


BRT Design Framework

Nairobi Metropolitan Area Transport Authority - NaMATA

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Contents

Definitions

Bunching: unintended arrival of two or more public transport vehicles in close succession, often occurring when vehicles operate at high frequencies and/or in mixed-traffic

Bus Rapid Transit (BRT): A high-quality bus-based transit system that delivers fast, comfortable, and cost-effective urban mobility through the provision of segregated right- of-way infrastructure, rapid and frequent operations, and excellence in marketing and customer service

Bus lane: A dedicated lane for existing bus services but without BRT features such as level boarding, electronic fare collection, information display etc. (See also closed and hybrid BRT system.)

Closed BRT system: Service by buses that operate only in exclusive busways, complemented by feeder service to trunk stations or terminals. (See also hybrid BRT system)

Dedicated lane: A lane in which entry is permitted for specific types of vehicles.

Depot: A facility with provision for bus cleaning, maintenance, and parking. Depots also offer office space for bus operators and facilities for drivers including washrooms, canteens, and rest areas.

Docking bays: A location in a BRT station where a bus stops and aligns to the boarding platform.

Dwell time: The amount of time that a vehicle occupies a given stopping bay.

Expressway: A divided highway for through traffic with access control and grade separations at most intersections.

Frequency: number of vehicles per hour that stop at a station

Headway: Length of time that elapses between vehicle arrivals at a stop or station

Hybrid system: Service that directly links origins and destinations with buses that operates both on and off an exclusive busway. (See also closed BRT system)

Light Rail Transit (LRT): Electric rail-based technology operated at surface level in exclusive lanes, typically composed of a single rail car or as a short train of cars

Load factor: The ratio of the number of passengers on a vehicle to the vehicle's capacity. For example, if a bus has a capacity of 70 and an average load of 60 passengers, then the load factor is 0.85. The load factor for a BRT system is determined by the frequency of vehicles and the passenger volume. Higher load factors are more profitable for the system but may result in overcrowding.

Median bus lanes: Lanes reserved for buses that are aligned in the middle of a roadway.

Mixed traffic lane: A lane designated for use by various types of vehicles and users.

Passengers per hour per direction (pphpd): The number of passengers passing by a particular point in a single direction every hour.

Passing lanes: Additional bus lane at the station for a given direction of travel that allows buses to pass (overtake) stopped buses.

Platform: An area in a BRT station where passengers board and alight from buses. Platforms also accommodate passenger waiting and circulation.

Ramp: An inclined walkway or roadway connecting elements at different levels.

Saturation: Percentage of time that a station bay is occupied

Sub-stop: Distinct stops within a single station, placed adequately apart to allow simultaneous, independent access to BRT buses via passing lanes.

1. Introduction

Gazette Notice No. 1093, dated 17 February 2017, established the Nairobi Metropolitan Area Transport Authority (NaMATA). The mandate of NaMATA is to oversee the establishment of an integrated, efficient, safe, reliable and sustainable transport system within the Nairobi Metropolitan Area comprising of Nairobi City, Kiambu, Kajiado, Machakos and Murang'a County. Five corridors have been identified for the implementation of mass rapid transit (MRT), with planning and design underway for some corridors due to high existing public transport ridership and potential to benefit the greatest number of residents.

For these corridors, NaMATA has selected BRT, a high-quality bus-based transit system that delivers fast, comfortable, and cost-effective urban mobility through the provision of segregated right-of-way infrastructure, rapid and frequent operations, and excellence in marketing and customer service. Compared to rail-based MRT technologies, BRT holds several advantages, including greater flexibility; shorter door-to-door travel times; faster implementation time; lower construction and operating costs; and improved accessibility. Realising the advantages of BRT is a function of several design elements, including dedicated lanes, median busway alignment, platform-level boarding, off-board fare collection, and intersection treatments, as displayed in Table 1 below. In combination, these features enable BRT to offer high capacity, high speeds, and safe and convenient access for all users. They also facilitate the recovery of operating costs through farebox revenues, ensuring that the system can attract private investment in buses and other system elements. This document is intended to offer a uniform specification for design of BRT corridors in the Nairobi Metropolitan Area (NMA) which in turn will facilitate flexible operations across the NMA BRT network.[1]

Table 1: Basic features of high-performance BRT systems.

Design feature	 **Dedicated BRT lanes**	 **Median busway alignment**	 **Platform-level boarding**	 **Off-board fare collection**	 **Intersection treatments**
Impact on system performance and service quality	• Faster speeds because buses can bypass congestion in mixed traffic lanes.	• Faster speeds because of avoided interference with property entrances, side streets on-street parking, and pedestrian movements. • Improved safety due to reduced conflicts with mixed traffic.	• Faster speeds because of avoided delays during boarding and alighting. • Accessibility for all users, regardless of disability.	• Faster speeds because of multiple-door boarding and avoidance of queues for fare payment and/or validation. • Improved convenience for customers. • Reduced revenue leakage.	• Faster speeds due to reduction in signal phases if right turns across the busway are avoided. • Improved safety due to reduction in potential conflict points.

[1] For topics not covered in this manual, designers should refer to the suite of Kenyan road design manuals, which provide detailed guidance on geometry, structures, materials, and other elements of road design.

2. Planning for BRT

2.1 Network selection

An initial step in the BRT planning process is to prioritise corridors where BRT can and should be implemented. Corridor selection is a function of multiple considerations, including:

- Existing and future passenger demand patterns.
- Presence of severe congestion.
- The need to offer equitable access to the system to people across all socio-economic groups.
- Potential to minimise passenger transfers.
- Potential to minimise land acquisition.
- Right-of-way (ROW) availability.
- Existing and planned land uses (e.g., business districts, educational institutions, etc.).
- Potential to reduce environmental impacts of the transport system.

Passenger demand is the key factor behind corridor selection. Demand studies for BRT projects in NMA should incorporate data from three basic types of surveys:

- **Frequency-occupancy (FO) survey**: An FO survey records how frequently each bus or matatu route runs and the approximate occupancy of each vehicle.
- **Boarding-alighting (BA) survey**: The BA survey is an on-board count of how many passengers get on and off of the vehicle at each stop along the route.
- **Transfer surveys**: A transfer survey is helpful in order to get a better sense of full passenger trips, including trips that involve more than one segment linked by a transfer from one route to another.

The planning team may opt to gather more data using other types of surveys such as intercept surveys and off-board surveys, depending on the project timeline and availability of funds. However, it is paramount that these surveys capture stop-by-stop trip patterns needed to assess the public transport demand. Data from travel demand surveys can be processed using a basic spreadsheet model or a travel demand model such as Transcad, Emme, or other software package approved by NaMATA. Key model outputs include the passenger load on different parts of the corridor and the expected boardings and alightings at each station. These demand data are used to determine the alignment and frequency of BRT services. Eventually, they also inform the sizing of stations, terminals, and other physical infrastructure elements. A four-step model is useful to estimate mode shift. However, it is equally valid to use rule-of-thumb assumptions for potential mode shift.

A BRT corridor should be long enough to provide a meaningful impact on travel times and passenger convenience. If warranted by passenger demand, BRT corridors must continue all the way into congested parts of the city. There is limited utility in building BRT infrastructure in uncongested outer roads while sending buses into mixed traffic as soon as they reach congested areas. BRT corridor designs should aim to minimise land acquisition and provide for an Environmental and Social Impact Assessment (ESIA) and a Resettlement Action Plan (RAP). New roads that are developed in NMA may be notified as BRT corridors. All notified BRT corridors must incorporate space for median lanes and stations to accommodate future BRT infrastructure. BRT infrastructure can be created once the demand is high enough to justify dedicated infrastructure.

