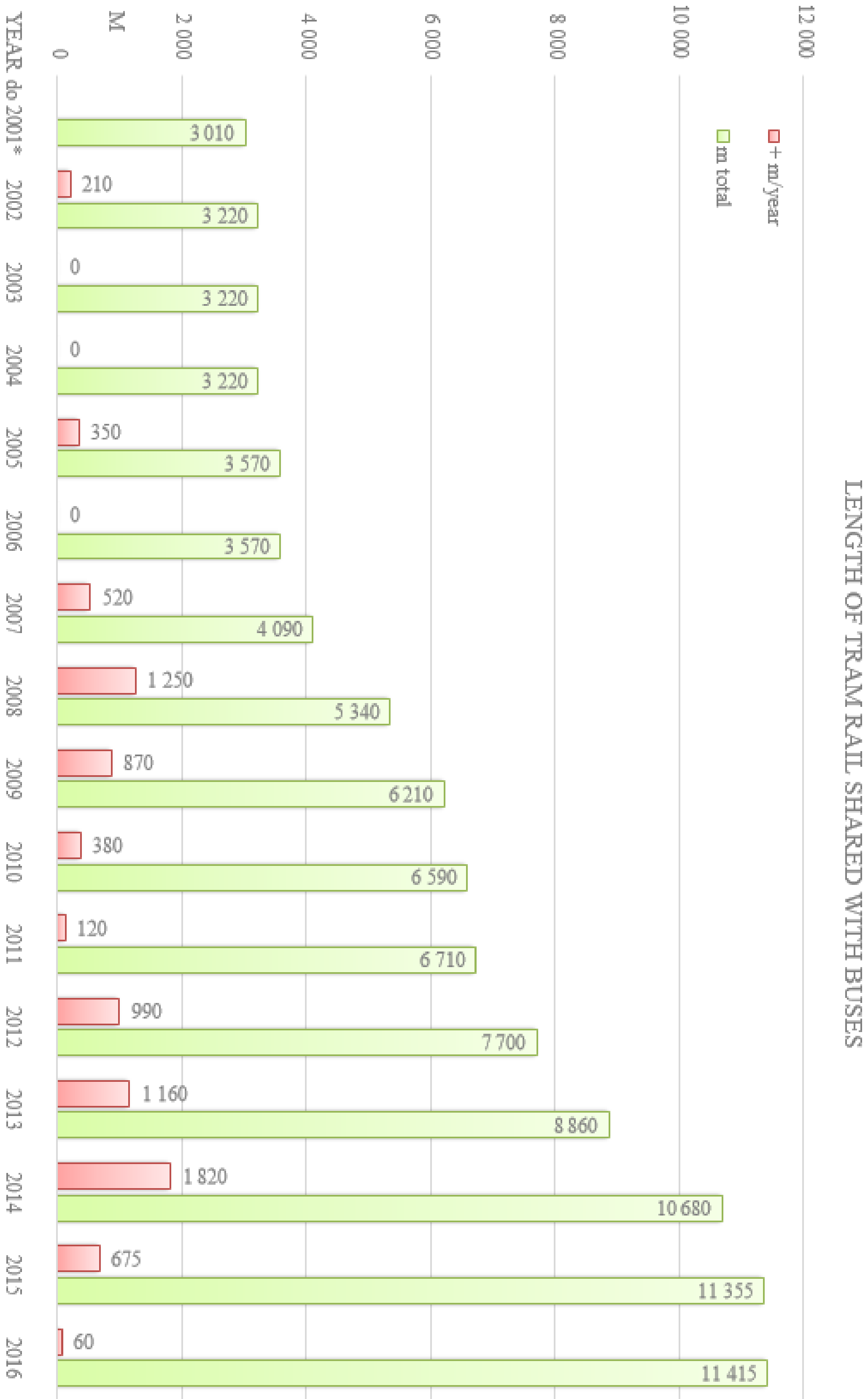
Fig. 66: a) Example of a two-way median-aligned busway; b) Example of a bus-only corridor with exclusive right-of-way; c) Example of a busway that runs two-way on the side of a one-way street; d) Example of a Busway centrally aligned on a one-way street

10.2 Reserved bus lanes and tram rail shared with buses in Prague



Graph 17: Development of the length of dedicated bus lanes in Prague

Graph 17 and Graph 18 show the development of reserved bus lanes and the tram rail shared with buses in Prague during last two decades.



Graph 18: Development of the length of tram rail shared with buses in Prague

10.3 Land use in Prague

Tab. 67: Areas with job concentration (82) and Residential areas

Areas with job concentration		Residential areas	
District	**Estimated number of jobs**		
Praha 1 - Nové Město	70 000	Jižní Město	Háje
Praha 8 - Karlín	23 000		Opatov
Praha 10 - Malešice	20 000		Litochleby
Praha 15, Hostivař, Štěrboholy	20 000	Housing estate Horoměcholupská	
Praha 6 - Dejvice	14 250	Jihozápadní Město	Stodůlky
Praha 14 - Horní Počernice	14 100		Lužiny
Praha 17 - Zličín	12 400		Nové Butovice
Praha 7 - Holešovice	12 000		Velká Ohrada
Praha 9 - Vysočany	10 500	Housing estate Řepy	
Praha 11 - Chodov	10 500	Severní Město	Ďáblice
Praha 22 - Uhříněves	10 000		Kobylisy
Praha 5 - Smíchov	9 500		Prosek
Praha 18 - Letňany, Kbely	9 000		Bohnice
Praha 4 - Michle	9 000		Čimice
Praha 4 - Pankrác	9 000	Housing estate Letňany	
Praha 13 - Nové Butovice	5 000	Housing estate Barrandov	
TOTAL	**258 250**	Housing estate Pankrác	
		Housing estate Modřany	

Tab. 68: Major business centers (82), Natural and recreational areas and Areas with universities

Major business centers	Natural and recreational areas	Areas with universities
Letňany	Natural park Šárka - Lysolaje	Česká zemědělská univerzita
Zličín	Natural park Draháň - Troja	České vysoké učení technické
Černý most	Natural park Klánovice - Čihadla	Vysoká škola ekonomická
Chodov	Natural park Košíře - Motol	Univerzita Karlova
Nový Smíchov	Natural park Radotínsko - Chuchelská háj	Akademie muzických umění
Palladium Nám. Republiky	Natural park - Modřanská rokle	
Nové Butovice	Natural park Botič - Milíčov	
Štěrboholy		
Šestka Ruzyně		
Eden Vršovice		
Flora		
Arkády Pankrác		