

BRT

General Guidelines and Design Regulations

2/2

BHNS

Lignes directrices et règlements de conception

2/2

باصات النقل ضمن المسار المخصص المبادئ التوجيهية ولوائح التصميم

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Abbreviations and acronyms

AASHTO: American Association of State Highway and Transportation.

AOTU: Autorité Organisatrice des Transports Urbains, Urban Transport Organizing Authorities

TCSP :(Transports collectifs en Site Propre, in French), Dedicated- Lane Public Transport

BRT: Bus Rapid Transit

BHLS: Bus of High Level of Service

BCMC: bonded thin cement concrete

CBD: Central Business District

CERTU : Centre d'études sur les réseaux, les transports, l'urbanisme et les constructions publiques

CNG: Compressed Natural Gas

HOV: High-Occupancy Vehicles

GNV: Gas Natural for Vehicles

LRT: Light Rail Transit

OA: Organizing Authority

PRM: Persons with Reduced Mobility

RET: Regional Express Transport

Tram-train: vehicle derived from the tram

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INTRODUCTION

In urban public transport, the bus is the most versatile, most flexible and least expensive in terms of implementation and infrastructure. Rising urban demand requires the development of buses' efficiency through increased speed and higher passenger capacity during rush hours. Hence, the concept of BHLS, which ensures the bus's independence by placing it in a reserved lane separated from traffic congestion, allowing for remarkable efficiency.

The purpose of the following guidelines is to introduce current concepts and ideas on the BHLS, and provide planners and designers with practical information and implementation provisions. These guidelines are therefore addressed primarily to decision-makers and specialists, with the objective of implementing dedicated lanes and general measures securing priorities for public transport facilities.

The purpose of this document is to provide advice to planners, transit agencies, local governments, promoters and people interested in the development of new collective urban transport systems, such as BRT (or BHLS), and consider procedures for adapting this system to major cities.

1 BHLS: BUS WITH HIGH LEVEL OF SERVICE (BRT)

The BRT is a TCSP (Transports collectifs en Site Propre “in French”, dedicated-lane public Transport) characterized by rolling stock, and compliant with traffic regulations (limited to 24,50m in length). Within a comprehensive approach (rolling stock, infrastructure, operations), the BRT provides a level of service superior to conventional buses (frequency, speed, regularity, comfort, accessibility) and closer to trams’ performance. The bus is considered here in its broadest conception. It can be guided (material or immaterial guidance) or unguided, with a thermal, electric or hybrid engine (which would significantly reduce environmental impacts).

If traffic flows are lower than a certain road section’s capacity in cities, it is not necessary to take measures to speed up bus traffic because there is no delay. However, if traffic exceeds the section’s capacity, buses are delayed. To solve this problem, resorting to the principle of bus traffic priority becomes necessary, and the solution of dedicated lanes (as with the BRT) can be considered.

1.1 BRT and BHLS

In American and European cities, specific public transport systems have been developed, ranging from conventional city buses to guided rail systems, such as trams or subways. In Syria and Lebanon, the old tramway was stopped at the end of the 1950’, under the pretext of negative impact on urban environment & context. The actual reason was to provide more and more space for private cars, following the trend in several cities during that period. The tramway was replaced by a bus network with an acceptable level of service until the mid of the war period (1975 – 1990). Since then, some lines still operate, but without a network framework and with very limited contribution.

The Bus Rapid Transit (BRT) in North America and the Bus with High Service Level (BHLS) in France have much in common, starting with the "B" that opens both acronyms, and refers to the same willingness to use the bus mode while trying to improve its performance.

But the American BRT and the French BHLS have also significant differences, revealing contrasting urban contexts, in which transport systems were developed with specific objectives and at a different pace. From these similarities and differences, it is interesting to draw some lessons for urban transport actors currently facing the issue of choosing the most suitable system for their country.

The BHLS approach has the same goal as the American BRT: to make the most of an economic system based on the bus, while using "ingredients" from heavier systems whose performances are recognized (tram in Europe, LRT in the United States, or metro for Full-BRT projects).

The BHLS was also largely inspired by the American BRT in its methodological and conceptual approach, favouring the transport system (consisting of the triptych: hardware, operation, infrastructure) in which the vehicle is only one of the components.

1.2 Main characteristics

The Engine: a road vehicle of more than nine seats, including the driver, limited to 13.50 m in length for standard buses, 18.75m for articulated buses, and 24.50m for bi-articulated buses; its width is limited to 2.55m.

Table 1 : Maximum capacity of different buses

Vehicle	Rolling Stock's maximum capacity in number of passengers (norm of 4 passengers/m ²)	The system's maximum capacity in number of passengers by hour and by direction (3 min. frequency)
Standard bus (12m)	80	1600
Articulated bus (18.5m)	120	2400
Bi-articulated bus (24.5m)	150	3000

Source: Certu

Buses use various sources of energy; they can be divided in 5 categories:

- Diesel and associated fuels
- Natural gas (NGV, biogas)
- Electric energy through poles related to overhead contact lines, as with Trolley-Buses
- Hybrid energy: diesel transformed into electric energy
- Dual-mode vehicles, which allow the successive use of electric energy collected by overhead contact lines, and thermal energy by fuel combustion.

1.3 Characteristics of a high level of service

The BHLS is a multifaceted tool that meets the needs of large cities (additional heavy TCSP network, intermediary network between heavy TCSP and conventional buses) and medium-sized cities (structuring of the Public Transport network around the first lines of TCSP). Beyond the social role of public transport, new issues related to urban congestion, atmospheric and noise pollution, as well as security make urban mobility problematic and require solutions.

For users to be encouraged to give up private cars and use public transport systems, these should have advantages in terms of comfort, speed and cost. A vigorous policy of car restriction in downtown areas, and a high level of service make it possible to meet these challenges.

A BRT system's approach is based on three components:

- Infrastructure (plateformes, stations...)
- Vehicle
- Operating conditions (priority at intersections, information, frequency...)

The table below gives, for each component of the service, the elements used to describe the high level of service for surface transport. (They have been defined by the experience and feedback of CERTU-France).

Table 2 : Main characteristics of the vehicles

Frequency	<ul style="list-style-type: none"> - 8 to 10min. maximum during rush hours according to the size of the city - 15 to 20min. maximum during off-peak hours according to the size of the city - No difference between school periods and other periods
Comfort	<p>Close to tramway's comfort :</p> <ol style="list-style-type: none"> 1. Limited vehicle movement 2. Comfortable seats and handrails, easy circulation for passengers 3. Quality atmosphere (lighting, general feeling) 4. On-board and in stations information on access to the trip and its course (next station, time, disruptions) 5. Information on waiting time
Schedule	From 5h to 24h with simple timetables
Accessibility	<ul style="list-style-type: none"> - Targeting a level of accessibility higher than in conventional buses - Adoption of a transport chain approach (path, ascent/descent, bicycles...)
Regularity, punctuality	<ul style="list-style-type: none"> - Circulation in continuous flow and punctuality at stops - The lowest possible variability in travel times
Travel time	<ul style="list-style-type: none"> - At least equivalent to cars, door to door - Regular speed along the route and during the day
Image, clarity of information	<ul style="list-style-type: none"> - Users must be able to locate the line on a map and in the city, and associate it with a high level of service - Give an image of modernity and performance to attract users - More or less extensive urban requalification

The BHLS concept can therefore adapt to socio-economic and urban contexts. It can also use all available energy sources (thermal, electric, hybrid...).

2 INTEGRATING THE BHLS WITHIN NETWORKS:

The BHLS broadens the possibilities of urban dedicated lanes public transport systems; it can be adapted to different urban configurations within an approach for structuring the public transport network. The BHLS provides flexibility to consider different forms of organization, characterized by the "degree of dependency" of BHLS lines on dedicated lanes infrastructure, and the "degree of openness" of the dedicated lanes to conventional lines.

2.1 The “Busway”, an infrastructure exclusively dedicated to the BHLS

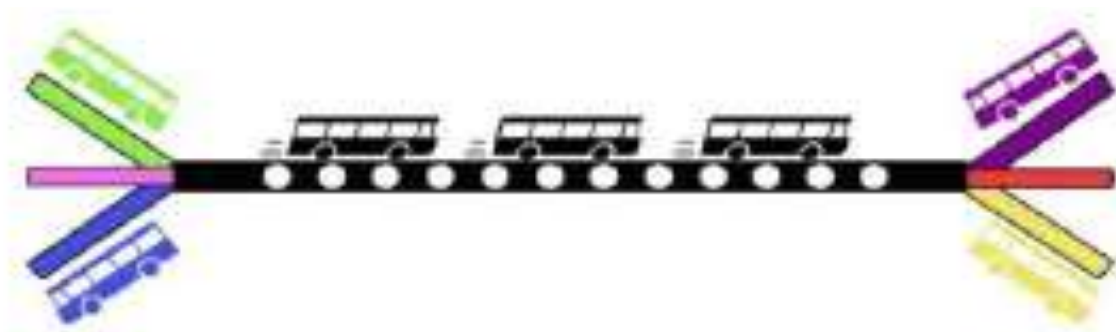
The Busway is a dedicated lane quite similar to that of a conventional tram:

- Lanes are exclusively dedicated to the BHLS to guarantee a high level of service.
- Possibilities for the circulation of a maximum of 2 to 3 BHLS lines on certain common lanes (limited by frequency).
- Connections with other bus lines are organized in the stations.

Implementation of a “Busway” BHLS requires a reconfiguration of the other bus lines, in order to significantly improve travel conditions for the greatest number of users. To retrospectively justify a TCSP to the population, the political temptation is sometimes to excessively encourage a feeder system at each end of the TCSP. This practice ensures a higher use of the TCSP, and increases the number of network trips. When connections are necessary, they should be treated to reduce inconvenience to users:

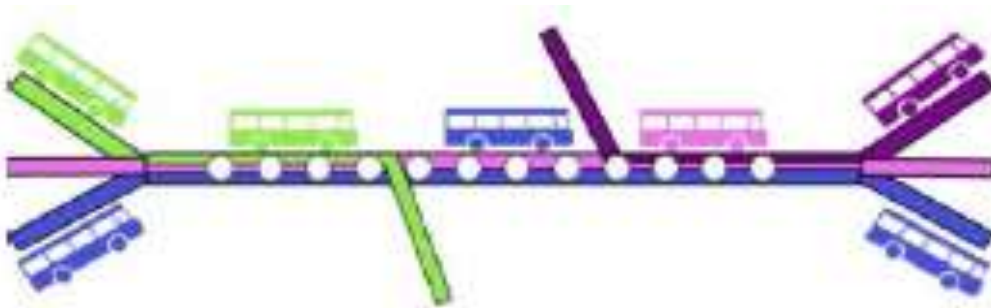
- Fast, readable and secure pedestrian paths
- Schedule organization to limit waiting time
- Comfort in waiting areas (shelters, services...)
- Information (on the bus, on the platform)

Figure 1: Operation plan for a Busway BHLS



2.2 Configuration of “high level of service common dedicated lanes”

Common dedicated lanes are reserved lanes serving several lines; it is also called “open system” and is used by conventional lines that are then distributed on the rest of the network. The high level of service for users is ensured by the adjustments made on the common lanes (reserved lanes, priority on intersections...). To ensure continuity of the high service level, special adjustments could be considered (stations, bus corridors, priority at intersections...).

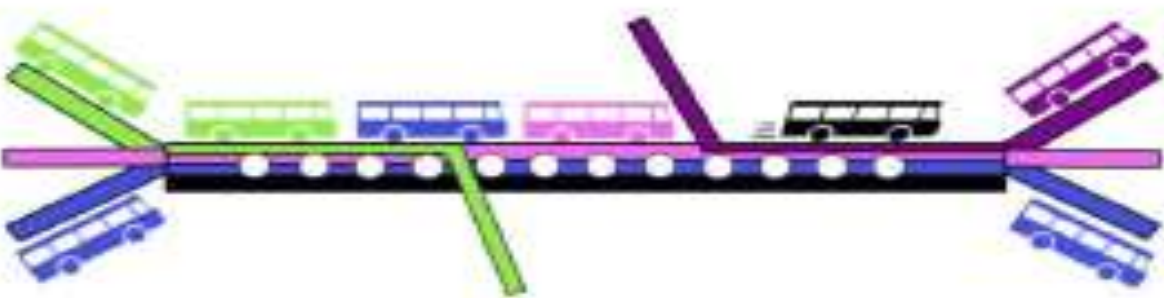
Figure 2: Operation plan for a “common dedicated lane” BHLS

2.3 “Mixed” configuration

For space, profitability or operational optimization of the Public Transport Network, some Regulatory Body or Organizing Authority, AOTU: (“Autorité Organisatrice des Transports Urbains”) opt for a mixed configuration based on:

- One or several well identified BHLS lines
- Opening sections in separate lanes for conventional lines (urban but also inter-city). In this case, the difficulty would be to find the right balance between the system’s performance objectives and optimal use of the reserved space.

This balance must be defined as early as possible in the debates, and maintained during studies development. The BHLS’s flexibility leads in fact to concede easily on performance goals during its implementation.

Figure 3 : Operating plan for a mixed BHLS

In all cases, reorganization of the entire Public Transport network should be part of the BHLS project, and examined as early as in the feasibility studies.

Reorganization constraints can indeed weigh in all possible scenarios.

3 CHOICE STEPS

The BHLS concept fills a gap between conventional buses and trams in terms of performance and image. It is not to be opposed to the tram, but to be considered as a new full-fledged system with its own relevance area, which will be detailed in this section. Considerations (technical, operational, financial) leading to the choice of a TCSP system (dedicated bus system) can be iterative, and depend on many technical elements with a significant impact on the public transport network's future. The choice the system must be made in harmony with specific steps according to very different criteria; it can therefore evolve with the studies.

3.1 Step 1: Long term vision for the city and TCSP objectives

The choice of a BHLS largely depends on the long-term vision for urban and Public Transport projects. Long-term location strategies for housing, jobs and facilities, as well as changing expectations and behaviours can alter balances and travel needs in a city. The construction of TCSP networks must therefore anticipate these phenomena. Organization and densification near TCSP axes theoretically allow the control of urban sprawl, and promote the use of public transport. In this case, the system capacity must take into account the possibility of a high increase in demand.

Due to their technical aspects, TCSP systems are relatively rigid and mutually incompatible. Thus, the community must have a long-term vision of its Public Transport network, in order for today's choices not to adversely affect those of tomorrow.

- To establish networks and balance the main nodes.
- To reorganize the Public Transport network by limiting connections.
- To make choices of service that do not compromise the future.
- To solve the issue of serving urban historic centers.

The desired high level of service and its related characteristics (speed, frequency, regularity, comfort ...) should be identified. The main constraints will be primarily connected to the space dedicated to TCSP (reserved lanes), and to its operating conditions (priority at intersections). Frequency is determined by traffic flow during peak hours.

Scheduling is a choice of the community, and is not related to the system. In terms of comfort and accessibility, the tram has shown its strengths; it has a good image because of its performance and capacity.