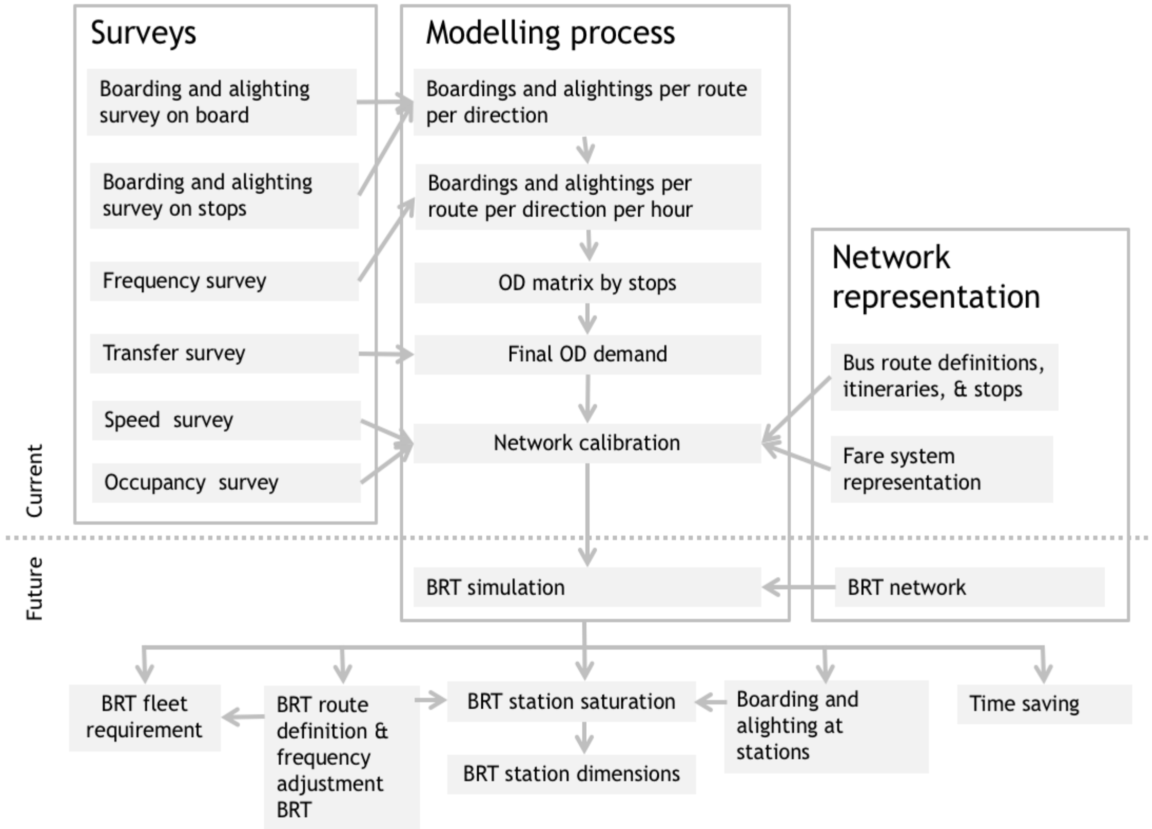


Figure 1: The planning process for NMA BRT corridors will use data on passenger trip patterns to develop a service plan. Service plan parameters, such as expected bus frequencies and passenger volumes at each station, inform the design of infrastructure elements, including station sizes.

Figure 2: BRT infrastructure that extends into congested city areas, such as Dar es Salaam's CBD (left), helps provide fast, reliable service where passenger demand is highest. Road width

need not pose a constraint to the implementation of BRT, as demonstrated by Mexico City (right) and other cities around the world that have built BRT corridors on narrow streets.

2.2 BRT configuration and system capacity

The passenger capacity of a BRT corridor refers to the maximum number of people that can be moved in a single direction on the corridor. BRT can increase the overall passenger carrying capacity of a corridor by encouraging commuters to switch from other modes. It is important to match the system design to the required capacity, as a design with inadequate capacity can lead to delays, overcrowding, and a poor image for the system.

Among the factors that determine the capacity of a BRT system, the configuration of the lanes and stations is the key. A simple BRT system with one lane per direction in station areas and regular 12 m buses can handle about 70 regular buses an hour, or around 5,000 pphpd. This configuration is appropriate for the corridors with moderate demand. Above these volumes, bus congestion caused by bus docking at stations results in delays and slower commercial speeds. The capacity of a system with one lane per direction can be increased to around 9,000 pphpd by adding articulated buses or 15,000 pphpd by using bi-articulated buses.

In situations with higher passenger demand, passing lanes at stations can increase the capacity of a BRT system. The TransMilenio BRT system in Bogotá (Colombia) can carry up to 45,000 pphpd—far above the capacity of LRT and monorails and competitive with high capacity metro systems. The TransMilenio system is able to handle these capacities through the use of articulated and bi-articulated buses, passing lanes at stations, and up to 60 per cent of services operating as express routes that stop only at limited locations. Another system with passing lanes, the Guangzhou BRT system in China, carries 27,000 pphpd.

For passing lanes to function effectively, stations must be long enough to accommodate separate stopping bays, also called sub-stops, that can function independent of one another. Multiple sub-stops increase the number of buses that can dock at a station without causing congestion and permit different types of services to operate from the same station.

Some systems with a single lane per direction increase capacity by operating buses in convoys of two or more vehicles operating in a closely bunched pack. In some cases, convoys are able to transport up to 20,000 pphpd in a single lane. However, at volumes above 13,000 pphpd, convoys experience a major deterioration in commercial speeds. If space is available, it is preferable to increase capacity through the use of passing lanes and stations with multiple sub-stops.

With a variety of configurations to handle varying levels of passenger demand, BRT capacities are competitive with rail-based modes. For example, LRT systems typically can accommodate up to 15,000 pphpd with a single track per direction—a level easily achievable with BRT. Monorails can handle around 19,000 pphpd on the busiest known systems. BRT with passing lanes, which can carry up to 45,000 pphpd, is comparable with all but the world's highest capacity metro systems.

Figure 3: A single-lane BRT system like that in Mexico City (left) can handle volumes from 5,000 to 15,000 pphpd. With passing lanes at stations, a BRT system can carry up to 45,000 pphpd, the capacity of Bogotá's TransMilenio (right).

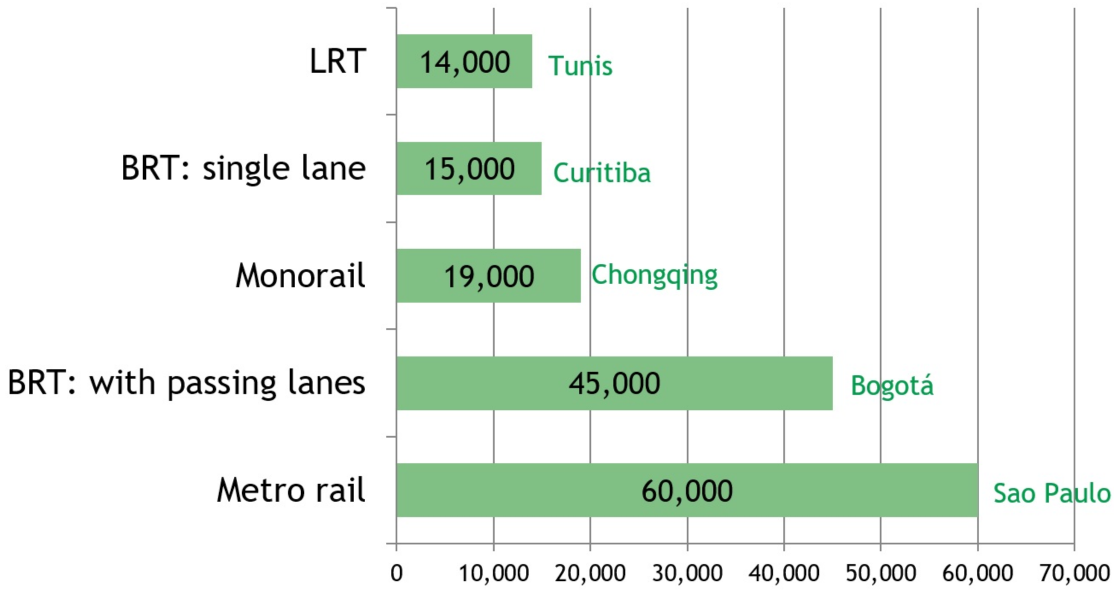


Figure 4: Comparison of the capacity of BRT with single- and double-lane configurations with other rapid transit modes, including examples of representative systems achieving the indicated capacity.

3. System design

Stations and corridor infrastructure in the NMA BRT system must be sized according to demand in order to prevent service delays and overcrowding. The size of a station depends on the level of "saturation," which depends on the bus frequency and level of passenger demand. Detailed calculations should be carried out to assess the level of demand and saturation at each station.[2] Stations with higher saturation require multiple independent docking bays to handle demand without reducing commercial speeds. As a general rule, BRT corridors in The NMA have high passenger demand, so designs should incorporate passing lanes and multiple sub-stops.

3.1 Corridor capacity

The capacity of the corridor is defined by the capacity at its bottleneck. Identifying this weak link in the system is the foundation for improving bus speeds and avoiding congestion. In many public transport systems, the critical factor is vehicle congestion at stops and station. Intersection capacity and other factors are also important to reaching speed and capacity goals, but none are as important as preventing docking bay congestion. The fact that BRT systems are now able to reach speeds and capacities comparable to all but the highest capacity metro systems is due to dramatic improvements in vehicle capacity at stations.