On all these points, the system has a great potential, which must be confirmed at the implementation of projects. It must also be able to create a spirit and an image to match its performance.

3.2 Step 2: Capacity and cost

Capacity and cost criteria are sometimes sufficient to strongly guide the choice of a system. The system's maximum capacity depends on frequency and rolling stock capacity. (Table 1).

In general, the capacity offered by public transport is an asset to decongest cities and make them more pleasant by redistributing space.

The issue of adequacy between Capacity and Demand is problematic because of forecasting difficulties. The systems' lifespan is long (about 30 years for a tramway, 15 to 20 years for a BHLS vehicle, depending on the engine), and the evolution of external factors is difficult to control: greater environmental awareness, changing economic conditions (oil prices), urban development, etc. Reserves should therefore be planned in order to increase the system's capacity.

Systems' costs vary greatly from one project to another. The number of engineering structures, construction of warehouses and park-and-ride facilities, as well as urban development choices can indeed have a significant impact on the final cost.

3.3 Step 3: Technological precautions and local impacts

3.3.1 The choice of technological innovation

AOTU: Autorité Organisatrice des Transports Urbains, in French: "Urban Transport Organizing Authorities" (or other authorities responsible for the sector's organization) must focus on the risks that may arise from technological innovation. Innovation related risks exist for buses and BRT (APS, batteries...), it is therefore best to anticipate problems by integrating the risk of technological innovation within the project (planning, fall-backs options...).

3.3.2 Impacts on the environment and the economy:

3.3.2.1 Impacts on noise and vibrations

Engine noise nuisance vary by vehicle, engine type (electric or thermal), and bearing type (tires or rails). For diesel buses, the noise noted at source is generally over 80 dBA, at any speed. For electric vehicles, noise nuisance increases with speed: at 10 km/h, the noted level noise is 65 dBA for trolleys, and 80 dBA at 50 km/h. So electric traction has advantages at low speed. As for vibration, potential nuisances mainly concern railway systems.

3.3.2.2 Impacts on CO2 emissions

Recent data on CO2 emissions are summarized in the table below; they highlight the advantage of electrical technology over thermal power:

Table 3 : CO2 emission by vehicle/km

CO2 emission (use+ energy production) for urban travels in g CO2/veh/km	
Car	230
Standard thermal bus	1400
Articulated thermal bus	1800
Tramway/ Trolley	200

3.3.2.3 Impacts on economic activities

A first constant: any change in the public space that affects its development, use and operation leads to reluctance or opposition, especially from business owners, who usually initiate protests.

After the construction phase, which is undoubtedly detrimental, businesses generally recover their activity, sometimes even better than before, especially in the city centre. But the situation of certain activities and centres in surrounding areas remains critical. The new traffic arrangements may worsen the situation of already fragile businesses, who mainly survive on traffic circulation. Finally, customer parking and deliveries are among the most contentious points in any project.

Whereas there are undeniable changes in the economic operation, it remains impossible to isolate the impact of TCSP (dedicated transport corridors) from the rest of social, economic and urban developments. It is important to expand consultation with the public and users in order to understand operation modes, practices and needs of stakeholders, within a very fine approach to the use of public space, taking into account different aspects, such as parking and deliveries, as well as communication and projects support.

3.4 Insertion and execution

3.4.1 Urban insertion of TCSP (dedicated transport corridors)

City streets' width can be a constraint in the implementation of public transport. The long-term vision of the city and its public transport network can lead in some cases to choosing systems and routes incompatible with insertion possibilities; which may require, during implementation, a proactive policy aimed at latent changes in the urban space in order to allow its adaptation to TCSP. Technically, BRT systems on wheels have the advantage to turn better, especially when they are guided and on single-tracks. Their minimal outer radius is less than 12m, while it is between 25 and 30 m for the tram. Low curvature radii for trams on iron are a source of noise, cause rapid wear, and limit speeds.

It is possible to reduce the right-of-way at the stations' level (a central platform of 4m instead of 2 side platforms of 2.5m). Systems on wheels climb slopes more easily with a limit of 13% for users' comfort, while electrical systems have a better acceleration capacity on slopes.

Impacts during construction

Construction works for TCSP generate major disturbances. During that time, access for residents and businesses, organization of deliveries, secure footpaths and road traffic must be ensured. The main issue is the disturbances' duration (BRT works last approximately 2 years).

There are always solutions to minimize discomfort and reduce impacts, or to facilitate deliveries on commercial streets during construction of BRT (creation of nearby delivery areas, with specific equipment).

4 PLANNING AND DECISION PROCESS

The launching, planning and delivery of a BRT system are illustrated in the Figure 4 below. Conceptually, it is a diagram composed of sequential steps, but it may be much more complex in practice. The stakeholders' interests involved are not always perfectly aligned or even compatible. Feasible elements in compliance with technical, legal and financial aspects can sometimes (or often) encounter resistance from certain stakeholders and pressure groups, or even be refused. Compromises may be needed, and some elements in the process may require lengthy negotiations to be conducted with understanding, flexibility, care and commitment. The process must be defined by identifying the stakeholders in projects of transport and mobility, as well as the goals of initiatives promoting public transport. Projects declared motivations and objectives have a significant influence on the BRT's characteristics and performance.

Figure 4 : Implementation BHLS process



Obstacles that could influence the characteristics of implemented BRT systems are also considered. The entire implementation process is illustrated in Figure 4

BRT projects arise from the identification of a problem for which a high quality bus system is a viable solution. Problem identification and / or development initiatives can come from urban planners, transport authorities, travelers, operators, stakeholders committed to sustainable transport, or politicians. The general experience and research conducted in Europe show that this step is usually associated with broader urban and mobility plans, and is normally accompanied by public consultation (mandatory in many countries). BRT's implementation sites emphasize the importance of representatives' involvement at an early stage.

Each BRT project follows a set of goals reflecting the interests of the instigator and other key stakeholders. The objectives address relevant issues or opportunities for the site. They identify the factors that are best able to solve stakeholders' problems or meet their requirements. When setting goals, it is important to have a good grasp of the various possible strategies and technical solutions available, as well as a good knowledge of the results they allow to reach. The design's context and constraints must be analyzed in a cyclical and recursive process before taking any decision on standards for routes, quality and design. The analysis highlights the difference in objectives according to sites: while some are very elaborate, others are rather general.

In many cases, the process results either from a need or a general wish to improve public transport's performance in order to favor sustainable transport and reduce car use, or from a clear necessity to find a solution for a decrease in the use of public transport. The first steps in a BRT project require thorough and open debate. When this is done carefully, it provides a solid foundation for the project's approval and financing, as well as for its design and final implementation. If the objectives are not well accepted, the risk of strong opposition and problems arising during the implementation phase increases, and could delay the project or even put it on hold.

5 INTRODUCING A BRT CONCEPT

The main highlighted features for structuring BRT bus lines are the following:

- Connection with the higher level (inter-city rail network, regional train, subway ...)
- Large capacity,
- High frequency,
- Extended range, straight itineraries, "Go fast."

Users' needs as the basis of any approach in the BRT concept

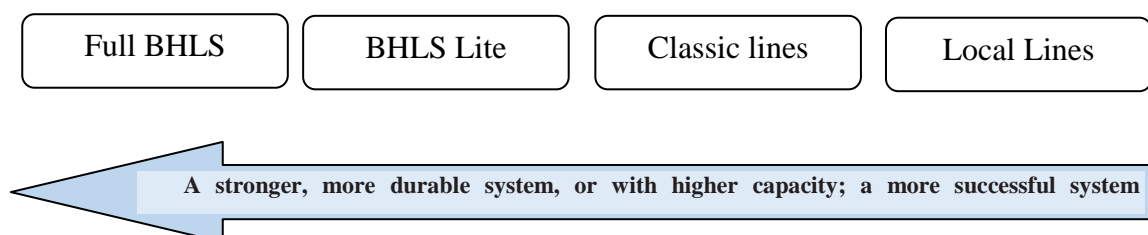
Reliability seems to be the most important goal

The main cited reasons to justify these characteristics are the following:

- To make the bus network clear and readable.
- To reduce traffic congestion and fight environmental problems.
- To prioritize investments on infrastructure by selecting potential capacity as the main criterion.
- To generate mass demand and consolidate it.
- To always, increase the rate of costs recovery (therefore eliminating certain inefficient bus lines).

Cities interested in the hierarchy of bus lines within the network consider several types of solutions based on the bus: they range from local lines to full BRT systems with a high level of quality, as shown in the chart below (Figure 5):

Figure 5 : Towards an approach of prioritized solutions based on the bus



The concept of BRT should be viewed as a method or guideline for local decision makers to study and design various solutions based on the bus. The identification of each service level can be reached by several means, among which:

- Bus lines numbering, choice of a logo,
- A specific design for the vehicle,
- A specific design for all stations,
- Specific features along the infrastructure: contrast elements, furniture, marking, etc.,

- Clear identification of the route on all plans and network information tools,
- Specific service features (frequency, schedule).

The BRT concept could be considered as:

- A strategy implemented in a system approach to improve, revitalize or restructure public transport (beyond the main lines): a renewal strategy in line with new requirements.
- A tool to establish the key characteristics of a high quality urban insertion adapted to the economic, cultural and social context.
- An educational tool for all stakeholders.

The importance of simultaneously planning urban development and investment in public transport was highlighted in many projects (Nantes, Zurich, Lund, Jönköping, Madrid, etc.). It is noted that successful BRT implementations correspond to projects where issues of planning, land use and transport were discussed simultaneously.

It is therefore important to involve politicians at an early stage of the project. Successful BRT projects have all required an extensive debate and significant involvement from stakeholders. Such a process can be long, but experience has shown that it leads to good results.

Selecting a transport technology and a priority concept are fundamental issues for the system's efficiency and its acceptance by stakeholders.

As a transport mode, the bus seems well suited for urban areas experiencing a gradual expansion. In order to meet the demand, the maximum size is the bus or the bi-articulated trolley. The BRT should also be provided with priority equivalent to the tram's as it travels on its reserved lane. Moreover, in the concerned areas, traffic regulations should be adapted and signs should be standardized to indicate the priority of trams and BRT.

In other words, priority regulations identical to those applied for tram should be ensured for buses. The observed customer growth has ranged from 15 to 150%; several years (3-4 years) are needed to attract customers. The case of a long distance line: an increase of 15% was reached in Hamburg within 3 years on a busy long distance bus line, through a better identification strategy and improvements.

Customer growth is related to a combination of factors: improved reliability, shorter travel time, increased service volume, image and marketing strategy improvement, and a targeted policy of constraints imposed on cars. No direct relationship with the percentage of reserved lanes could be observed, although it is often the most important factor.

The collected data demonstrate the ability of BRT projects to achieve significant levels of modal shift from private cars to public transport: 5 to 30%. This result varies according to specific contexts. Rates of public transport use are already high in Sweden and the Netherlands, while rates of private cars recorded in France, Ireland and Spain are often higher.

It is also noteworthy that the concept of high level of service does not necessarily mean high technology. Moreover, the concept of high level of service must apply to the entire passengers' travel. Two approaches can be used to establish a definition: level of service and quality. With any chosen method, services' characteristics must be formulated explicitly, and correspond to the travel demand and customers' preferences and priorities.

BRT's features and performance reflect these requirements. Frequency, regularity and punctuality are essential factors for achieving a high level of service. These characteristics generally define the main key performance indicators adopted (in association with various calculation methods) by operators, and found in service contracts.

Table 4: Choice strategy for components of the BRT system

BRT components	1	2	3	4	5
Lanes	Primary lateral reserved lane	Mostly reserved two-way lane	Reserved lane with some uneven crossings	Strategic partially reserved lane	Strategic reserved lane (A) with passing lanes (high capacity)
Stations	Parking on sidewalks no improvement	Improved design (accessibility)	Improved with dynamic information	Identical to col.3 with specific and modern design	Identical to col.4 with automated ticketing and security cameras
Vehicle	Conventional bus	Conventional bus (CNG, biofuel, Hybridization,)	Trolleybus	Specific design	Guided bus (specific fleet)
ITS	None	Partial priority at traffic lights	(nearly automatic priority at traffic lights)	Identical to col. 3 with dynamic information	Identical to col. 4 with no ticket sale by driver
Itinerary identification	None	Specific stations	Specific color fleet	Specific stations and bus, (special visual aspect for dedicated lanes)	Strong identification (logo, specific design for the system)
Operation	No priority at traffic lights	Demand for priority at traffic light at selected period	Demand for priority at traffic lights at most intersections	Demand for priority at traffic lights at all intersections	No traffic lights (grade separated junctions)

Classification example for the BRT project

Travelers are in favor of public transport when they judge it more advantageous than the car. Criteria influencing this decision include speed and / or cost, ease of use and reliability, especially when a strong policy in favor of public transport is conducted (i.e. applying parking restrictions in the city center, which concerns many BRT cases studied). Citizens' acceptance of BRT is generally satisfactory. The quality offered by the BRT in terms of service, accessibility and security is comparable to the trams.

6 BRT STATION DESIGN

Station: a term adopted for the BRT (mainly for full BRT systems with high capacity). A robust design, similar to trams' and light rail stations', must indeed be adopted for stops, which cannot be moved under any circumstances. With few exceptions, the location of a station should never vary.

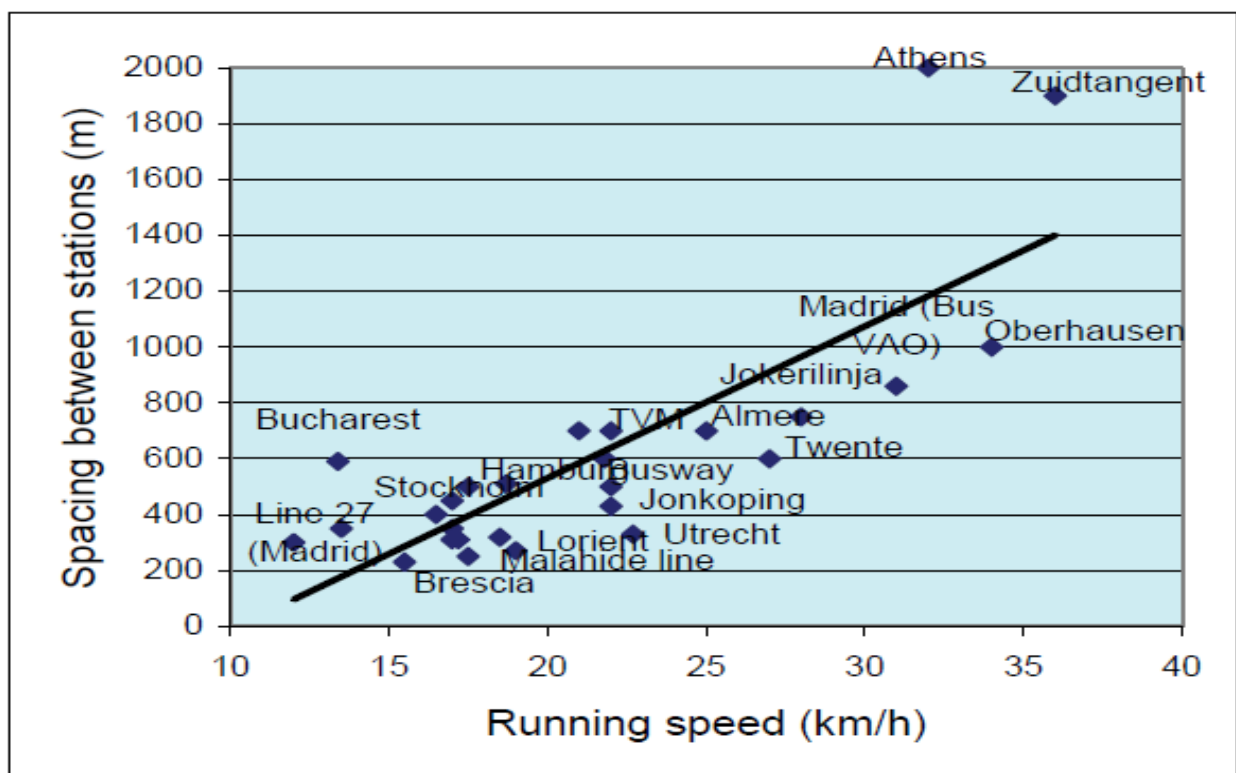
In BRT systems, a station cannot be reduced to a simple bus stop that could be moved for various reasons (works on underground water or gas distribution networks, etc.). A station is meant to be durable; it structures the surrounding space according to the line's central role, as it is the case for full BRT systems or trams.