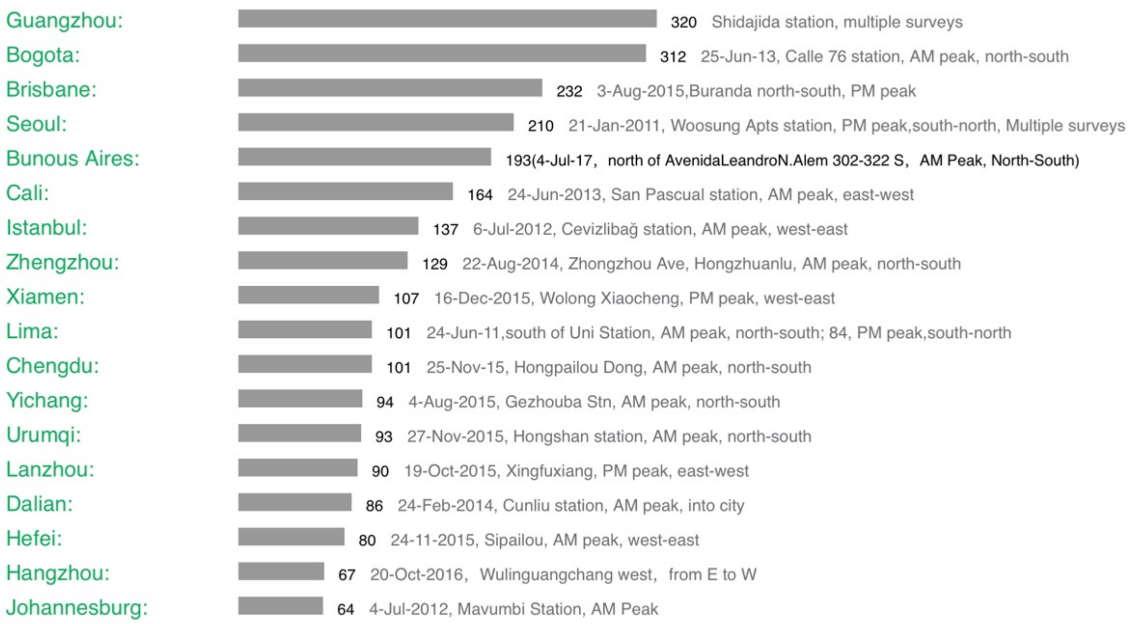


Figure 5: BRT systems can handle high bus frequencies (indicated here in terms of buses/hour) if stations and intersections are designed well.

3.1.1 Corridor capacity: simplified formula

The capacity of a BRT corridor depends on the load factor, vehicle size, the service frequency, and the number of stopping bays at each station. The equation below shows the basic relationship between these factors and the capacity of a BRT system:

$$C_{corridor} = C_{vehicle} * L * F * B$$

Where:

[2] The formulas in this section are reproduced from the BRT Planning Guide (https://brtguide.itdp.org).

- $C_{corridor}$ is the number of people the corridor can transport, expressed in passengers per hour per direction (pphpd).
- $C_{vehicle}$ is the passenger capacity of the vehicle (including standing passengers).
- L, load factor, is the average occupancy of the vehicles, expressed as a per cent.
- F, service frequency, is the number of vehicles per hour per stopping bay.
- B is the number of independent stopping bays in each station.

Table 2 gives the corridor capacities estimated by the basic capacity formula for a range of frequencies and station sizes. The capacity of a single sub-stop is typically limited to 50-60 buses per hour. As can be seen, the provision of passing lanes and multiple stopping bays leads to a dramatic increase in system capacity. It should be noted that the number of stopping bays also affects the type of busway infrastructure. If the number of stopping bays increases to four or more, then it is likely that two lanes per direction will be required along the entire length of the busway—not just at stations.

Table 2: BRT corridor capacity scenarios

Vehicle type	Passenger capacity of vehicle	Vehicle frequency per hour per sub-stop	Sub-stops per station	Approximate peak capacity (pphpd)
Standard	70	70	1	4,900
Articulated	150	60	1	9,000
Bi-articulated	210	60	1	12,000
Articulated	150	50	2[3]	15,000
Articulated	150	50	4	30,000

3.1.2 Calculating corridor capacity: advanced approach

While the basic capacity formula described in the section above provides a broad idea of the capacity that is achievable on a BRT corridor, a more detailed analysis of theoretical system capacity should take into account the quantity of passenger movements at each station:

$$C_{corridor} = \frac{3600 \cdot X \cdot B}{\frac{T_{Dwell}\,(1-E)}{C_{Vehicle}} + R \cdot T_{passenger}}$$

Where:

- $C_{corridor}$ is the number of people the corridor can transport, in passengers per hour per direction (pphpd)
- $C_{vehicle}$ is the passenger capacity of the vehicle
- X is the saturation level
- B is the number of independent stopping bays in each station
- E is the fraction of vehicles providing limited stop or express service

[3] More than one sub-stop per station requires an additional passing lane at the station.

- R is the renovation rate, the total boardings along a given route divided by the maximum load on the critical link
- T_{Dwell} is the dwell time of the vehicle
- $T_{passenger}$ is the average boarding and alighting time per passenger in seconds

3.2 Station saturation

The "saturation" of a station refers to the degree to which passenger and bus volumes have reached the station's design capacity. Station saturation is a significant parameter in BRT planning as it indicates the maximum number of commuters that a particular BRT configuration can handle while providing an acceptable level of service.

In literal terms, saturation refers to the percentage of time that a vehicle-stopping bay at a BRT station is occupied. Based on empirical evidence, BRT systems perform best when the saturation level is below 40 per cent at each station. Above this level, BRT systems run the risk of congestion and system breakdown. Therefore, it is desirable to keep saturation levels as low as possible. It should be noted that overcrowding in a station does not necessarily indicate a high level of saturation. Crowding in a station can result from inadequate bus frequency, even if the saturation level is low.

Figure 6: In Sao Paulo, high saturation levels at BRT stations can lead to bus queuing (left). In Jakarta, passengers experience delays due to high saturation levels at major terminals (right).

For corridors with moderate demand, stations should be constructed with at least two docking bays per direction. The additional docking bay allows two buses to dock at the station simultaneously. To further reduce saturation, stations should incorporate multiple sub-stops and passing lanes. Sub-stops are independent docking units that allow buses to pass one sub-stop and dock at another. Passing lanes are required at stations to allow buses to pass other vehicles that are stopped for boarding and alighting, but the corridor can return to a single lane per direction between stations. Each sub-stop can handle around 50 buses per hour, leading to a dramatic increase in system capacity. Further, express services that stop only at a limited number of stops increase capacity further. Systems have two to three sub-stops per station but some systems have as many as four sub-stops per station. Beyond this, it is better to create a new station with its own sub-stops

The number of sub-stops required at a station is determined using data on the number of passengers boarding and alighting at the station and the frequency of buses. The following formula indicates the saturation level at a station:

$$X = T_{Dwell} * F + P_{Board} * T_{Board} + P_{Alight} * T_{Alight}$$

Where:

- X is the saturation level
- F, service frequency, is the number of vehicles per hour
- T_{Dwell} is the dwell time in seconds
- T_{Board} is the average boarding time per passenger in seconds
- T_{Alight} is the average alighting time per passenger in seconds
- P_{Board} is the number of boarding passengers
- P_{Alight} is the number of alighting passengers

Figure 7: Stations with multiple sub-stops in Bogotá (left) and Dar es Salaam (right) increase system capacity and speed. A gap of 1.8 times the bus length is required between sub-stops to allow buses to pass other vehicles that are stopped for boarding and alighting.

3.3 Service design

An efficient service plan is needed to improve customer experiences, reduce the need for transfers, prevent bottlenecks at stations, and prevent delays along BRT corridors. Given that many passenger trips will include origins and destinations beyond a single BRT corridor, the following types of additional services should be considered:

- **Services that operate on multiple BRT corridors** (e.g., a service that begins on corridor 3 along Ngong Rd and continues on corridor 1 along Mombasa Rd). Multiple routes operating in a single corridor expand the travel options for passengers and reduce overcrowding at transfer stations.
- **Services that begin in a BRT corridor and then exit the BRT lanes to provide direct services**. Such services prevent the need for time-consuming transfers for trips with origins and destinations not immediately located within the catchment area of BRT corridors.
- **Express services that skip some stations**. Express services offer faster commercial speeds than all-stop services and reduce congestion at stations.

- **Feeder services** that do not enter the BRT lanes but are provided by the BRT operator and offer high-quality transfer through a physically integrated transfer station with integrated fare payment.

While service typologies may differ from corridor to corridor, the design of physical infrastructure in the BRT system should permit flexible operations. In particular, the system designs should incorporate the following elements:

- **Buses with doors on both sides**. Buses providing direct services will require doors on the right side to facilitate level boarding at median stations as well as doors on the left side that can be used for service extensions.
- **Provision for BRT turning movements at intersections**. Intersection designs should allow for turning movements of BRT buses at the intersection of key corridors (e.g., Corridors 1 and 2; Corridors 1 and 3; Corridors 4 and 5; and Corridors 4 and 5).

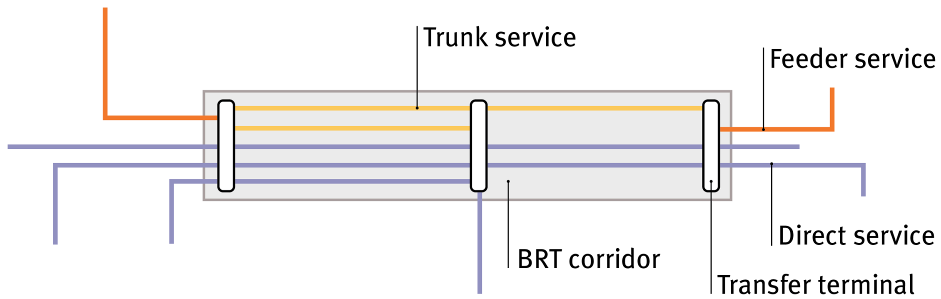


Figure 8: The NMA BRT will incorporate a variety of services to improve efficiency and minimise passenger transfers, including direct services that extend beyond the dedicated BRT corridors to outlying areas.