Therefore, all underground networks should be diverted when their path crosses such a station.

6.1 The effect of distance between stations

Inter-station distance: the distance between stations influences passengers' travel time and the number of destinations served throughout the route. Commercial speed is truly strategic for the economic aspect of the project. As illustrated in the Figure 6 below, its correlation with distance between stations is obviously fundamental.

Figure 6 : Strong correlation between inter-station distance and commercial speed



Source: COST action TU0603/2011

The main observations in **Figure 6** are:

Extending the distance between stations to an average of 400 to 500 m is a minimum for BRT projects. In Stockholm, for example, the initial average of 200 m was later increased to 450 m for financial reasons (increased speed).

Spacing varies between central and peripheral routes, as demonstrated by the following systems:

** Zuidtangent (in the Netherlands): the distance between stations varies from 700 to 5000 meters on the section using the highway, thus having significant variations.

** Cambridge (UK): the distance between stations varies from 400 m in urban sections to 2500 m on the guideway between dense areas.

The smallest distances are recorded on line 27 in Madrid (300 m) and Utrecht (350 m) - two systems implemented in areas with high density - as well as in Lorient (270 m) and Dublin (250 m). These projects are designed to keep existing stops, and the objective of improving the service is based exclusively on the right-of-way.

Increasing the distance between stations is inconvenient for travelers, because it increases the walking distance. This is problematic for the elderly and disabled.

A stop (bus): a term adopted for conventional bus lines. They offer more flexibility because they can easily be moved, which occurs frequently during road works, markets, exceptional events, etc.

6.2 Comfort & Image

A station (located on a reserved lane or in a mixed traffic area) requires a high safety level for pedestrian crossings, a sufficient number of shelters to meet attendance needs, a straight line access for buses, a platform width suitable for the demand, and all the features of an attractive and visible design (route identification strategy).

The most remarkable BRT stations are associated with the most comprehensive systems. All the most ambitious projects are equipped with ticket distributors in all or the majority of stations. Other BRT projects, with lower capacity or traffic, have also adopted these ticketing systems at their stations.

It is not efficient to allow the driver to sell tickets, especially on strong lines; it can also cause significant delays at peak hours, and disturb priority requests at traffic lights.

6.2.1 The trend in quality of docking devices / guiding practices

Investing in devices offering high quality docking at every door is very important for high capacity BRT. It reduces and regulates the duration of stops in stations, while providing excellent accessibility.

In the absence of a guidance system, stops must have entrances allowing buses to run in a straight line (according to the vehicle length); border height must be compatible with the type of bus and installed rail (recommended height of 18 to 21 cm in general).

6.2.2 Pavement quality at stops (rutting problems)

The use of solutions entirely based on concrete (or BCMC: bonded thin cement concrete) is observed mainly in Central and Northern Europe (Sweden, UK, Netherlands, Germany), as well as in Switzerland.

This is a long-lasting solution, allowing efficient docking and an interesting visual contrast at stops.

The "percolated" coating could be an alternative, although it is not suitable for heavy use. It was adopted for all Busway stations in Nantes.

Figure 7 : BRT stations based on concrete (BCMC)



7 SUBURBAN OR INTERURBAN ROUTES

Suburban areas usually refer to cities' surroundings with a scattered model as opposed to the dense central city.

7.1 The issue

Three convergent goals justify the need to promote inter-city fast connections, which for emergent countries can be in the range of 80 to 120/150 km, or connections classified as suburban around an urban center:

- A- The will to reduce car traffic;
- B- Priority and fast public transport service for less densely populated areas;
- C- Efficient intermodal network integrating urban public transport and individual mobility means.

The current service differs from the urban bus mode in the following characteristics: generally more distant and longer trips, greater inter-stations distances, smaller capacity and frequency, less exchange at stops, accessibility for PRM (Persons with Reduced Mobility) more difficult to implement in case of high platforms. (

Figure 8)

Two types of public transport, with different characteristics from the urban bus, are suitable for these connections:

- the BRT, often with a departmental or local OA (Organizing Authority)
- rail transport with different techniques (RET "regional express transport", tram-train "vehicle derived from the tram") with a regional OA

Interconnection is possible between the rail network and the urban network (BRT), but compatibility between them is very complex:

- Low population density in suburban areas around big cities is not conducive to high capacity systems
- The urban sprawl is to be built by combining BRT, RET, carpooling, transport on demand, etc.
- Financial resources remain limited in terms of public transport networks development issues: limited profitability of urban networks and suburban rail
- The nature of railways and highways (curves, gauges, and obstacle limitations ..), lack of real global vision on a national and local scale

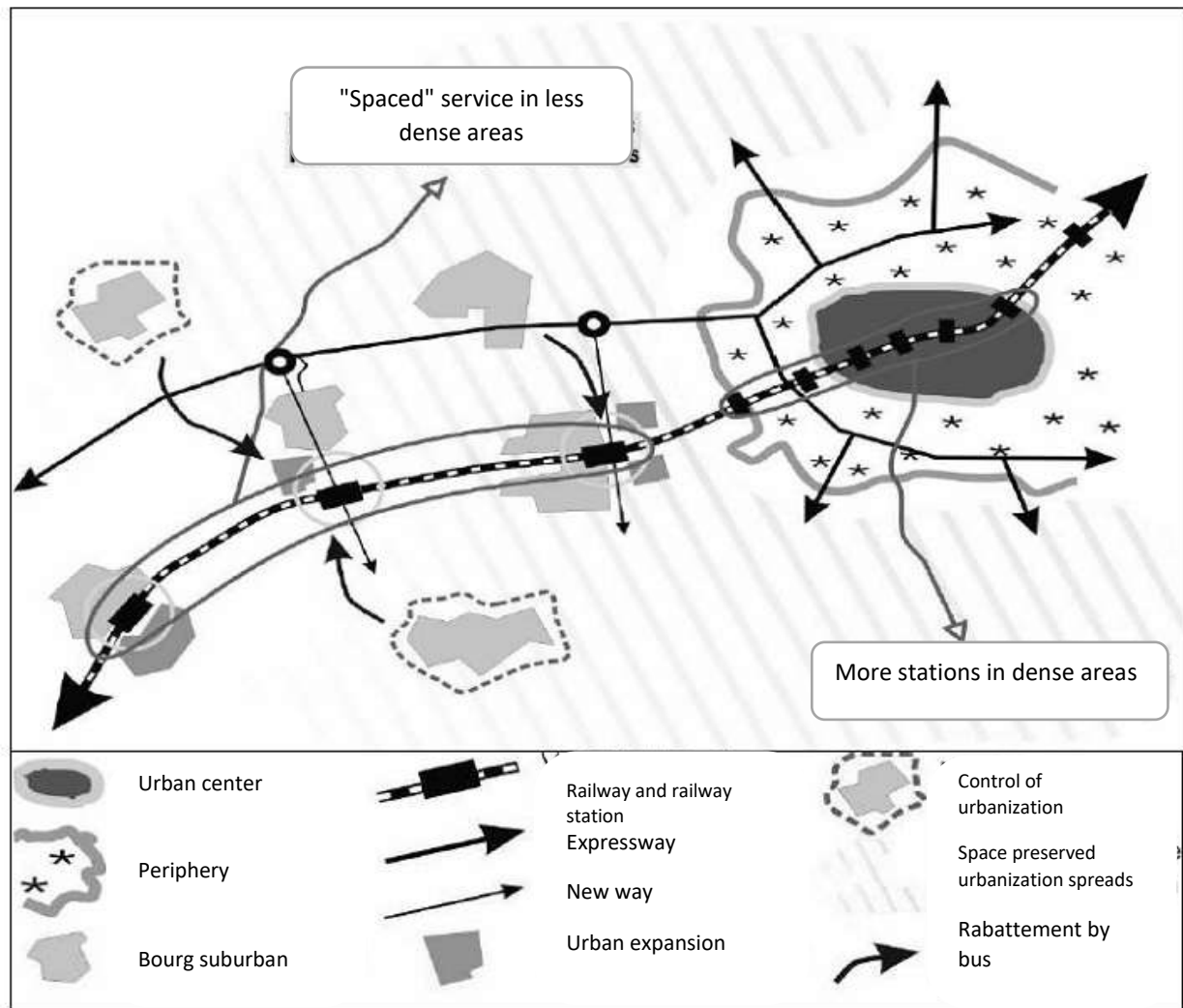
BRT can be seen as an intermediate step towards a future tramway. But the choice of the tram requires heavy modifications and a long-term vision to ensure the compatibility of successive choices.

For example:

The shared dedicated lane on Highway 48 in Grenoble: With the creation of a dedicated lane on A48 motorway, the bus line use increased significantly; in 2008, approximately 4,000 passengers per day use the suburban line, whereas in 2002 they were 500, (46% of users are former car users).

There is a growing demand to develop frequent and rapid BRT lines as a complementary solution to the rail mode. However, buses remain subject to traffic conditions risks, and growing and recurring congestions on main roads to cities (especially in dense neighborhoods).

Figure 8 : Evolution of suburban travel (Revue Géographique de l'Est)



7.2 Current proposals

There are many ways to give priority to BRT systems, two of which are the following:

7.2.1 The case of roads with no highway characteristics

The built environment is either absent or sparse, and often far from the road, or compact in villages. Beyond the first critical approach to optimize existing operations, particularly at intersections and stops, developers can create dedicated lanes on all or part of the route. At intersections, for example, the BRT could have the possibility of passing car queues and going on a specific green light.

7.2.2 The case of roads with highway characteristics:

On these lines, it is strongly recommended to consider opportunities for improving the overall operation of the highway system, along the following lines:

- speed control, especially before congestion, in order to maintain a fluid traffic service
- video monitoring and Automatic Incident Detection (AID)
- regulating access at peak hours:
 - *at entrances: adapting demand to supply capacity, and prioritizing the BRT
 - *at exits: controlling the crossroad end in order to prevent car queuing on the highway, and giving traffic priority to the BRT
- closing certain accesses (entrance and/or exit) at peak hours
- authorized access (entrance and/or exit) for the BRT

Having exhausted all these possibilities, it is necessary to consider heavier solutions on infrastructure. In reference to a state of the art produced in Europe, there are two development trends to prioritize public transport:

- 1- Creating an axial or lateral exclusive dedicated lane (one-way or two-way). This option would in fact be the heavy TCSP (dedicated transport corridors).
- 2- Creating a side dedicated lane. This option must first be applied on regularly congested sections.

Figure 9 : suburban BHLs



7.3 Development perspectives

The technique of High Service Level Buses, integrated in the BRT, may often allow better distribution of investments, at a city level, on the entire Public Transport network structure, thus avoiding heavy investment on one particular line (metro, tram-train, regional express tramway, etc.).

These development perspectives require improvements in the following sectors:

7.3.1 Infrastructure

For service efficiency, there must be a regular line with respected schedules and travel times. The issue of reserved lanes becomes especially significant at peak hours, when service is disrupted by congestion.

Moreover, for the credibility of any reserved lane approach, frequency levels must be sufficiently high; several lines or other modes, such as HOV or taxis, could also be included.

7.3.2 Rolling stock

Innovation is not limited to the design; there is indeed the possibility of development and research for rolling stock more adapted to the needs of these High Service Level Buses or BRT. The challenge will be to increase comfort and offer services on board, and especially to optimize accessibility for all.

7.3.3 Ticketing

As with the urban bus, ticketing can delay boarding, because in most cases the driver is in charge of tickets sale and control. An intermodal offer with the urban network would then undoubtedly be an important progress.

7.3.4 Interoperability with the urban BRT network

Express Bus lines should be connected to the urban network structure, and therefore to potential BRT lines, so travelers can benefit from continuity of service level.

The need to use the same infrastructure: the difficulty will be to reach technical compatibility between both systems on the docking issue (height of different thresholds), as well as on operational issues and passenger information (supervision, crossings coordination, priority at traffic lights, disturbance management, integration within the same signaling, and rights-of-way regulation).

8 BUS VEHICLE CHARACTERISTICS

This paragraph contain more detailed information about various types of bus design, and comparative turning radii (Radius) for different types of vehicles (Bus) to be considered in the design of transit facilities on streets and highways.