4. Infrastructure design

4.1 Street elements

BRT corridor design requires careful planning covering cross section designs, busway placement, intersection treatments, and station positions. BRT corridors function best if they are designed to meet the needs of all users, including public transport users, pedestrians, cyclists, and personal motor vehicle users. Various elements of a BRT corridor and their suggested dimensions are given below:

- A BRT lane for one-way movement should have a width of 3.5 m. The width of a passing lane, where required, should be 3.5 m.
- A divider minimum 0.5 m wide should separate BRT lanes from mixed traffic. These should be expanded to at least 1 m at street crossing points by marginally reducing carriageway and BRT lane width or utilising the space created when the cross section at a station tapers to the standard cross section.
- Median stations that serve both directions of BRT services should have a minimum internal clear width of 3.5 m. The outer width would be at least 4 m, with wider stations provided where demand is higher.

- The width of BRT elements, at stations without passing lanes, would be 11 m. In case of systems that require a passing lane, the total width of BRT elements at station expands to 19 m (or 15.5 m in the case of a staggered station). Since passing lanes are not required at non-station locations, the width of BRT elements drops to 8 m in both cases.
- Footpaths are essential for safe pedestrian access to BRT stations. Footpaths with a minimum clear width of 2 m should be provided on either side of the carriageway. A tree line next to the footpath—with a minimum width of 1 m—should be included where adequate right-of-way is available. Existing trees should be preserved wherever possible during corridor construction.
- Cycle tracks may be provided along the corridor for the safety and convenience of cyclists where adequate right of way is available.
- In case of BRT, since a majority of large vehicles (buses) do not use the carriageway, the carriageway width may be reduced from 7 m to 6.0-6.5 m for two lanes.
- At non-station locations along the BRT corridor, parallel parking may be provided at the edge of a carriageway or a service lane, depending on the section.

BRT requires wider cross sections at stations. Elsewhere, a multi-utility zone that provides space for on-street parking and bus stops can occupy the extra 4 m of ROW that is available between stations. Walking and cycling provide last-mile connectivity to BRT stations, and space for these modes should not be compromised in station areas. BRT lanes require physical separation to prevent entry by mixed traffic. Physical delineators should be paired with adequate signage and road markings to alert personal motor vehicle users that they may not enter the lanes.

Table 3: BRT corridor elements: Widths

Street element	Specifications	Minimum width (m)	Maximum width (m)
BRT	One-way lane	3.5	4.0
	Two-way lane	7.0	7.5
	Median station	4.0	*
	Passing lane at station	3.5	4.0
Buffer		0.5	*
Pedestrian refuge		1.0	*
Carriageway	Mixed traffic lane (per lane for carriageways with two or more lanes per direction)	3.0	3.5
Loading bays	Parallel orientation	2.0	2.2
Bus and BRT direct services	One-way	2.0	*
Cycle track	Two-way	3.0	*
	One-way on each side	2.0	*
Footpath	Total width including furniture zone and frontage zone	3.5	*
	Clear space	2.0	*
Tree line	Next to the footpath or in the parking lane	1.0	*

* Width as per requirement

Table 4: BRT corridor elements: Heights (with respect to carriageway level)

Street element	Specifications	Minimum height (mm)	Maximum height (mm)
BRT	BRT lane between stations	0	0
	BRT lane at station	0	150
	Station	At the same height as the bus floor	
	Median between BRT lanes and carriageway	300	400
Carriageway	Raised zebra crossings	100	150
Footpath		100	150
Cycle track		100	100
Bus stop	Kerb-side bus shelter	150	150

4.2 Median BRT lanes

The NMA BRT will have exclusive median-aligned bus lanes. BRT lanes shall not be used by other type of traffic, except for ambulances and fire engines responding to emergencies.[4] Vehicles authorised to use BRT lanes in NMA shall be buses designed and specified for BRT use only. Bus lanes will be designed with physical barriers to prevent access by other types of vehicles.

Figure 9: Median alignment secures BRT speed, capacity and service quality and is a defining feature of successful BRT systems across the world, including the DART BRT in Dar es Salaam (left) and the Metrobús BRT in Mexico City (right).

In cases where potential conflict points such as property entrances and side streets are completely absent for a considerable stretch (e.g., Juja Road along Moi Air Base), then it is permissible to locate both BRT lanes on that side of the cross section. In such a configuration, mixed-traffic movements can operate on the other side of the BRT lanes without any conflict with BRT movements. However,

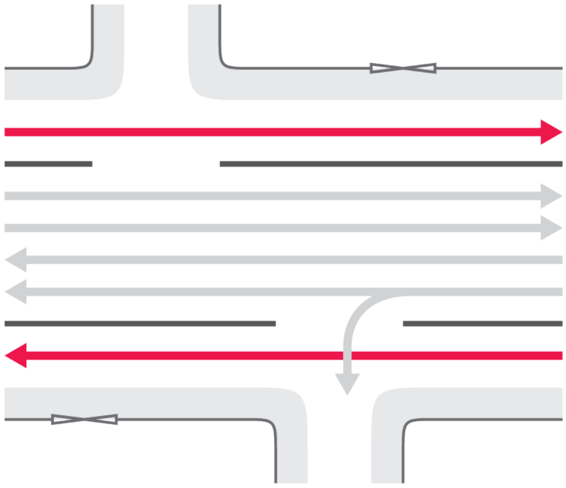
[4] To enhance efficiency, other government vehicles, including VIP vehicles and police vehicles, shall not use BRT lanes.

kerbside alignment of BRT lanes on either side of the road is not permitted. Similarly, BRT lanes should not be positioned between a service lane and express lanes due to the conflicts that may arise as mixed traffic moves across the BRT lanes between the service lane and express lanes.

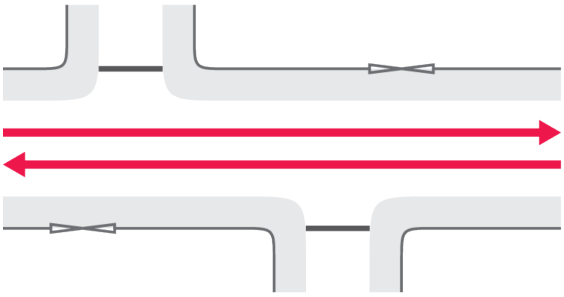
A physical barrier with a height of 400 mm should be used to prevent other vehicles from accessing the BRT lanes.[5] This median can be used for street lighting columns. A grill may be installed above the barrier to prevent pedestrians and other road users from crossing the busway, provided that frequent pedestrian crossing opportunities are available (i.e., at least one crossing every 200 m). A solid double yellow line should be marked between the bus lanes, with a single solid yellow line placed at the side of each bus lane.

[5] For one way pairs, lower barrier …

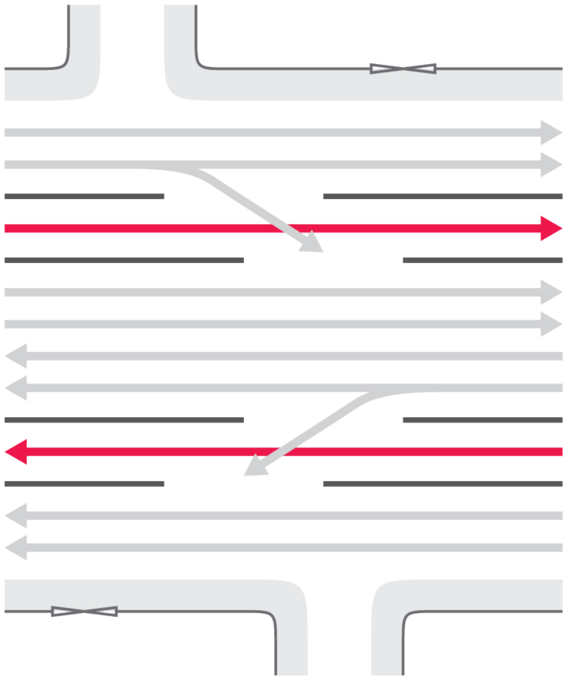
✔ Standard lane alignment for BRT corridors in Nairobi.



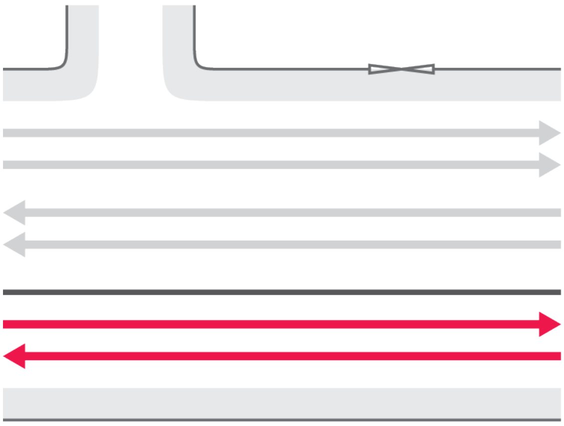
✘ Not permitted: Kerbside alignment results in delays for buses, safety challenges, and complex signal cycles at intersections.



✔ Street with BRT and pedestrian access only.



✘ Not permitted: Alignment between central express lanes and outer service lanes results in delays for buses where mixed traffic merges across the bus lanes.



Possible alignment if there are no intersections or property entrances on one side of the street (e.g., Juja Road along Moi Air Base).

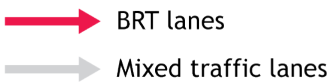


Figure 10: Bus lanes will be located in the median of to improve BRT system safety, efficiency, and throughput.

4.3 Pavement design

Pavements should be designed for a 40-year life with a 90 percent probability of achieving the design life. The pavement design should support frequent operation of heavy buses without deterioration, taking into account the ambient temperature and humidity of the local climate. Busways should be designed to carry buses with the following characteristics (maximum):

- Length: 25 metres
- Width: 2.6 metres
- Maximum number of axles per bus: 4 (single or double articulated vehicles)
- Gross weight: 30,000 kg
- Axle weight: 15,000 kg

It is expected that the initial services will operate with a combination of 12 m regular and 18 m articulated buses.

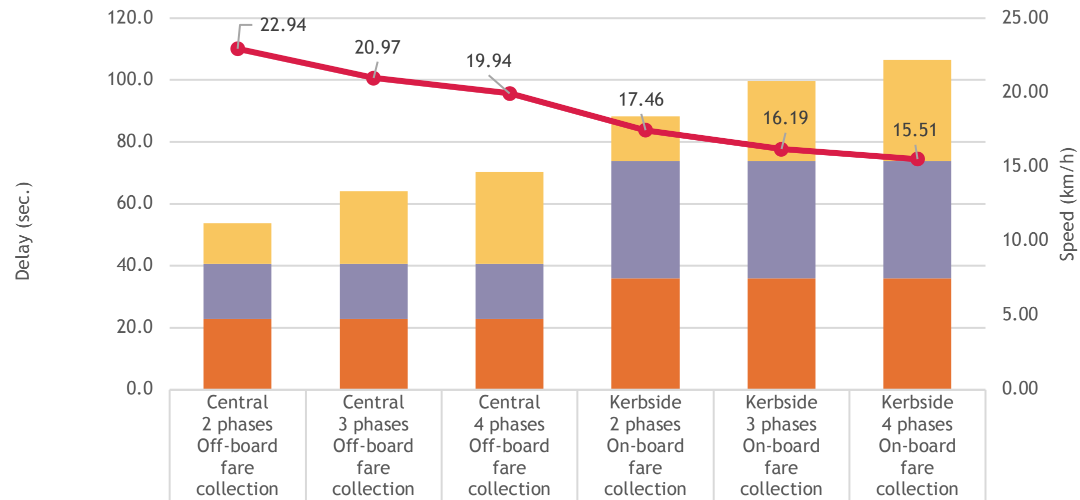
To minimise the likelihood of rutting or tracking, particularly at stations, it is recommended that pavements use a concrete wearing course at and on the approach to stations and either concrete or asphalt between stations, depending on the expected loadings. Pavement designers must demonstrate to NAMATA that proposed pavement designs are able to meet these requirements.

4.4 Intersection design

Special intersection treatments are required along BRT corridors in order to reduce delays and maintain system capacity. The aim of junction design for a BRT system is to:

- Minimise delays for the BRT system.
- Provide safe and convenient pedestrian access to stations.
- Minimise delays for mixed traffic.

BRT junction operation should focus on reducing turning movements across the busway to improve safety and reduce signal delays. BRT intersections should be signalised, and as a general rule, signal cycles for BRT intersections should not have more than two phases. Intersection designs that minimise the number of phases reduce the amount of delay experienced by BRT passengers by combining BRT and mixed traffic movements (Figure 11). Bus priority signals that extend a green phase if the system detects an approaching bus can further improve bus speeds but tend to have the largest impact on corridors with low bus volumes. Junction design will vary according to the volume of turning vehicles, bus operations, and volume of pedestrians crossing the junction. Grade separation, if pursued, should prioritise BRT, allowing buses to remain in dedicated lanes in the median. Depending on the local situation and traffic data, a design consultant shall explore all solutions that minimise signal phases and bus delays and propose the best solution.



	Central 2 phases Off-board fare collection	Central 3 phases Off-board fare collection	Central 4 phases Off-board fare collection	Kerbside 2 phases On-board fare collection	Kerbside 3 phases On-board fare collection	Kerbside 4 phases On-board fare collection
Intersection delay	13.23	23.53	29.78	14.52	25.81	32.66
Bus queuing	17.62	17.62	17.62	37.80	37.80	37.80
Dwell time	23.0	23.0	23.0	36.0	36.0	36.0
speed	22.94	20.97	19.94	17.46	16.19	15.51

Figure 11: BRT systems with two phase signals at intersections and median lanes are best at reducing delay and maintaining high bus speeds.

One way of reducing the number of phases at BRT intersections is to substitute mixed traffic right turns for movements at the network level. For example, right turns for mixed traffic can be substituted by three left turns (Figure 12 and Figure 13). Alternately, U-turns combined with left turns can replace right turns across the busway (Figure 14 and Figure 15).

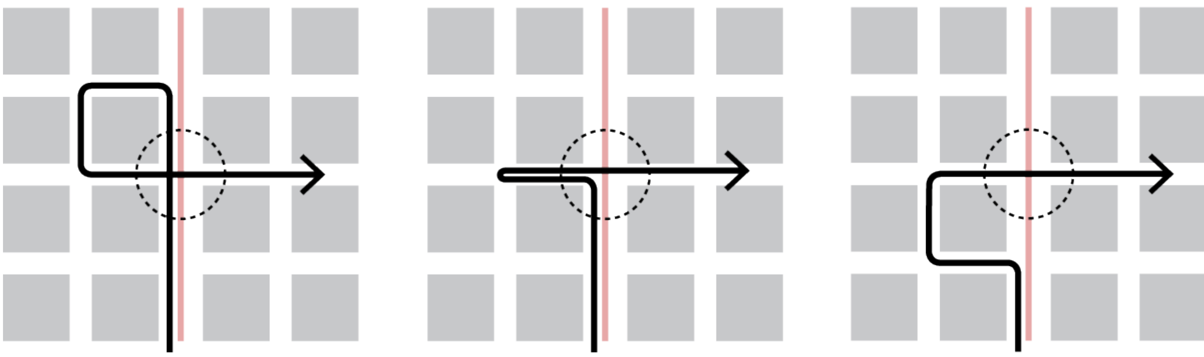


Figure 12: To reduce intersection delays along BRT corridors, intersections should prohibit right turns for mix traffic. Instead, vehicles can make a series of turns and then cross perpendicular to the corridor.

Figure 13: Forbidding turns across the bus lanes increases bus speeds at intersection: Las Vegas BRT (left) and DART BRT, Dar es Salaam (right).

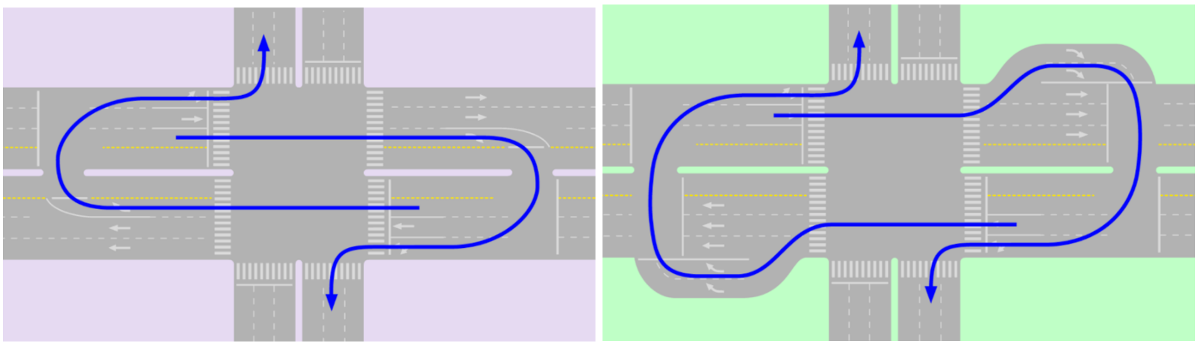


Figure 14: U-turns combined with left turns can replace right turns across the busway.

Figure 15: Signal cycle at Chebai BRT station in Guangzhou.

Squareabouts are a means of managing right-turning traffic at large intersections while minimising signal cycle time. Squareabouts make the right-turn phase obsolete by creating right-turn queuing space within the intersection itself. Vehicles queue in this space during one phase and exit during the next phase. By combining BRT and mixed traffic movements, the square-about accommodates all turning movements in only two phases.

Figure 16: Signal phases for a squareabout intersection.

Figure 17: Two phase squareabout intersection in Ahmedabad.

BRT stations should be set back from intersection stop lines to allow sufficient space for bus and mixed traffic queues. When stations are located immediately adjacent to intersections, significant delays can be caused when a queued bus blocks the docking bay and prevents other buses from accessing the station. The setback distance depends on corridor bus frequency and the signal cycle duration. Lower frequencies and short signal cycles require lower setbacks. Higher frequencies and longer signal cycles require greater queue lengths, and hence, larger setbacks from intersections. At a minimum, the setback should be equal to the length of two articulated buses (40 m).