It covers the following sections:

1. Design vehicle guidance from AASHTO
2. Turning radii guidance from AASHTO
3. Pavement structure

8.1 Design Vehicle Guidance

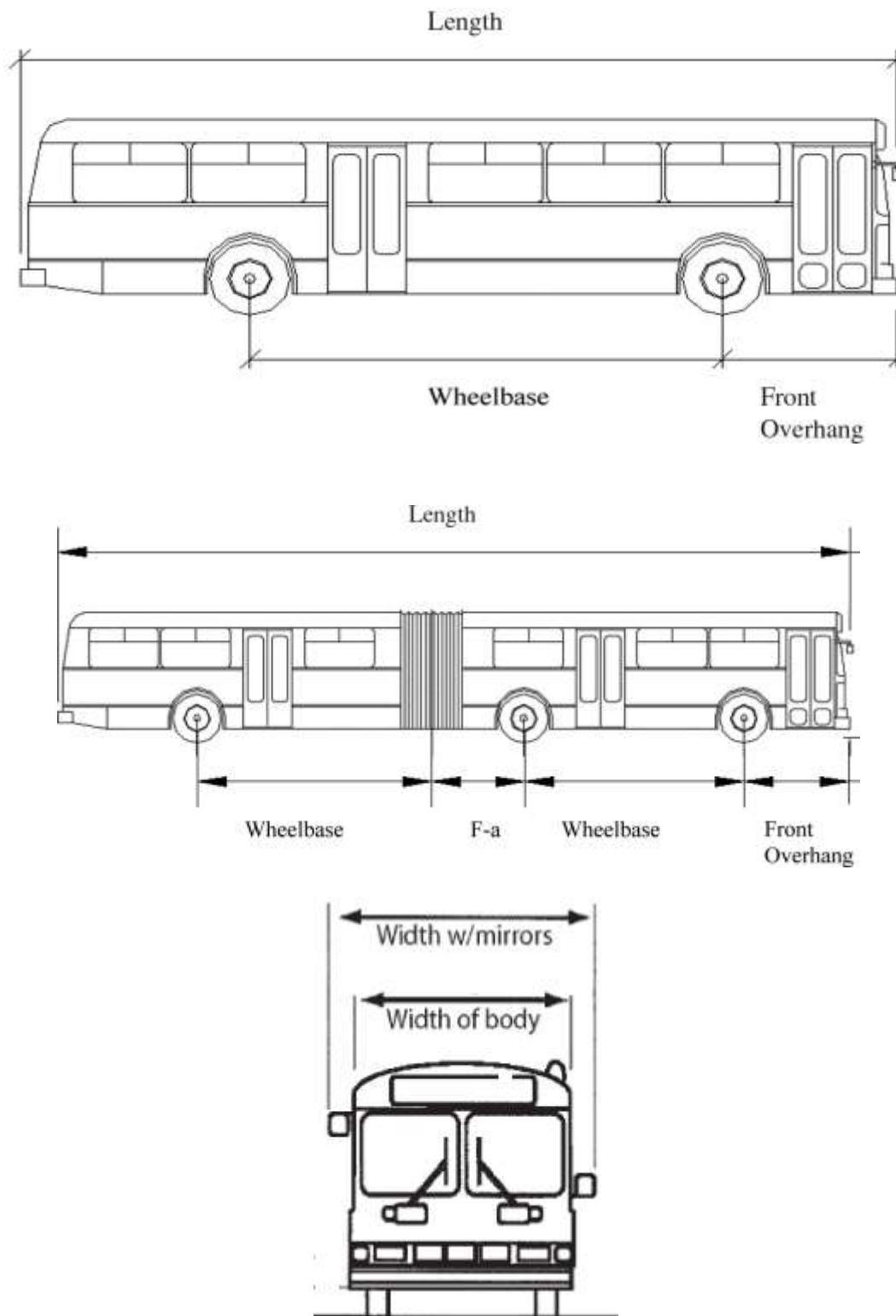
The following information is taken from the AASHTO A Policy on Geometric Design of Highways and Streets (The Green Book) for various turning requirements associated with different types of buses and other vehicles operating on a street or highway environment.

The vehicle survey revealed a proliferation of vehicle types, dimensions, and associated turn radii. The AASHTO design vehicle templates covered most categories of vehicles and, for the most part, represented the largest vehicle in each class of surveyed vehicles. Two categories of vehicles were available: 14 m city transit buses, and city transit buses of less than 12 m. The extended 14 m transit buses represent a new style that is becoming increasingly popular with bus operators. While they are similar in length to the intercity buses, they are configured as regular city buses, with a single rear axle, and greater front overhangs.

Key controls for design are the physical characteristics and proportions of vehicles of various sizes using the highway. Therefore, it is appropriate to present all vehicle types based on generally recognized groupings, and representative sizes within each class of design use. The selected vehicles, with representative weight, dimension, and operating characteristics used to establish street and highway design controls for accommodating vehicles of designated classes, are known as design vehicles.

Figure 10 shows dimensions of design vehicles, representing vehicles within given classes, with their respective conventional measurements.

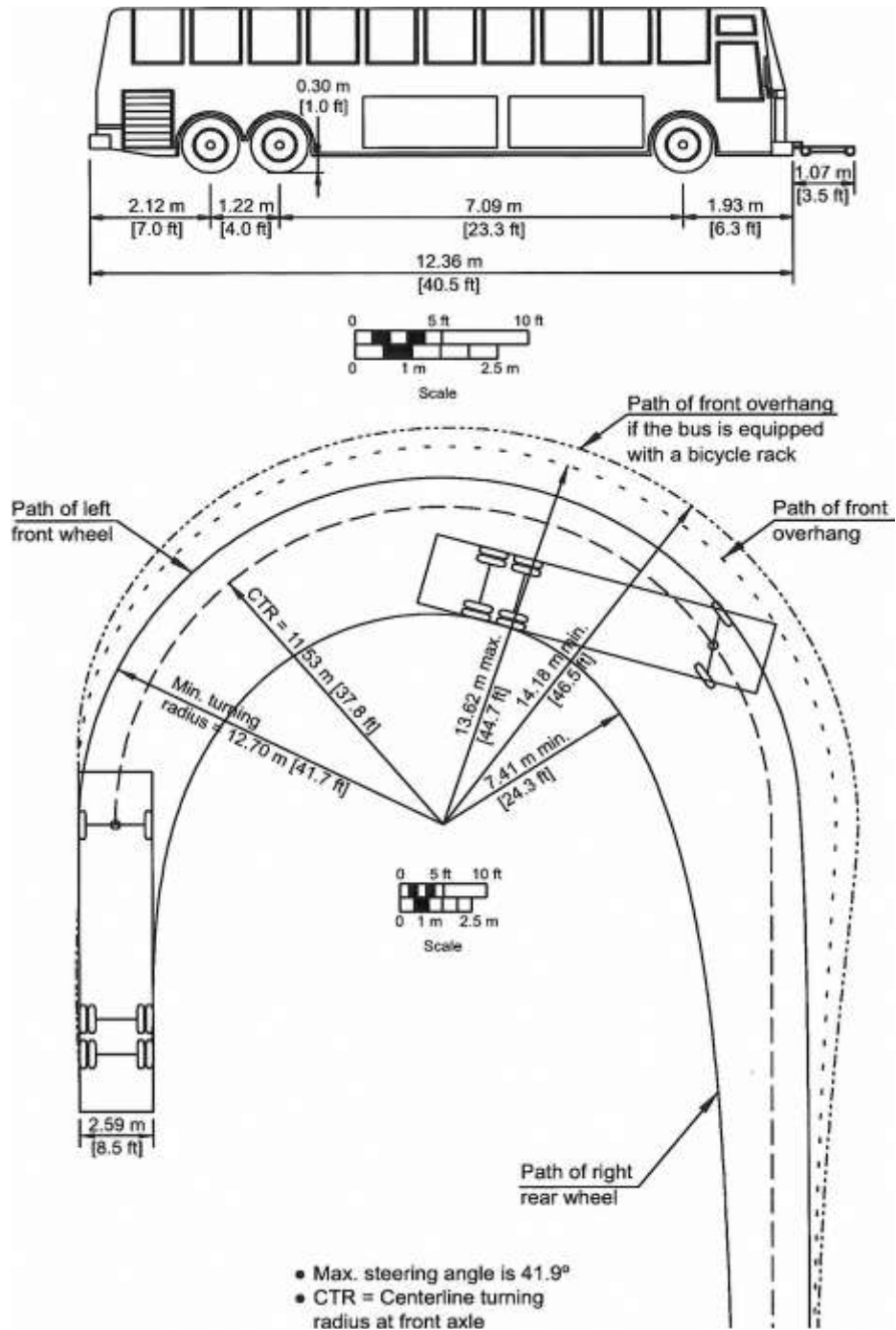
Figure 10 : Vehicle Dimensions Reference Points



(source: AASHTO)

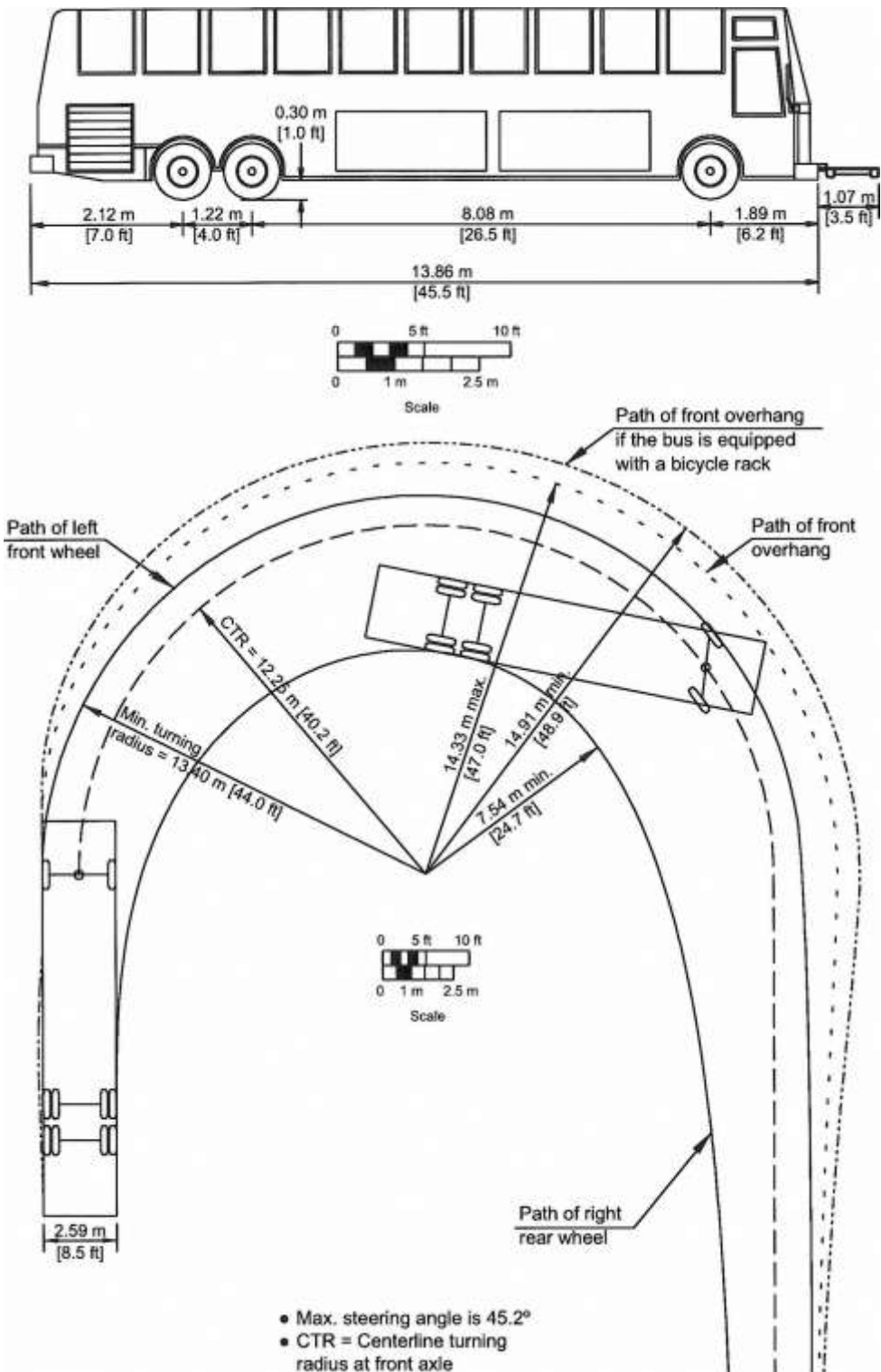
8.2 Minimum Turning Radii Guidance

Figure 11 : Minimum Turning Path for a 12m Intercity Bus Design Vehicle



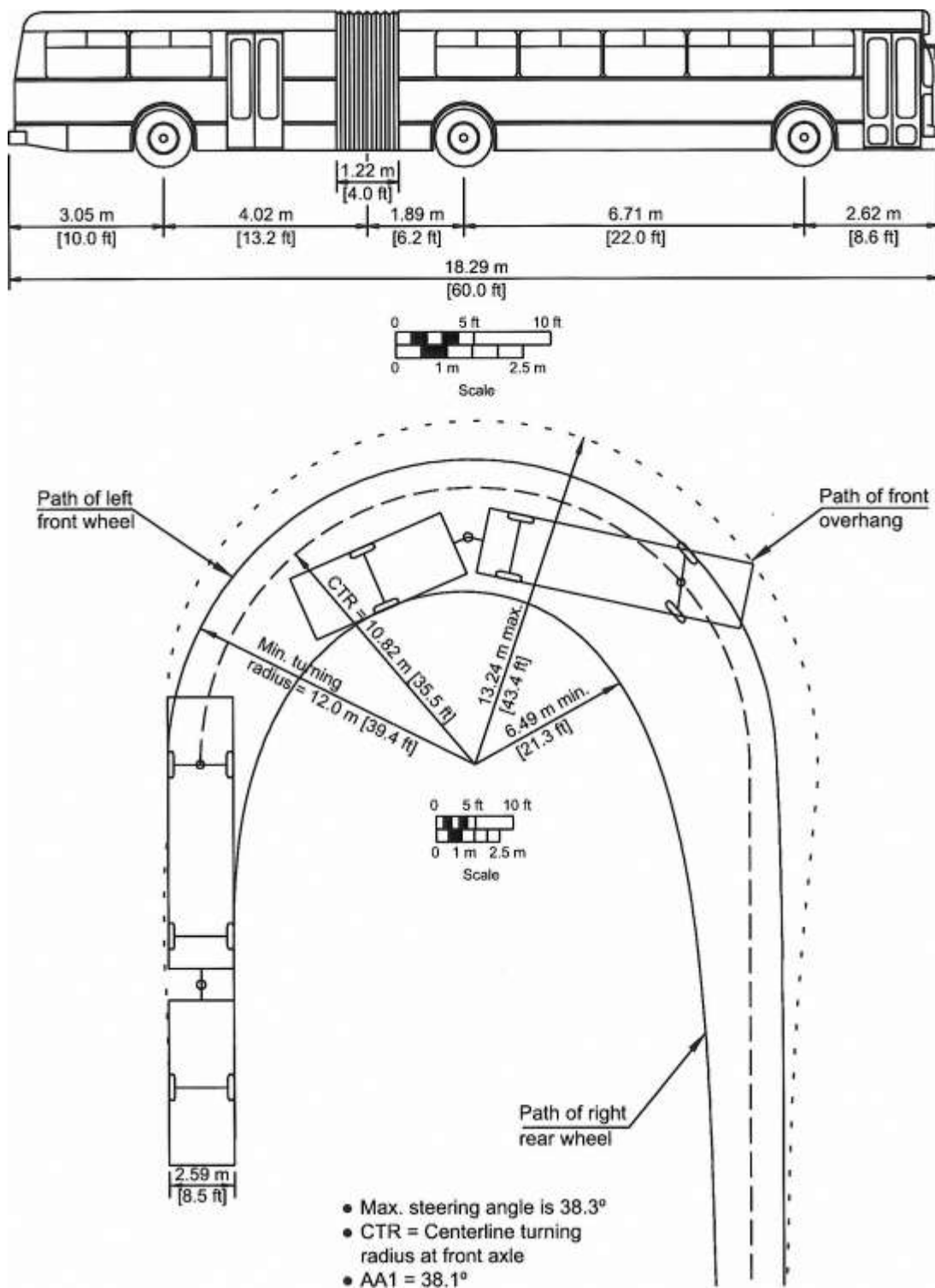
(Source AASHTO)

Figure 12 : Minimum Turning Path for a 14m Intercity Bus Design Vehicle



(Source: AASHTO)

Figure 13 : Minimum Turning Path for an Articulated Bus Design Vehicle



(Source AASHTO)

Table 5: Minimum Turning Radii (Radius) of Design Vehicles for Low Floor Characteristics

Design Characteristic	Classic Bus		Articulated Bus
	12 m	14m	
Minimum Design Turing Radius (m)	12.7	13.4	12
Centerline Turing Radius (CTR) (m)	11.6	12.3	10.8
Minimum inside Radius (m)	7.6	7.6	6.5

Table 6: Bus Dimensions for High- and Low-Floor Design Vehicles

Bus Type	Overall Body length / width (m)	Width Edge of mirror to mirror (m)	Overall height (m)	Floor height (cm)		Weight (Kg)	Turning Radius (Outside) (m)
				Standard	kneeled		
H.F* 12m	12.2/2.5	3.4	2.8-3.4			12800	
L.F** 12m	12.2/2.5	3.4	2.8	34 - 38	29 - 30	12600	11.16-13.71
H. F 18m	18/2.5	-	2.8 – 3.1	-	-	18500	13.41
L.F 18m	18.3/2.5	-	2.8	32 - 36	29 - 30	18100	12.95

*H. F: High Floor

**L. F: Low Floor

8.3 Pavement structure

Guidelines for the design of busway pavements stem from direct experience with the design of flexible and rigid roadway pavement systems. These guidelines are proposed for use in the planning stage only, and do not preclude the need for detailed pavement structure design.