At all intersections, special lights should be provided for BRT buses to improve safety. Intersections should also incorporate separate pedestrian lights, even if pedestrians cross during corresponding traffic phases. Signals should be timed to give pedestrians sufficient time to cross at a walking speed of 1 km/h.

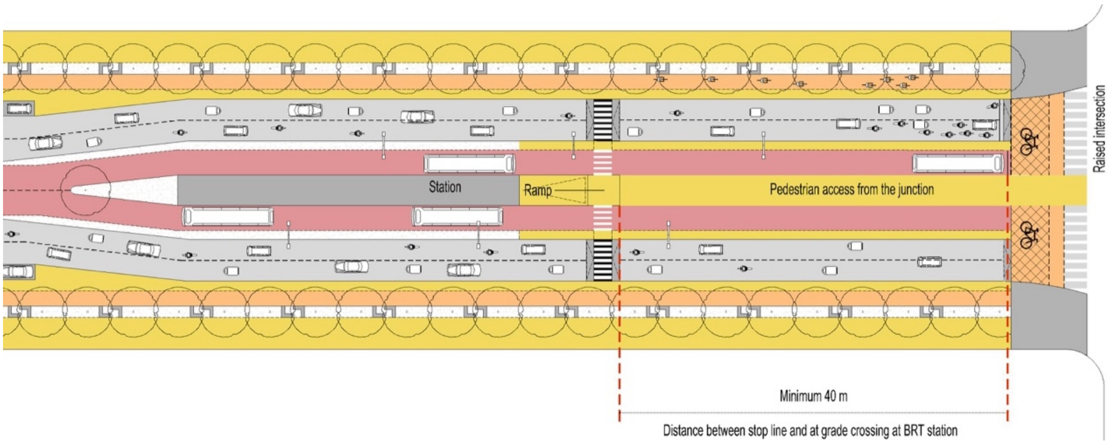


Figure 18: BRT stations should be offset at least 40 m from intersection stop lines.

Figure 19: Station placement exactly at the intersection results in operational inefficiency in Taipei, Taiwan (left). A station shifted away from the intersection allows buses to queue at the intersection without blocking the docking bays in Guangzhou, China (right).

4.5 Provision for ITS

BRT standards require a cable duct bank for BRT communications and electrical supply. This channel shall be separate from any drainage and shall be designed to release storm water quickly and effectively. The minimum requirement is one bank of 12 ducts of 150 mm diameter. Fibre cables should be installed on all BRT corridors to facilitate the operation of fare collection and other IT equipment. Wiring conduits also should be incorporated in BRT stations and terminals.

4.6 Camber and gradients

Corridor elements shall be constructed with sufficient camber of approximately 2.5 per cent, allowing rainwater to drain off the busway rapidly. Drains shall be constructed at both sides of the busway to take this water from the surface of the busway and direct it into suitably dimensioned storm water drains. The ruling gradient on all busways shall be 6 per cent, although in the case of a restricted location 8 per cent may be used with agreement in advance from NaMATA. The crest and sag for grade changes should be rounded off adequately.

5. Station design

Stations play a major role in shaping a passenger's overall experience of using a BRT system. Stations need to have sufficient capacity to handle anticipated ridership, and should offer a safe, comfortable space that eases the wait. Beyond functionality, stations are important in defining the image of a BRT system. A prominent, attractive station has the potential to inspire the communities around it and demonstrate that BRT is a lasting investment in the urban environment.

5.1 Station alignment

The NMA BRT system will have centrally located stations for both directions of travel.

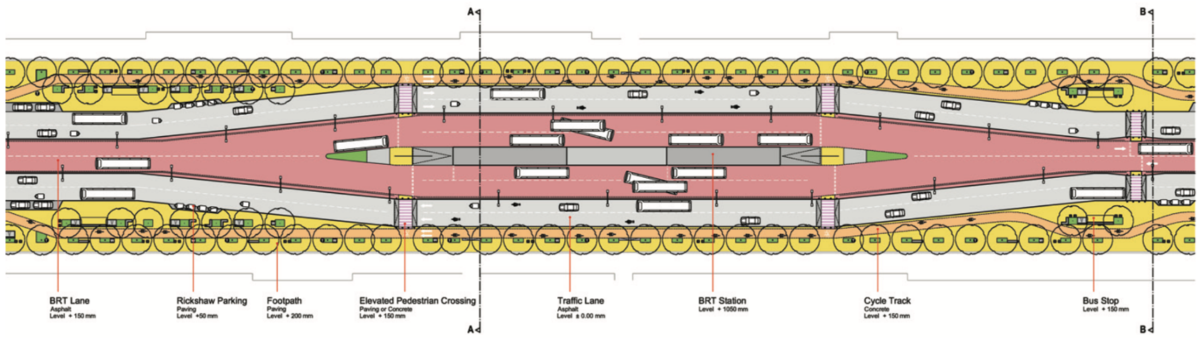


Figure 20: BRT stations in NMA will have central platforms serving both directions of travel.

5.2 Station layout

A BRT station contains three primary areas:

- **Ramp(s)**: Provided on one or both ends of the station, ramps make the station accessible to all users. The ramp should have a slope not exceeding 1:12, making it convenient for the disabled. The ramp should have railing on both sides and should have tactile paver blocks for people with visual impairments.
- **Fare collection area**: The fare collection area contains system information displays, a place for customers to buy tickets and make enquiries, and barrier controls for off-board fare collection. The service booth should be at least 1.1 m by 1.5 m. Fare barriers should have a reversible design allowing the direction of passenger movement at each barrier to be adjusted according to passenger flows at different times of the day.
- **Boarding area**: The boarding area should provide space for people waiting for buses as well as circulation space for people entering or leaving the station. For small to medium stations, bus

docking positions on either direction should be staggered for easy circulation of people inside the station.

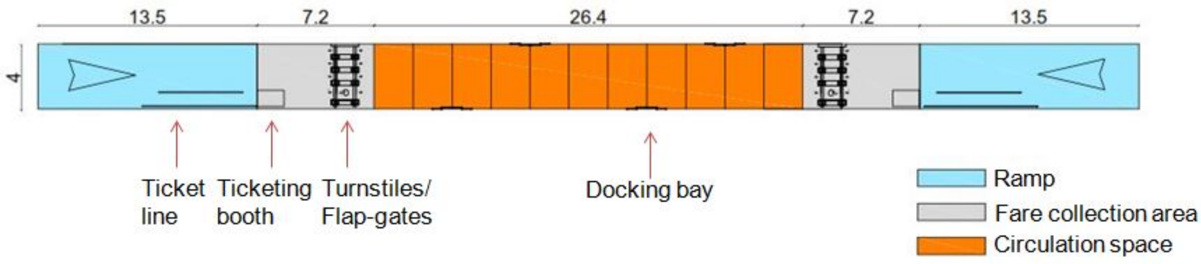


Figure 21: A typical BRT station configuration incorporating ramp, fare collection area, and circulation space.

The width of station platform depends on width of the structural elements, the waiting area for both directions, and circulating width. Staggering the docking bays for opposite directions reduces the total width required. Length required for waiting passengers at each docking bay should be equal to the length of the bus. Station widths should be sufficient to accommodate expected demand. While a 6 m width is a desirable width on corridors where sufficient right-of-way is available (e.g., on Mombasa Road and Thika Highway), it may be difficult to accommodate a full 6 m on corridors with ROWs under 36 m (e.g., Juja Rd, Jogoo Rd, and some streets in the CBD). A 4-m width is generally sufficient for a spacious interior and corresponds to the width available if parking lanes on either side of a road (with a width of 2 m each) are discontinued near the station. Above the minimum standard, the following formula can be used to check whether the proposed with is sufficient to meet expected passenger demand:

$$W_p = 1 + W_u + W_c + W_{opp}$$

Where:

- W_p = Total platform width, in metres
- 1 m = Width required for infrastructure (i.e., 0.5 m for the wall and fixtures on each side of the station)
- W_u = Width required for waiting passengers in one direction, typically calculated as:

$$W_c = \frac{Maximum\ waiting\ passengers\ between\ bus\ arrivals}{(3\ passengers\ per\ sq\ m) \cdot (Length\ of\ waiting\ area)}$$

- W_c = Width required for circulating passengers, typically calculated as[6]:

$$W_c = \frac{Circulating\ passengers\ per\ hour}{2{,}000\ passengers\ per\ hour\ per\ metre\ of\ width}$$

- W_{opp} = Width required for passengers waiting for vehicles going in the other direction, calculated using the formulas above.

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[6] For more information on level of service for pedestrians, see New York City Department of City Planning. (Apr 2006). "Pedestrian Level of Service Study, Phase 1." Retrieved from http://www1.nyc.gov/assets/planning/download/pdf/plans/transportation/td_pedloschaptertwo.pdf

As discussed in section 3.2, high-demand corridors should be designed with passing lanes and independent sub-stops. The distance between the independent sub-stops should be 1.8 times the bus length to enable buses to manoeuvre easily (see Figure 22). BRT stations should be designed to allow for the addition of new sub-stops based on future increase in passenger demand. Space in the median may be reserved for future extension of the station.