Subsequent detailed investigation, necessary before final design, will probably indicate the need for modifications to the typical pavement thickness given. Factors such as design traffic, subgrade conditions, environmental effects, availability of acceptable construction materials, construction traffic, performance of similarly loaded pavements in the area, and economics need to be considered as part of a detailed design to reach an optimal pavement structure. In Table 7 some typical bus and gross vehicle weights for different potential BRT vehicle types.

Table 7: Typical Bus Weights and Gross Vehicle Weights

Bus type	Bus Weight Kg	Gross vehicle weight Kg
L= 12 m		
Diesel	12500	18000
CNG	13100	18000
Hybrid (Diesel- Electric)	14000	18000
L= 18 m		
Diesel	18800	29000

The expected number of heavy axle loadings, as opposed to the gross vehicle weight, directly influences pavement design, since multiple axles help spread the load on the pavement and reduce impact. However, loading is not even across axles, and the rear axle on a two-axle vehicle will typically carry 70 to 75 percent of the gross vehicle weight. Note that even small increases in weight on an axle can cause disproportionate damage to the pavement structure.

For design purposes, the traffic volume is represented by the number of equivalent standard axles (ESAs), typically using a design period of 20 years for flexible pavements, and 40 years for concrete pavements. When comparing different pavement structures, a whole-life analysis of the alternatives is required to produce an equitable comparison.

Typical pavement section depths for a rigid pavement are in the range of 175 to 250 millimeters (mm) of Portland cement concrete, on a 150 mm deep crushed granular base course. For a flexible pavement, the typical depths are 125 to 175 mm of asphaltic concrete pavement, over 300 to 375 mm of crushed granular base course. The life cycle of asphalt would include an overlay of 50 mm over approximately 12 to 15 years (AASHTO).

Additional consideration should be given to pavement design in BHLS systems with lane guidance systems, since they tend to maintain a single wheel line loading that might promote faster rutting.

Experience has shown that rigid pavements perform better at bus stops and intersections, and their use is recommended in these cases.

9 TYPE OF RUNNING WAYS

Running way types vary in the degree of grade separation and lateral segregation from general-purpose traffic. Running ways can be classified into four types:

1. Separate (or segregated)
2. Freeway
3. Urban street
4. Arterial street

9.1 Separate busway design guidelines

A separate running way is the most developed form of busway and consists of a road or guideway dedicated to buses built on its own alignment. It can include both at-grade and grade separated intersections, with cross-streets and free-flow ramps to and from other types of BRT running ways. Figure 14 illustrates a separate busway facility.

Figure 14 : BRT, a separate busway facility



Source: McCormick Rankin Corporation

Separate busways represent the highest level of running way for a BRT system. Dedicated lanes allow buses to travel freely and without obstruction (except for other buses), which provides a clear time advantage over mixed-flow running ways. Separate busways also represent a significant advantage for use by emergency vehicles to and from travel areas that might otherwise be congested or difficult to access during peak travel times.

Where possible, the best balance of the most direct route and the smallest number of grade-separated crossings and other costly project elements should be chosen. While this may seem obvious from the outset, cost considerations tend to take precedence over user convenience/attraction, which more often than not tends to be the amount of travel time. Striking the right balance between overall cost and user convenience is one of the most challenging, yet most important, aspects of the planning process for a separate busway facility. Because bus services are flexible and may be modified over time to reflect changing passenger and development growth patterns, where possible, connections between a dedicated bus roadway and the street system should be designed from the outset to accommodate turns in all directions.

9.1.1 Geometry

The geometry of a separate busway facility can be considered for two types of corridors:

- The first type of corridor, “greenfield busways”, are busways constructed in areas with few limitations in terms of space, on direct routes to the desired destinations, and requiring few, if any, expropriations, since they are on mostly undeveloped lands.
- The second type of corridor, a “constrained corridor”, uses routes limited in width, located along routes that are not entirely direct and/or are constructed adjacent to or within developed areas. These factors will have a significant influence on the construction cost, convenience, and travel time associated with the busway(s).

Assuming that sufficient land space has been acquired, separate busways should be constructed with passenger comfort in mind. Similar to any other busway lane(s), geometry will influence the comfort and, ultimately, the attraction of transit users, particularly those who have to stand. Therefore, abrupt changes in horizontal alignment should be avoided as much as possible.

The design speed of the busway should be selected with the notion that for a restricted access road with few obstructions, design speeds should match those of major comparable thoroughfares, while recognizing that constraints or local policy may limit the maximum design speed to some degree or in some areas. In general, the geometry of the busway should meet current AASHTO geometric design guidelines for the desired design speed.

Table 8 presents a summary of basic geometric design criteria and recommended values for separate busway facilities. Exceptions can be warranted on a case-by-case basis.

Table 8: Typical Busway Geometric criteria and Recommended Desirable Values

Criteria	Recommended value
Minimum design speed, Mainline	70 km/h
Minimum design speed, station and CBD areas	60 km/h
Minimum design speed, arterial ramps and access road	40 km/h
Minimum stopping , sight distance	AASHTO / TAC standards
Minimum sight distance at station area (Passenger comfort)	85 m
Minimum passing sight distance (station area only)	AASHTO / TAC standards
Minimum horizontal sight distance	AASHTO / TAC standards
Maximum super elevation , separate busway	3%
Maximum super elevation , arterial/ expressway facility	6%
Maximum super elevation at station	2%
Maximum super elevation runout, main busway	1:400
Maximum super elevation runout, station	1:200
Minimum horizontal curve radius, mainline	Based on minimum design speed
Minimum horizontal curve radius, station and CBD areas	120 m
Minimum horizontal curve radius, absolute minimum	80 m
Minimum horizontal curve radius, ramps and access	45 m
Spirals, all curve less than 870m radius " when potential convertibility to LRT	AASHTO / TAC standards
Minimum tangent at station ends (Platform)	20 m
Maximum intersection skew angle	20°
Minimum turning radius at intersections	Depending on vehicle type, 12 absolute minimum
Minimum grade, rural section	0%
Minimum grade, urban section	0.3%
Minimum grade, mainline	5% up to 8% for short run (120-150m)
Grade range, stations	0.5% to 2.0%
Maximum grade, access roads and ramps	6%
Minimum crest and sag curves	AASHTO / TAC standards
Minimum crest and sag curves at stations (passenger comfort)	K= 17

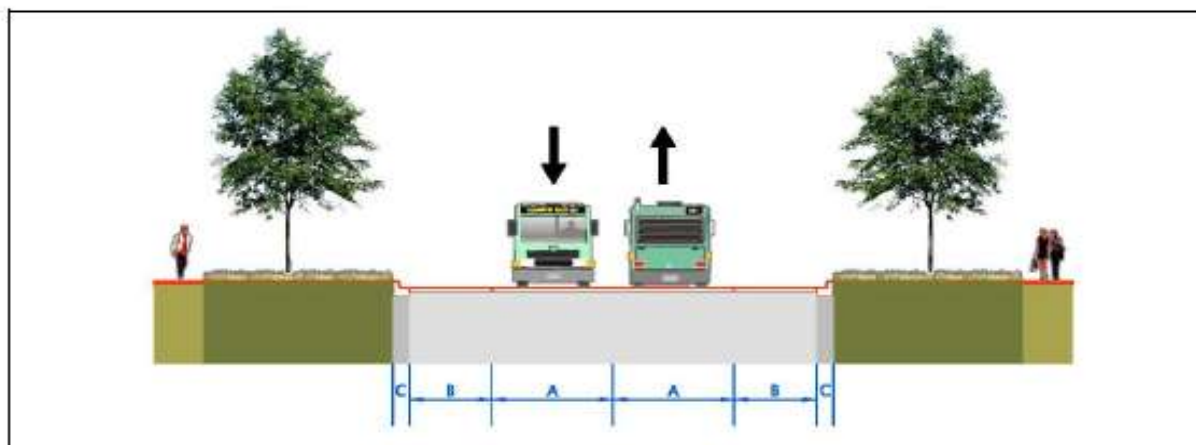
Source: American Public Transportation Association /BRT/ 2010

9.1.2 Cross-section

Desirable cross-sections are based on those for public roadways with the same design speed. Minimum cross-section widths are constrained by the bus's physical width. Typically, the bus width constraint occurs at the mirror level, where bus mirror-to-mirror widths can be of approximately 3.35 m.

The variability of separate busway cross-section elements and dimensions, under both ideal and constrained conditions, is illustrated in Figure 15, for a completely separated busway facility on one side of a roadway corridor.

Figure 15 : Separate Busway Typical Section



Designation	Description	Dimension (m)	
		Preferred	Constrained
A	BRT / Bus lane	3.65	3.35
B	Shoulder	1.20	0.60
C	Barrier/ curb and gutter	0.60	0.60

Ideally, lane widths should be of 3.65 m, with shoulder widths outside station areas of a minimum of 1.2m. Minimum recommended lane widths are 3.35 m, with a minimum shoulder width outside station areas of 0.60 m. Cross-section widths should be maintained across structures; although for long structures (more than 60 m in length), cost constraints may warrant some reduction in the shoulder width.

Figure 16 : Busway with curbing - Nantes France

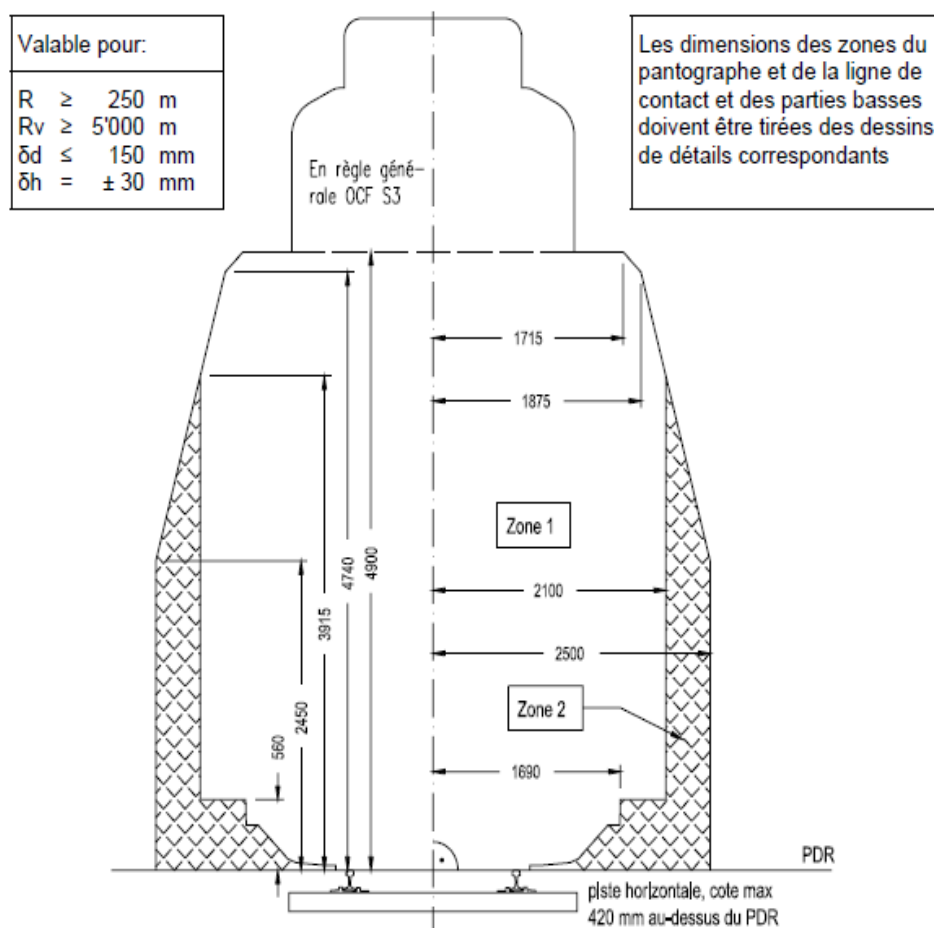


At stations, the width of a bus bay or parking area at a station platform may be reduced to 3.0 m, assuming a separate bus-passing lane is available. Added width should be provided where needed to allow parking for maintenance vehicles or out of service buses.

In the case of a guided busway, the width of each bus lane can be reduced to as narrow as 2.8 m, with curbing provided on one or both sides of the busway. Curbing can also be provided on the outside of the busway cross-section outside station areas, where there is limited lateral clearance, assuming bus-operating speed is reduced.

The unobstructed vertical clearance over the busway should ideally be a minimum of 5.0 m. The minimum recommended clearance is 4.7 m. This will allow other vehicles, such as maintenance and emergency vehicles, to utilize the busway, and provide a margin for possible future conversion to light rail transit. Figure 17 shows the clearance box for a typical light rail vehicle.

Figure 17 : Typical Light Rail Vehicle Clearance Box



Source: Integration of Light Rail Transit into City

9.1.3 Access

In some situations, it might be desirable to link the busway with a crossing or adjacent high-standard roadway or controlled access highway. Conventional one-way or two-way ramps are used.

Single-lane ramps should have a minimum width of 4.2 m, with 1.2 m shoulders, to allow for passing of out of service buses or maintenance vehicles. For radii of 120 m or less, tracking of a bus becomes significant and should be determined to verify the minimum width needed for passing. Multiple lane ramps should have lane widths consistent with sections adjacent to the busway. In the case of an urban section ramp, the width of the curb and gutter are added to the width of the ramp lanes.

9.2 Freeway design guidelines

A freeway running way is built within the limits of a freeway's cross-section, either as part of a new construction or for retrofitting an existing facility. The running way's geometry is controlled by the geometry of the freeway's general traffic lanes. The running way can have one of three forms (Figure 18):

Figure 18 : illustrates these three forms of freeway BRT running way



Source: Texas Transportation Institute
Freeway median busway (Interstate 45, Houston)



Source: Texas Transportation Institute
Freeway HOV lane (Highway 403, Mississauga, ON)



Source: McCormick Rankin Corporation
Bus on freeway shoulder (Ottawa, ON)

- **Median busway:** A dedicated bus facility in the median area, usually physically separated from other forms of traffic, and with free-flow ramps to and from other types of BRT running ways.
- **HOV lanes:** A running way shared with high-occupancy vehicles on either the median side or the outer lanes of the freeway, and not necessarily physically separated from the general traffic lanes.
- **Shoulder:** Permitted use of the outside shoulder of general traffic lanes by BRT vehicles. Sometimes limited to peak hour periods or congested conditions, and usually with various operating constraints, such as maximum operating speed.

9.2.1 Median busway

On freeways and expressways, there are often opportunities to construct busways between the median barrier and the general-purpose traffic lanes.

9.2.2 Geometry

The design speed of the median busway should match the design speed of the adjacent freeway in order to avoid differences in alignment geometry between the busway and the freeway. As a result, the geometry of the busway should meet current AASHTO or TAC geometric design guidelines.

9.2.3 Cross-section

The median busway should be designed with at least a 0.6 meter paved shy distance between the edge of the median barrier and the edge of the bus lane. The bus lane should be at least 3.2 meters wide, with a preferred width of 3.6 meters. The median busway does not require a horizontal separation between the bus lane and the adjacent general-purpose traffic lane; although 0.6 meter of painted marking separation is considered desirable, unless speed differential regulation applies, in which case greater separation may be required.

The unobstructed vertical clearance over the busway should ideally be a minimum of 5.0 meter. The minimum recommended clearance is 4.7 meters. This will allow other vehicles, such as maintenance and emergency vehicles, to utilize the busway, and provide a margin for possible future conversion to light-rail transit.

9.2.4 Bus use of shoulders

A possible configuration for longer-distance BRT routes is to use the existing shoulders on expressways or freeways.

This configuration is often referred to as a reserved bus lane (RBL) or bus on shoulders (BOS). BOS typically uses the right-hand shoulder, though left-hand shoulders can also be used for BOS if it is an express-type service.

There are a number of advantages to placing the BRT running way on the shoulders, including the following:

- Transit vehicles have the ability to enter and exit the shoulder whenever necessary to leave or enter the general-purpose outer traffic lane to maintain operating speed.
- Investment costs to convert a conventional shoulder to a BRT guideway are relatively low, typically limited to upgrading the pavement structure on the shoulder to accommodate the heavier and more constant use by BRT vehicles, and adjusting storm water inlets for ride quality.
- Transit vehicles have the ability to exit the freeway without weaving when making connections at interchanges.
- Freeway design standards usually permit high BRT vehicle operating speeds.

The disadvantages of having the BRT running way on a freeway shoulder include the following:

- Out of service, vehicles on the shoulder force all transit vehicles to re-enter the adjacent general-purpose traffic lane for passing.
- Upgrading of the shoulder pavement structure to accommodate the loadings from BRT vehicles might delay freeway traffic during construction work, unless there is sufficient space in the median to shift lanes during construction.
- Extra signage and motorist information is required to explain shoulders' use by buses.
- Transit vehicles may have to merge into the general-purpose lanes before interchange exits if the bus does not exit at that location.
- Operating policies should consider potential major speed differentials between buses and other traffic on adjacent congested general-travel lanes.

A RBL should have a 3.35 meters wide travel lane, with an additional 0.6 meter wide paved shy distance between the edge of the running way and any obstructions, piers, sign supports walls, ditch edges or guiderails; as well as a 0.6 meter buffer between the RBL and adjacent general-purpose lanes.

9.3 Urban Street

An urban street BRT running way is developed within the limits of the roadway cross-section, either as part of a new construction or for retrofitting an existing facility. The running way geometry is controlled by the geometry of the roadway.

The running way can have one of three forms: (Illustrations of these urban BRT running way treatments are shown in Figure 19)

- **Median busway:** A dedicated bus facility in the median area, sometimes shared with other high occupancy vehicles, and sometimes physically separated from other forms of traffic, with some form of transit priority at locations where it intersects with other traffic.
- **Bus lanes:** Similar to a median busway, but typically located on the outside of the arterial roadway, and sometimes shared with other high-occupancy vehicles. Typically, the bus lane is not physically separated from general traffic lanes. Variations of this form include shared use of the lane for business access and right turns; it is commonly known as a Business Access and Transit (BAT) lane.

- **Mixed-use lane:** Mixed use of a lane by both transit and general traffic. Intersection treatments, such as roadway widening and added auxiliary lanes at intersections, provide buses with the ability to “jump the queue” at such locations, and allow for some level of improved service times and reliability.

Figure 19 : Urban BRT Running Ways



Source: McCormick Rankin Corporation
Former No. 3 Road Median Busway (Richmond, British Columbia)



Source: TCRP Report 118 – BRT Practitioner’s Guide
On-street bus lane (Silver Line, Boston)



Source: TCRP Report 118 – BRT Practitioner’s Guide
On-street bus priority corridor (London)



Source: Kittelson & Associates, Inc.
Queue jump lane (Portland)

In many instances, site constraints within established urban roadway sections (such as building faces, parks, curbs, rights-of-way, frontage business improvements, etc.) may only allow little, if any, expansion of the street section. This typically happens in the “last mile”, when the BRT corridor in question terminates into a Central Business District (CBD) to tie into an existing transit or transfer facility. In these cases, travel speeds are relatively slow (less than 50 Km/h), and the BRT in mixed traffic congestion may or may not meet the system’s travel speed goals.

To address this issue, several strategies may be considered. These concepts are not ideal, and should only be used when other strategies are financially or politically prohibitive:

- bidirectional lane
- reversible lane
- peak hour only exclusive lanes

9.4 Arterial design guidelines

In many locations, BHLS will operate on an arterial street, which implies a much greater degree of interaction with other elements and users of the transportation system (i.e., private vehicles, pedestrians, cyclists).

Dedicated lane (or designated or reserved lane): a lane reserved for transit vehicles' exclusive.

Dedicated lanes can be located on different positions of the arterial street, and are classified accordingly:

- One-way lateral or concurrent flow curb: next to the curb, used by buses to travel in the same direction as the adjacent lane.
- Contra flow Curb: located next to the curb, used by transit vehicles to travel in the opposite direction to the normal traffic flow.
- Bi- lateral lanes.
- Two-way lateral lanes.
- Median lane: within the center of a two-way street. It can be one-way axial or two-way axial.

They are protected at different levels:

- by official marking or a simple difference in color or texture; the lane is easily physically accessible to be crossed by other vehicles.
- by a higher curb over which it is allowed to drive at very low speed, (it allows a flexible use of the dedicated space).
- by using a system, that does not allow the crossing of other vehicles.

They can be shared with certain categories of identified vehicles like taxis, bicycles...

An arterial running way's context can vary from urban arterial, in a dense built-up area, to suburban or even semi-rural arterial with shoulders. Given this diversity of potential locations and surrounding contexts, each BHLS running way on an arterial must be carefully designed to match each location's specific needs. This section attempts to lay out the major types of arterial running ways, and some of the most common design issues that must be addressed.

9.4.1 Median busway

A median busway is a reserved (exclusive) lane running down the center of a street, with stations located within or adjacent to the busway. This layout is similar to the operation of many LRT systems, particularly as they travel through areas where a separate right-of-way is not available.

These are typically two-way facilities, although it is possible to have a one-way facility paired with another on a parallel street, or a bidirectional lane, or a reversible facility (when demand is high). Another variation exists on a one-way street, where the “median” busway would actually be located adjacent to one curb, since there is no opposite direction.

One major advantage of a median busway is that there is typically no demand for other vehicles to stop in the center in case of a breakdown or for parking. Vehicles have no reason to want to occupy the center of the road; there is therefore less resistance to creating a physical barrier separation between the busway and adjacent general-traffic lanes. This results into fewer problems with enforcement, and a better-integrated bus lane.

9.4.1.1 Geometry

1- Between stations

Typically, a two-lane road located within the right-of-way of a larger road, a median busway functions as a road within a road. As such, the geometry of the busway will almost follow the geometry of the existing road, unless there is some very specific need for a separate layout. One example, although rare, would be to have the busway cross a major intersection with a grade separation, while the rest of the roadway uses an at-grade intersection.

2- Station areas

The geometry of the busway and surrounding roadway must be given careful consideration when approaching stations. Two main types of BRT stations are associated with a median busway: center platform, and side platform:

A - Center platform: The use of center platforms is most practical when buses’ doors are on the left side, but it is also possible if buses operate on contraflow lanes. The busway and surrounding roadway must usually be realigned to the outside to provide adequate space for the station. The design of tapers for this transition must carefully take into account the design speed for both the roadway and busway, as well as any unique handling bus characteristics.

An outside passing lane (located to the right of the stopping lane) should be provided to accommodate multiple services or to improve the overall level of service. This will increase the space required for the station, both laterally, to accommodate the extra lane, and longitudinally, to accommodate the additional taper length for the main roadway.

Figure 20 : Typical BRT station center platform



- B- Side platform:** In the case of a side platform station, the busway will typically continue straight, but the adjacent roadway will need to be realigned to the outside to accommodate the stations. Platforms should be protected from general traffic in the taper area, and wherever general traffic is adjacent to the platform. The taper length should also be increased beyond the minimum required in order to provide a smooth transition for general traffic, and to minimize the chances of an errant vehicle crashing into the platform area.

Figure 21 : Typical BRT station side platform



9.4.1.2 Cross-section

The recommended cross-section of a median busway is similar to a two-lane road, with a 3.65 meters wide lane in each direction divided by a pavement marking. If space is available, the width of bus travel lanes could be expanded to 3.9 to 4.5 meters, to provide greater lateral separation, particularly through curves, and improve safety. In constrained urban areas, the recommended minimum travel lanes' width is 3.35 meters.

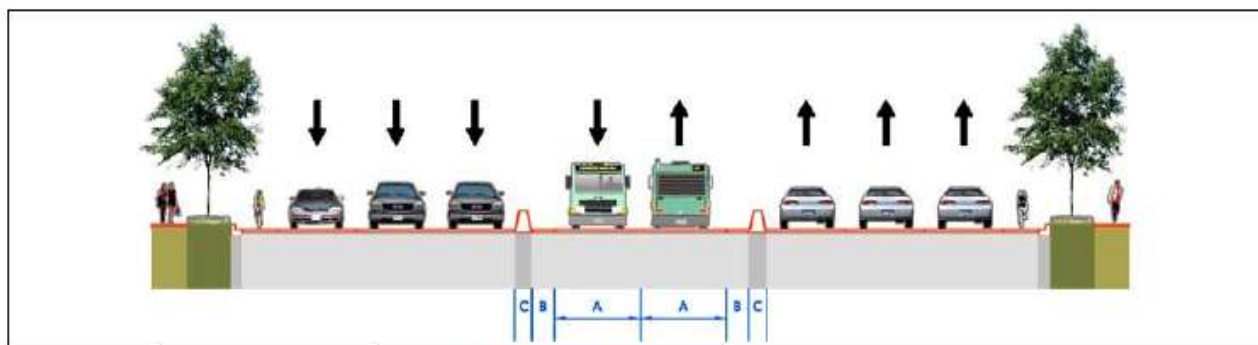
One of the major advantages of a median busway is that other vehicles have no legitimate reason to want to access the facility. Whereas on curb lanes, there might be a demand for short-term loading or parking, even when it is a bus lane.

It is possible to design a greater level of physical separation to self-enforce the facility. A wide range of treatments is possible, including options such as median barriers, low curbs, landscaping, vertical delineators, rumble strips and painted markings. Although the introduction of a physical separation, such as a concrete barrier, gives additional protection, it also expands the section's width, since shy distance on both sides of the barrier needs to be added to the barrier width. The choice of separation between the busway and the main road's general-purpose lanes should take into account operational impacts on buses using the busway, blocks' length, adjacent land uses, and the street's character. Levels of traffic also need to be considered, since high congestion levels could lead some drivers to use the busway as a bypass lane, if it is not protected.

In the stations area, the cross-section of a median busway will widen significantly, if space is provided for both stopping lanes and passing lanes. This may require acquiring additional right-of-way. If it is impractical to acquire additional right-of-way, the extra space needed for the station can sometimes be provided by restricting on-street parking in the area adjacent to the station, or by reducing the number of general-purpose traffic lanes. This roadway widening can also be used to create protected left-turn bays.

Figures (22, 23, 24, 24 et 25) illustrate typical cross-sections for two-lane, two-way and one-lane reversible median busway designs, with different surrounding roadway widths and station configurations. They are shown for both an ideal cross-section (where available right-of-way is not an issue), and a constrained cross-section (where the available right-of-way is limited). Although each median busway will need to be carefully designed according to its specific implementation context, these typical cross-sections provide a good starting point for a detailed design, as well as a good visual tool for explaining this configuration to decision makers, community residents and other stakeholders.