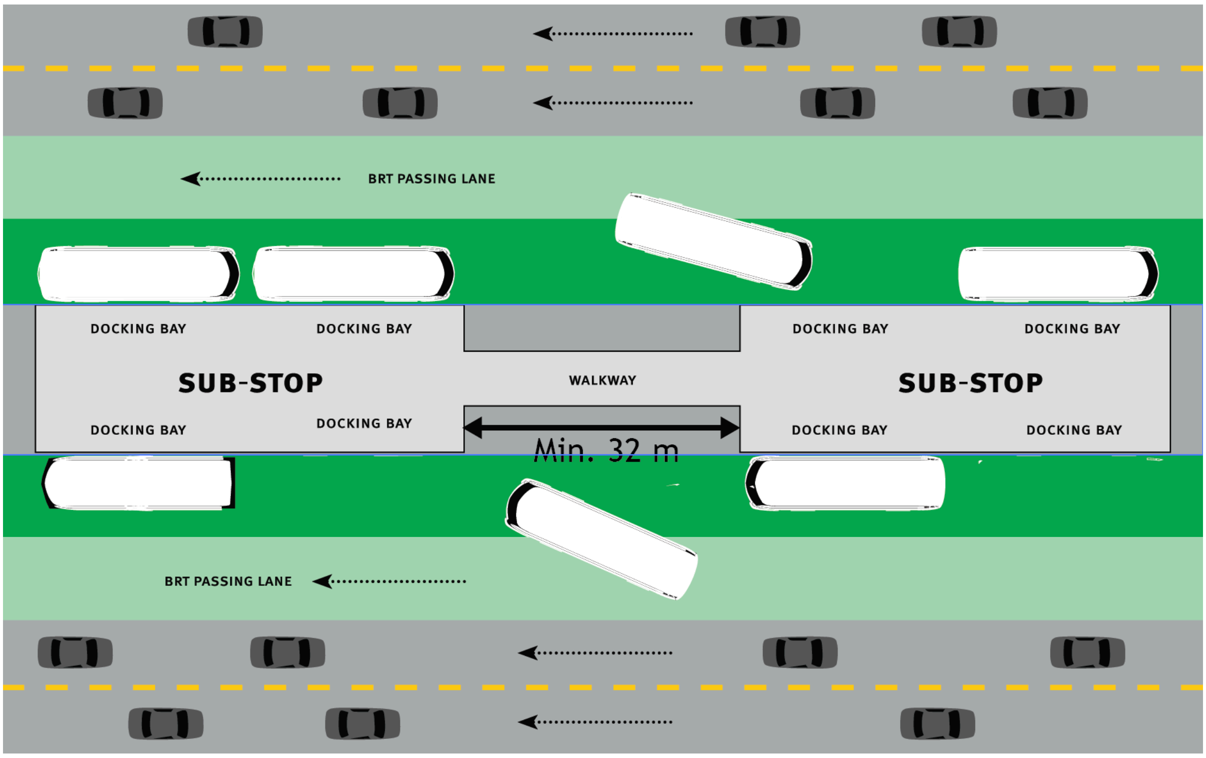


Figure 22: At stations with passing lanes, the distance between two docking bays on stations should be 1.8 times the length of the bus for easy manoeuvring. For 18 m buses; the distance between two docking bays should be at least 32 m.

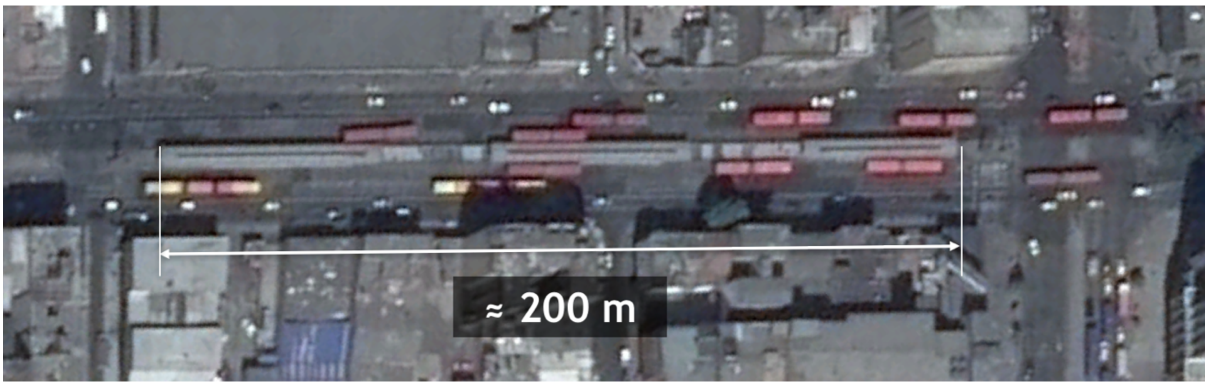


Figure 23: A large station with three sub-stops in Bogotá's TransMilenio system occupies a length of approximately 200 m.

5.3 Bus-station interface

Platforms should be built to allow level boarding from station to bus and vice versa. Level boarding means that the platform height is the same as the bus floor height, thereby eliminating any internal steps and making the system fully accessible to persons in wheelchairs, the elderly, persons with disabilities, and people with suitcases or strollers. To accommodate such users, the NMA BRT system requires modern buses with floor height that matches the height of the station floor. The NMA BRT system will have buses and station platforms with a height of 350 mm.

The reduction or elimination of the vehicle-to-platform gap is also key to customer safety and comfort. The platform should extend toward the bus to reduce to the vehicle-to-platform gap to a minimum: not more than 5 cm. Physical measures such as kassel kerbs or alignment markings can help guide bus drivers closer to the station. Alignment markings can be placed on the bus dashboard and in the bus lane. Platforms should be straight at all stations unless otherwise authorised by NaMATA. Ultimately, good bus docking is a function of the level of driver training and system monitoring.

Figure 24: Level boarding has been applied in BRT systems in Dar es Salaam (left) and Ahmedabad (right) to facilitate faster boarding and alighting and universal accessibility.

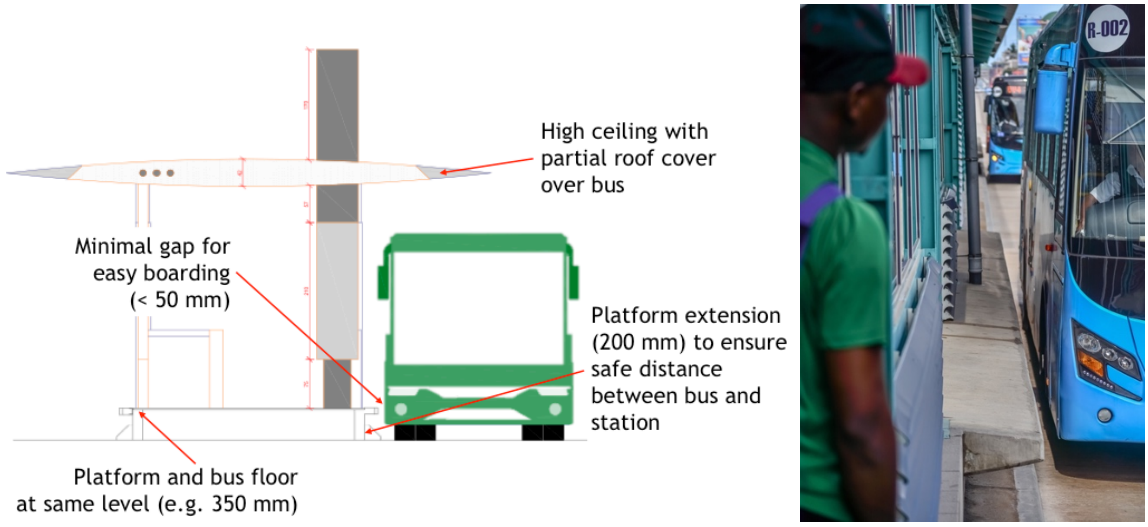


Figure 25: Platforms should extend toward the bus to minimise the gap between buses and stations.

BRT vehicles should be designed with sufficient wide doors to facilitate rapid boarding and alighting at stations. Regular 12 m buses should have at least two doors on the station side, while articulated buses should have four doors. Each door should be at least 1.2 m wide. Where doors are situated together, they should be separated by at least 400 mm. In case of buses with median doors for trunk corridor operations, doors also should be provided on the left side of the bus to enable the system to operate direct services that extend beyond the dedicated corridor.

To improve safety, the NMA BRT system will make use of half-height sliding platform screen doors at stations. Doors give a degree of security to commuters and protect against weather, reduce accident risks, and prevent fare evaders from entering the BRT system. An allowance of 150 mm should be assumed for the width of platform doors.

Figure 26: Wide doors on the station side of buses allow for fast boarding and alighting: 18 m articulated bus in TransMilenio, Bogotá (left) and a 12 m bus in Rainbow, Pune (right).

Figure 27: Platform screen doors improve safety and reduce fare leakage.