Figure 22 : Two-Way Median Busway, Typical Cross-Section



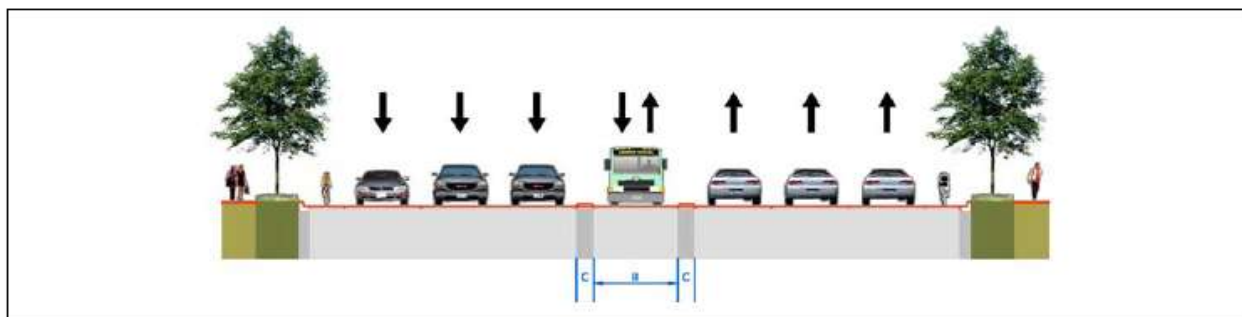
Designation	Description	Dimension (m)	
		Preferred	Constrained
A	BRT / Bus lane	3.65	3.35
B	Shy distance*	1.20	0.30
C	curb separator**	0.60	0.60

*No shoulder with guided busway

** Possible to replace with 20cm ripple paint stripe (Photo)



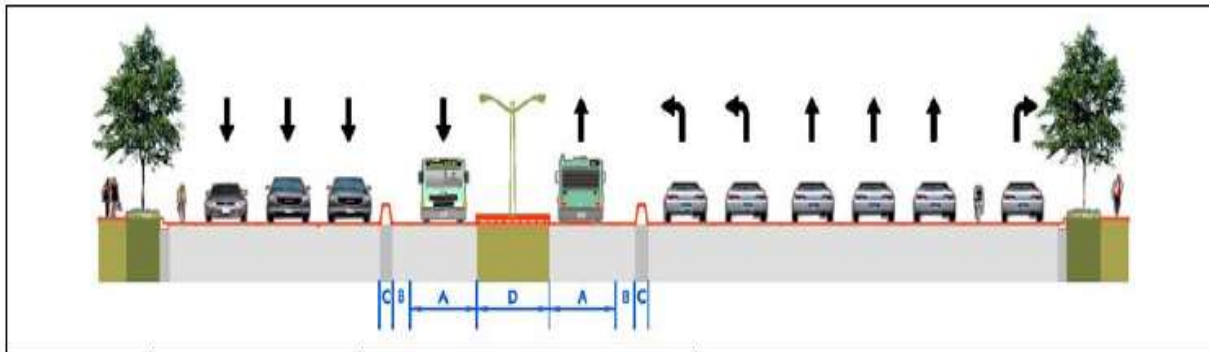
Figure 23 : two- way Median Busway, Typical Cross-Section



Designation	Description	Dimension (m)	
		Preferred	Constrained
B	BRT / Bus lane	3.65	3.35
C	curb separator**	0.60	0.45

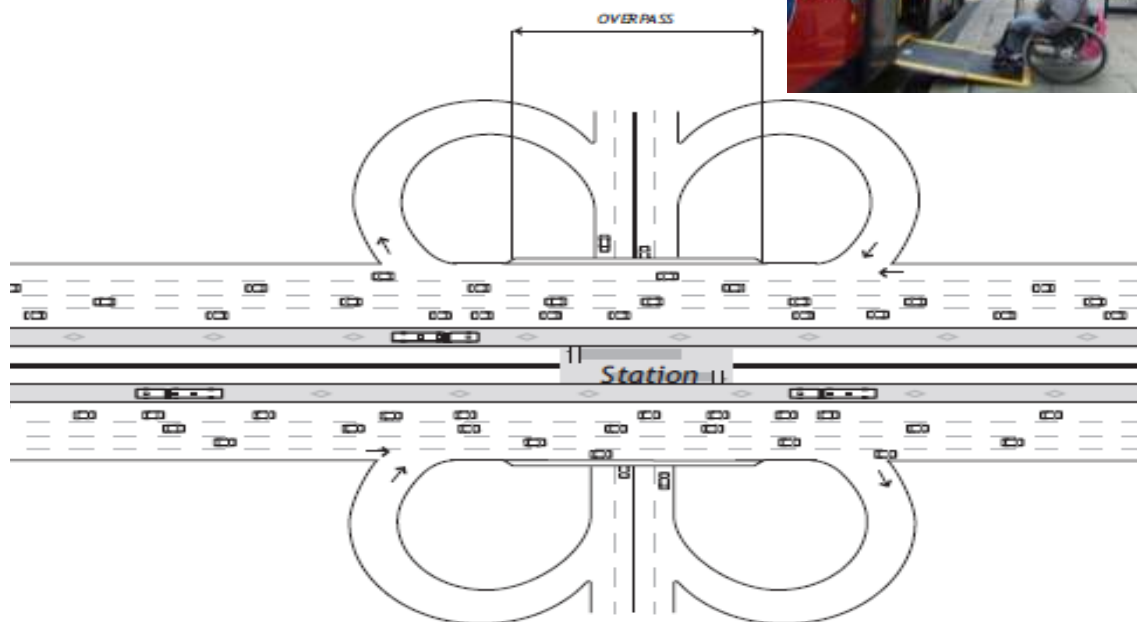
** Separator should be mountable to allow access and egress to the lane (pass and service disabled vehicle).

Figure 24 : Two-Way Median Busway and two Stations Parallels Section, typical cross-section



Designation	Description	Dimension (m)	
		Preferred	Constrained
A	BRT / Bus lane	3.65	3.35
B	Shy distance	1.20	0.30
C	Barrier/ curb separator	0.60	0.60
D	Station platform*	4.25	3.65

*If narrower more than 3.65m, must meet ADA requirement (Photo)
 ADA = Americans with Disabilities Act

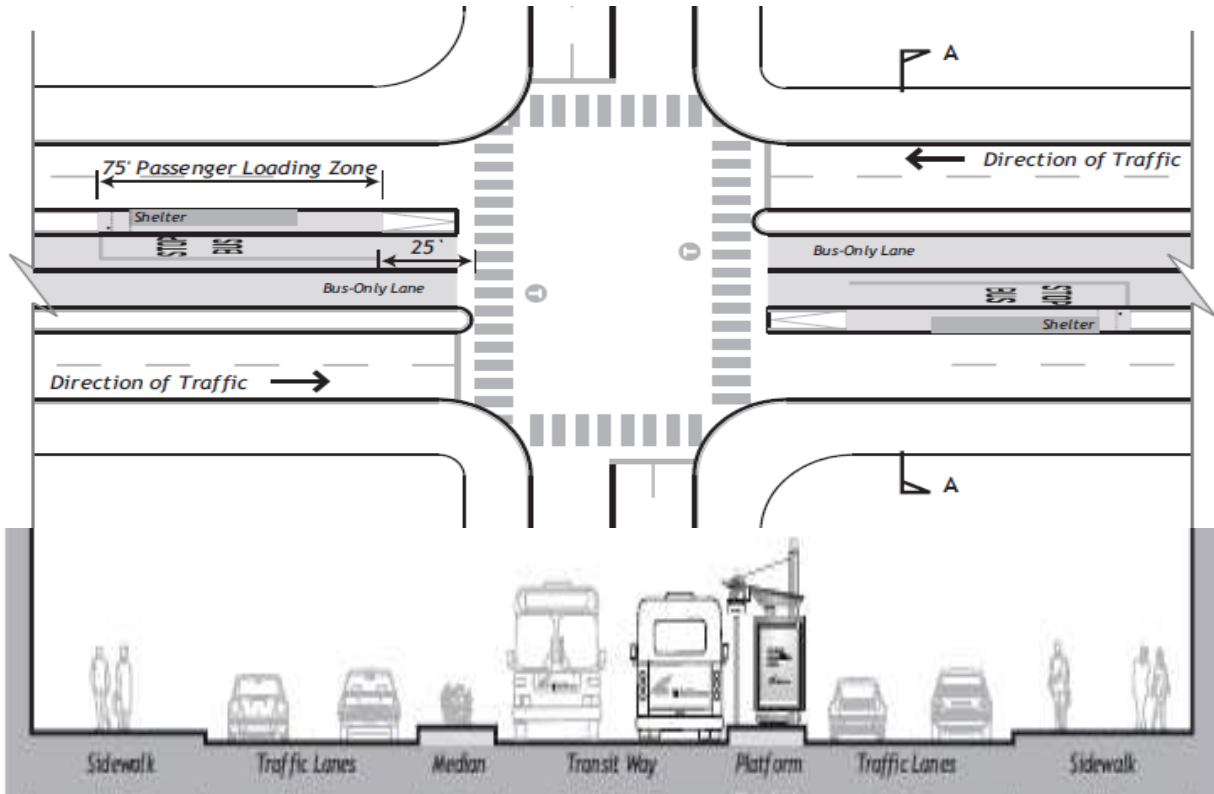


LEGEND:

- 60' Articulated Bus
- Automobile
- HOV Lane

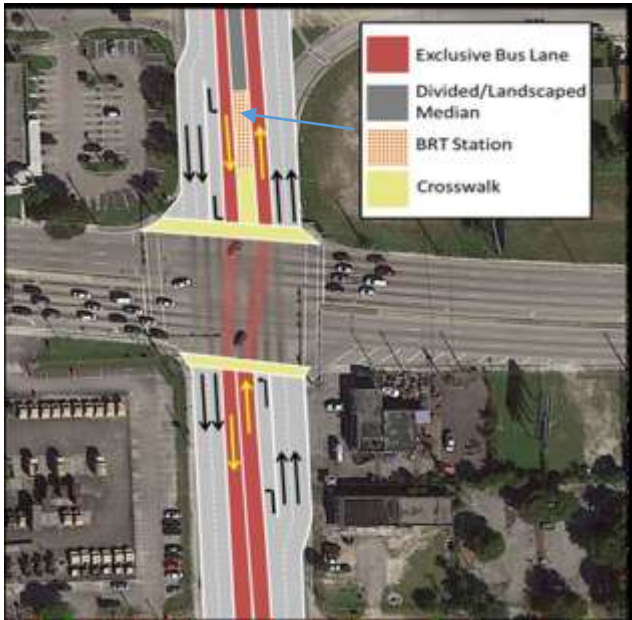
NOTE: For some median HOV facilities, direct median access ramps have been installed.

Figure 25 : Two way Median Busway and stations alternating section, typical cross-section

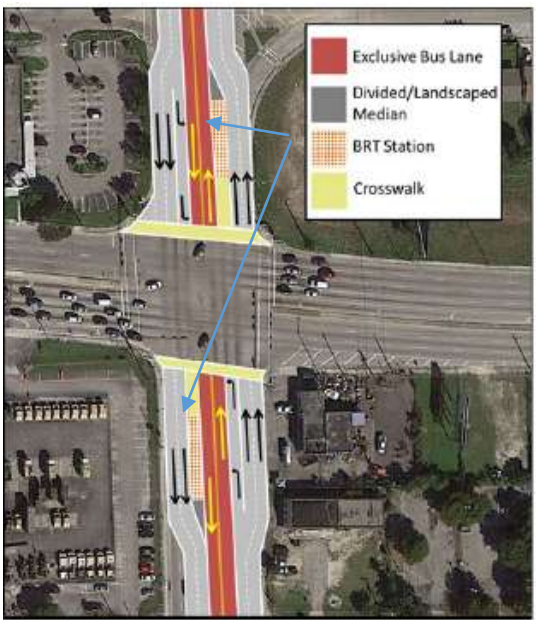


Typical Section A – A

Figure 26 : Two typical middle stations



BRT Middle Stations Parallels



BRT Middle Stations Alternating

9.4.2 Curb bus lanes

The most common form of arterial bus lane is located at the right side of the street, adjacent to the curb or shoulder. While this layout is common in locations throughout North America, installing a curb bus lane does not imply the creation of a BRT running way. Curb bus lanes are indeed subject to a variety of interference and conflicts, including right-turning vehicles, vehicles seeking to park or load at the curb, and vehicles entering or exiting at curb cuts. In this context, maintaining the integrity of the bus lane through signs, markings, education and ongoing enforcement is critical to ensuring speed and reliability of bus service.

A variation of the curb bus lane that addresses some of these conflicts is an interior or “offset” bus lane, which operates in the adjacent lane. This configuration leaves the curb lane available for other uses, including direct curb access for loading, parking, and right-turns. The negative aspect of an interior or “offset” bus lane is its significant impact on the street’s travel capacity, whereas a curb bus lane on a street with on-street parking will not change capacity. However, in some locations there may be less concern about eliminating roadway capacity, particularly if there are good alternative routes, compared to eliminating parking or loading that may have a greater impact on local businesses’ viability.

9.4.2.1 Geometry

Both a curb bus lane and an interior bus lane will necessarily follow the geometry of the roadway along which they are located.

As a result, very little consideration needs to be given to the road’s geometry, since it is typically a fixed input. In case a bus lane is being installed as part of a new street, its presence should be taken into account while laying out the street geometry. But this is unlikely to be a significant factor, since arterial streets are, by nature, typically designed to handle buses as a baseline condition.

When space is available and there is likely to be a need for buses to pass each other (for example, if there are multiple tiers of service operating on the same bus lane), it is sometimes desirable to install bus pull-outs, similar to the passing area at stations, which allow buses to pull to the right and leave the bus lane. The design of these types of pull-outs should take into account issues such as deceleration distance, the distance necessary for a bus to transition into the pull-out, and maintaining proper drainage.

In the case of an interior bus lane, it is common to use curb extension bus stops, or “bus bulbs,” where the sidewalk is extended out into the curb lane to meet the interior bus lane. This avoids the need for buses to pull to the curb to stop, speeding bus operations and potentially reducing bus stops duration. This design also increases the space available for station amenities and can allow for a raised curb height that provides level boarding with a low-floor bus.

9.4.2.2 Cross-section

The cross-section of a curb bus lane is typically only a re-designation of the curb or an interior lane as a bus lane. The recommended minimum width for a bus lane is 3.65 meters to allow for unimpeded bus operations, although a reduction to 3 m may be necessary in particularly constrained locations. If

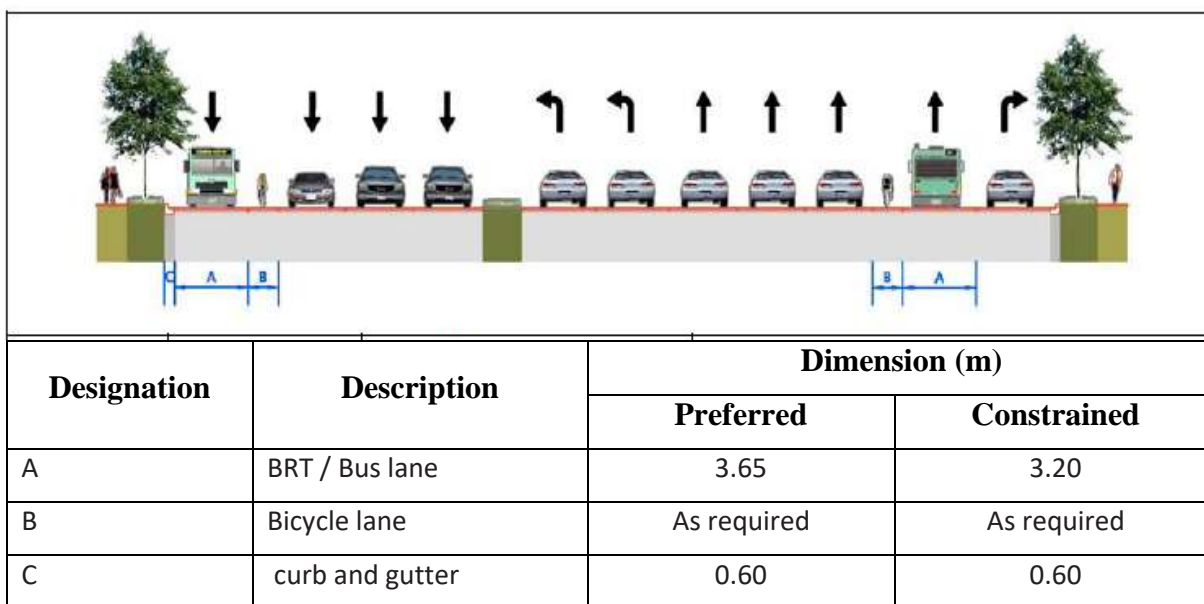
additional width is available to provide a 3.9 to 4.5 m curb lane, it would be best; because it is often difficult or uncomfortable for bus drivers to travel directly adjacent to the curb due to the presence of catch basins, uneven pavement, and adjacent mounted signs.

If a curb bus lane is replacing on-street parking or loading, it will typically require greater width than the parking lane it is replacing. Adjusting adjacent lanes' width might be necessary to provide sufficient width to the bus lane. An interior bus lane, however, is usually installed in place of an existing travel lane, which will typically be of the appropriate width.

Existing roadway cross-falls need to be considered. If excessive, they may not allow the use of the wheelchair ramp provided in many modern buses.

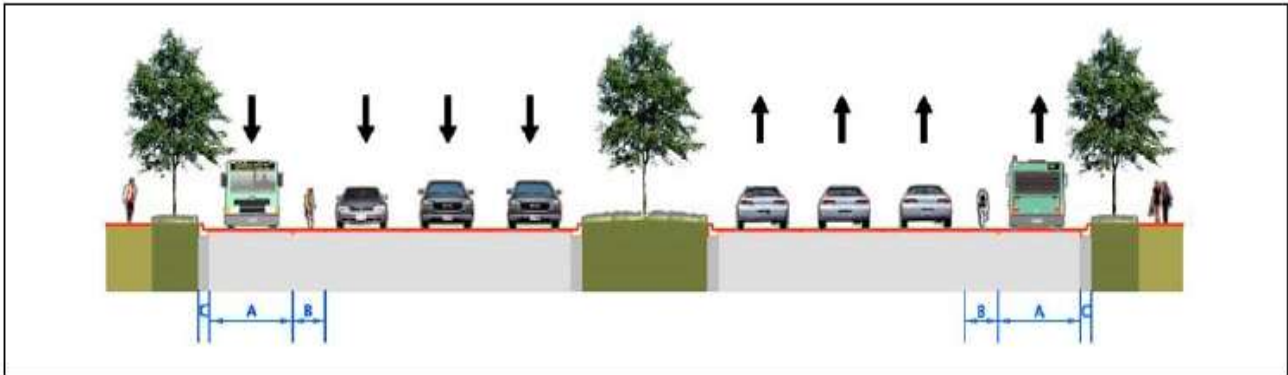
Given the other uses of curb space, it is generally not possible to totally physically separate a curb or interior bus lane, unless these other uses are relocated to the outside of the physically separated area. However, some options do exist for providing a “soft” separation between the bus lane and general traffic. They include a continuous rumble strip, similar to what is commonly used along the edge of highways, raised pavement markings (usually only used in areas where snow plowing is uncommon), or widely spaced vertical delineators. Because experience with these types of treatments is not sufficient, they should be carefully considered and analyzed in any given location or context to ensure their safety and appropriateness.

Figure 27 : Concurrent Flow Curbside Bus Lanes on a Two-Way, Typical Intersection Section

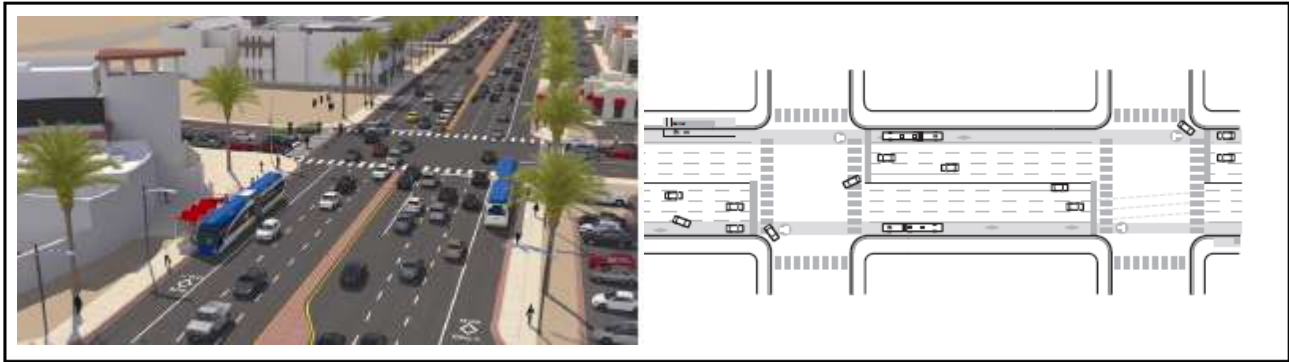
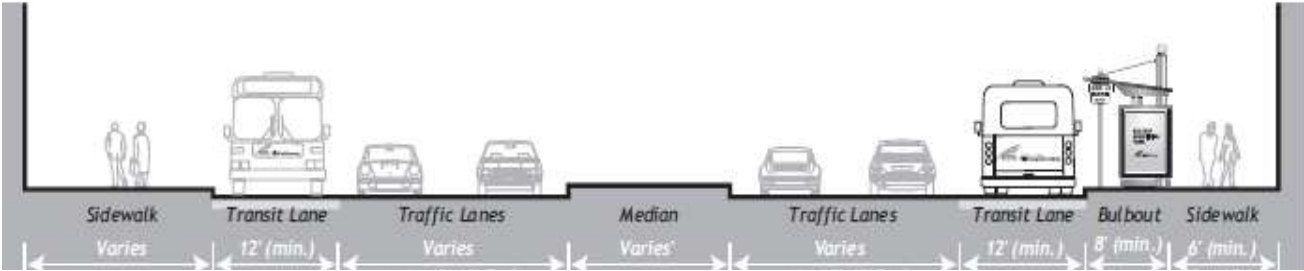


Figures (27, 28, and 29) illustrate several typical cross-sections for both concurrent and contraflow curbside bus lanes in midblock areas and at intersections, with different surrounding roadway widths. They are shown for both an ideal cross-section, where available right-of-way is not an issue, and a constrained cross-section, where the available right-of-way is limited. Although every bus lane will need to be carefully designed according to its specific implementation context, these typical cross-sections provide a good starting point for a detailed design, as well as a good visual tool for explaining this configuration to decision makers, community residents, and other stakeholders.

Figure 28 : Concurrent Flow Curbside Bus Lanes on a Two-Way, Typical Midblock Section

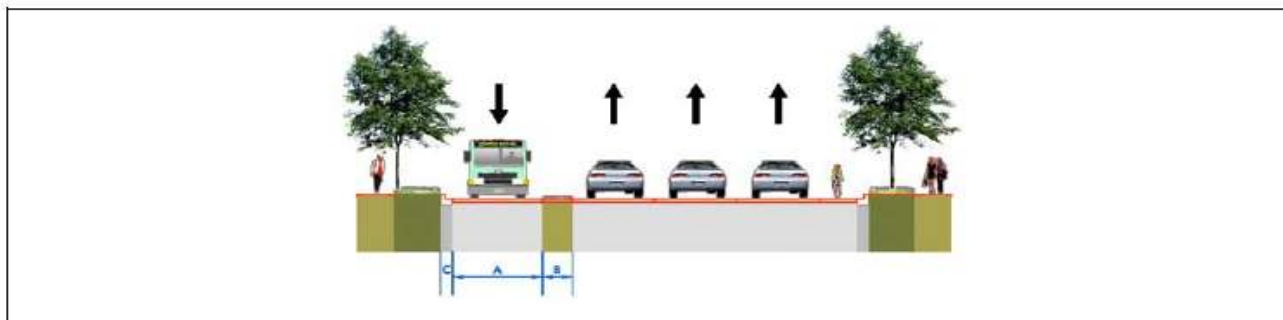


Designation	Description	Dimension (m)	
		Preferred	Constrained
A	BRT / Bus lane	3.65	3.20
B	Bicycle lane	As required	As required
C	curb and gutter	0.60	0.60

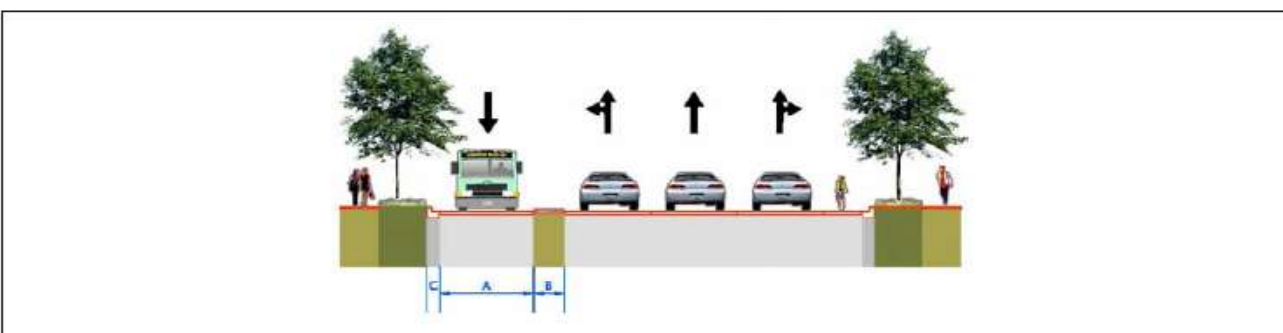


Curbside Bus only lane typical lane configuration

Figure 29 : Contraflow Curbside Bus Lanes on a One-Way Street, Typical Section



Designation	Description	Dimension (m)	
		Preferred	Constrained
A	BRT / Bus lane	3.65	3.20
B	Separator	1.20	0.15
C	curb and gutter	0.60	0.60



10 CONCLUSION

Implementing a BRT calls for a clear understanding of its benefits and costs, the availability of funding, and various mechanisms to finance, develop, and operate it.

In developing BRT systems, it is necessary to establish how the system will be planned, designed, built, operated, and fully integrated into the overall transport system. Each development stage should be keyed to levels of passenger demand and available resources. In addition, because BRT systems can operate on different types of running ways (e.g., dedicated busways or local streets), a number of agencies will be involved in implementing and operating the system.

Further data collection, feedbacks and research are still needed, mainly on:

- Evaluation of BHLS' benefits and impacts, beyond technical and ridership performance.
- Design and optimization of BHLS.
- Quality / regularity measurements.
- Improving / assessing the quality system approach
- BHLS market knowledge.
- Financing mechanisms for BHLS.
- Coordination between EU research on BHLS and North and South American research on BRT.

BRT on city streets works! It can attract riders, reduce pollution, decrease travel times, and improve service reliability. It may be the only practical running way in many cities, or provide the first stage for future busway and light rails systems in others.

DEFINITIONS:

- **Arterial:** A moderate- or high-capacity roadway designed for the continuity of movement. Arterials are usually broken into categories by their throughput ability, with principal arterials being of higher capacity than minor arterials.
- **Bi-directional lane:** A single, exclusive BRT-only lane.
- **BHLS: Bus of High Level of Service:** refers to the adaptation of the concept of BRT to the French context.
- **BRT: Bus Rapid Transit:** Frequent, faster and higher-capacity bus service designed as an integrated system of service, facilities and strategies that distinguish it from regular bus service. The elements of bus rapid transit can vary depending on the operating environment and may include priority through separate right-of-way, preferential treatments at intersections, intelligent transportation systems, as well as other actions that improve bus speed and reliability, including limited stops, vehicle design, fare collection systems, and high quality bus stations that allow for greater efficiency. Bus rapid transit is often branded to promote the service as unique compared to regular bus transit service.
- **Bus lane:** A traffic lane for dominant or exclusive use by buses, generally used to speed up public transport otherwise held up by traffic congestion
- **Center platform:** A horizontal surface above the level of rails or roadways, positioned in the center to allow boarding and alighting of passengers. Center platforms make it difficult to separate passenger and vehicles flows, and can require crossing vehicles to reach the platform to board and alight passengers if vehicles are not equipped with left-side doors.
- **Contraflow lane:** A lane going in the opposite direction to general traffic.
- **Freeway:** A type of road designed for safer high-speed operation of motor vehicles through the elimination of at-grade intersections, usually with limited access points. This is accomplished by preventing access to and from adjacent properties, and eliminating cross traffic through the use of grade separations and interchanges
- **HOV lane:** A traffic lane limited to carrying high-occupancy vehicles designated by a minimal vehicle occupancy requirement. This includes carpools, vanpools and buses.
- **Median busway:** A middle section of a roadway reserved for buses only.
- **Mixed-use lane:** A roadway lane designated for use by different types of vehicles and users. Shared use lanes may be limited to specific users and include business-access transit lanes, HOV lanes, and lanes designated for both motorists and bicyclists.
- **Right-of- way segregation:** A fully controlled legally and physically separated strip of land for use by transit vehicles without grade crossings or any legal access by other vehicles or pedestrians.
- **Running way:** A path that provides exclusive lanes and roadways to transit vehicles travel

- **Shy way:** The space left between the travel lane and a barrier, between vehicles, or between vehicles and pedestrians as they pass each other. The amount of shy distance required for safety tends to increase with speed.
- **Side platform (lateral platform):** A horizontal surface above the level of rails or roadways, positioned on each side of the roadway or rail tracks to allow boarding and alighting of passengers. Lateral platforms can easily separate the directional flows of passengers, and minimize conflicts with vehicles without requiring vertical pedestrian movements.
- **Separate running way/busway:** A roadway reserved for buses only. It may be grade-separated or a controlled-access roadway.

REFERENCES

- American Public Transportation Association, Bus Rapid Transit Service Design; 2010
- American Association of State Highway Transportation Officials, “AASHTO Policy on Geometric Design of Streets and Highways,” 2001.
- CERTU (ed.), (2005) Bus with a high level of service: concept and recommendations Certu, Lyon, France.
- CERTU (ed.), (2009) Bus with a high level of service: choosing and implementing the right system Certu, Lyon, France. www.certu.fr
- COST action Buses with High Level of Service/ TU0603 /EU, Fundamental characteristics and recommendations for decision-making and research, October 2011.
- Kittelson & Associates, Inc. (KAI), transportation engineering, planning, and research services, <http://www.kittelson.com>.
- Korve, Hans W., Jose I. Farran, and Douglas M. Mansel. Integration of Light Rail Transit into City Streets, TCRP Report 17, 1996.
- McCormick Rankin Corporation provides planning, design, construction management, and asset management services for roads, highways, railways, and transit systems www.mrc.ca.
- Revue Géographique de l'Est, Périurbain et tram-train: enjeux, projets et réalisations; Joël Forthoffer, vol. 52 / 1-2 (2012)
- Texas transportation institute urban mobility: <http://mobility.tamu.edu/ums>.
- Transit Cooperative Research Program, “BRT Practitioner’s Guide,” TCRP Report 118, July 2007.
- Transit Cooperative Research Program, “Bus Rapid Transit Volume 2: Implementation Guidelines,” TCRP Report 90, August 2003.
- US Department of Transportation “Characteristics of Bus Rapid Transit for Decision-Making” – 2004.