5.4 Passenger access

Well-designed crossings allow pedestrians to cross busy streets safely and conveniently. For BRT to function well, people must have safe access to stations. At-grade crossings are the preferred mode of access for BRT stations. Foot overbridges are acceptable only in the case of BRT corridors located on limited access highways. Such bridges must cater to accessibility requirements by providing ramps or working elevators and escalators. Ramps slopes should be no steeper than 1:12 and may be more gradual if space permits. Pedestrian crossings at BRT stations must meet the following standards:

- A raised crosswalk that is at least 2.4 m wide should be provided, elevated to the level of the adjacent footpath (150 mm above carriageway) with a speed table for motor vehicles. The slope for vehicles should be at least 1:8.[7]
- Pedestrians should not have to cross more than two lanes of traffic before reaching a pedestrian refuge. On streets with more traffic lanes, signalised crosswalks should be provided.
- Speed bumps in mixed traffic lanes in advance of pedestrian crossings can help reduce motor vehicle speeds further.

[7] Bus lanes should be ramped up to the level of the raised crossing but at a more gradual slope than that employed in mixed traffic lanes. The BRT lane can remain at 150 mm for the entire length of the BRT station, with a final down ramp provided after the pedestrian crossing at the other end of the station.

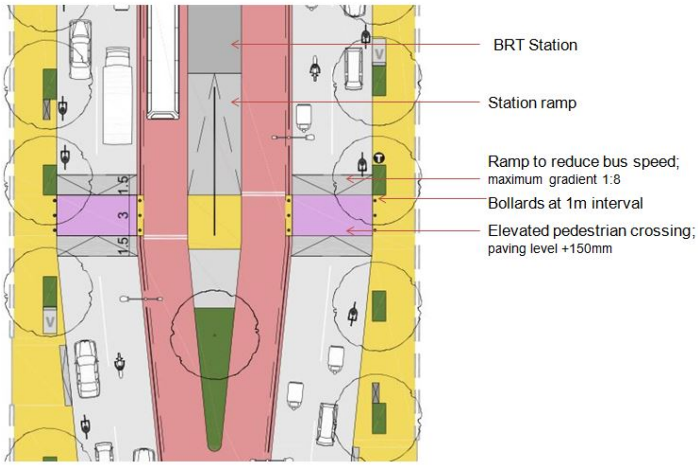


Figure 28: Raised crosswalks at station area.

Figure 29: Safe at-grade pedestrian crossings, such as the speed table crossings in Dar es Salaam (left), are preferred as they provide easy, convenient access to BRT stations. On highway corridors such as in Istanbul (right), foot overbridges can be considered provided they have adequately sloped ramps or working escalators or elevators.

5.5 Station spacing

Spacing between stations of 500 m is preferred in order to ensure that stations are accessible to adjoining neighbourhoods. In cases where close placement of stations is not feasible or is not justified due to local passenger demand, wider spacing of up to 800 m is acceptable. Agreement on station locations should be reached with NaMATA before starting corridor design work.

5.6 Station amenities

The waiting area of a BRT station must provide seating, lighting, and real-time passenger information. The ticketing area just outside of the station should include displays with information on available bus routes and schedules as well as a map of the station precinct. The use of open station architecture allows for natural ventilation and lighting. However, the station roof should provide protection from rain and sun. Roofs should extend over the entire station area (including an overhang over the bus) to provide weather protection as passengers are boarding.

Stations should be built with durable, low-maintenance materials to minimise maintenance costs. Stations will be incorporate perch seating and leaning bars. For night time operations, adequate lighting (e.g., an illumination level of 150 lux) should be provided to ensure the safety of BRT passengers. Reduced intensity lighting should be provided at station ends to mitigate changes in brightness experienced by the driver while pulling into the station. Specific areas for traders may be provided, if space permits, near to station areas, subject to discussion with NaMATA. Finally, stations should incorporate spaces for signage and customer information.

Figure 30: BRT stations should offer seating, leaning bars, and adequate circulation space to meet expected passenger demand: Rainbow, Pimpri-Chinchwad, India (left) and Guangzhou BRT (right).

Figure 31:Passive solar design provides shading and encourages natural ventilation: Janmarg, Ahmedabad, India (left) and Yichang BRT, China (right).

5.7 Terminal design

A terminal is a large station that functions as a major interchange between trunk and feeder routes or between the BRT system and paratransit or intercity services. Individual bus routes often start or end at terminals. The location of terminals is a function of passenger demand, travel patterns, and the size of the BRT network. Terminal and interchange facilities require space for the buses to turn around and multiple bays for the various routes that pass through the terminal.

Larger terminals should also provide passenger amenities (e.g., retail outlets, ATMs, and public toilets), administrative offices, and space for midday bus parking. Terminals located at intermediate locations along corridors should be sited within the corridor ROW. Terminals at corridor endpoints may be sited along or slightly off the corridor. The position of a terminal should be close enough to major destinations to facilitate passenger access by foot and on other modes.

Good terminal design should minimise bus circulation and passenger movements. A single platform serving BRT buses on one side and feeder buses on the other is the most convenient design for passengers. It also permits fare free transfers or integrated fare collection, depending on the fare structure of the system. BRT and non-BRT platforms need physical separation in between the two areas if transfers are not free. Terminals at corridor endpoints can incorporate saw-tooth docking positions to reduce space requirements.

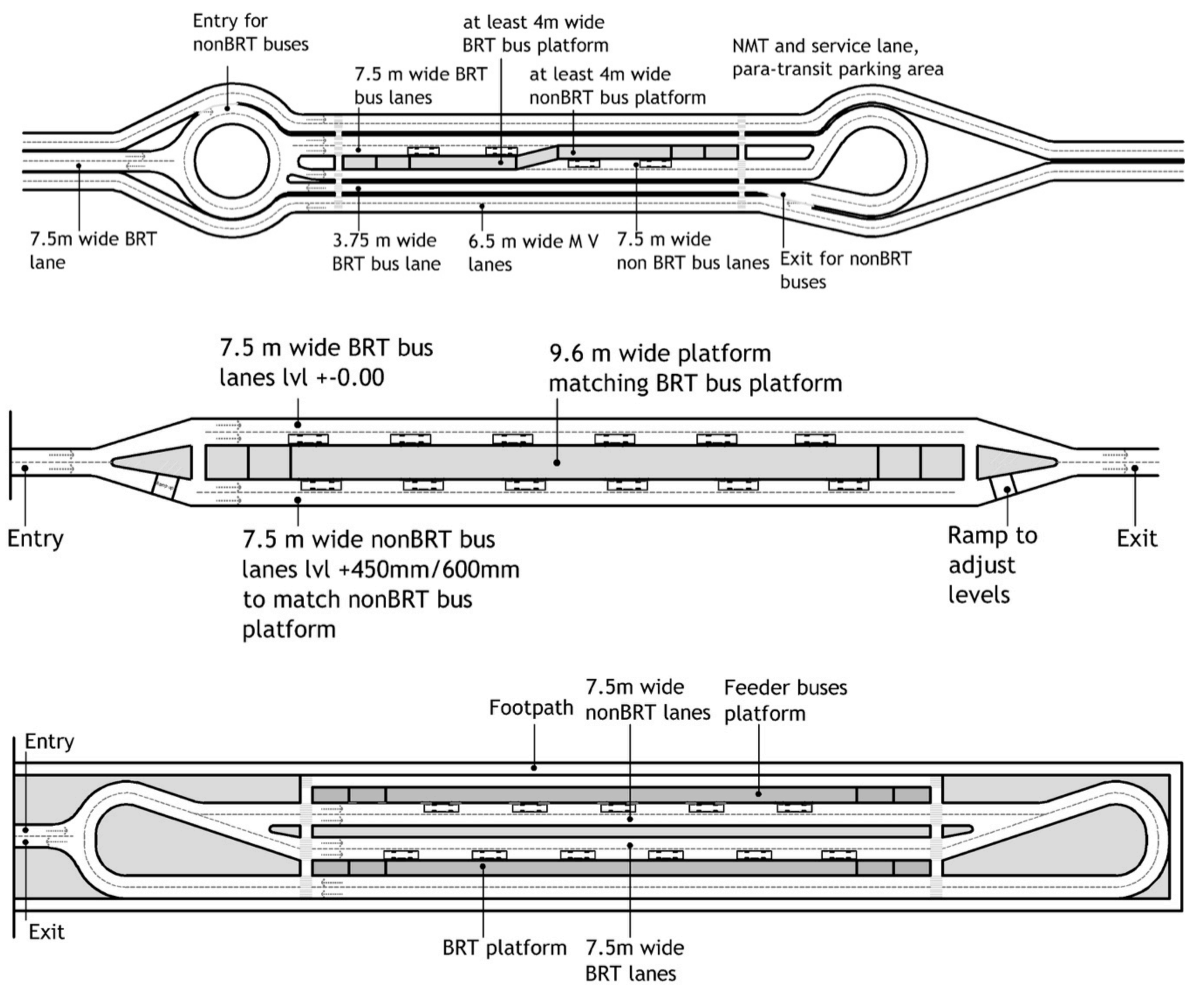


Figure 32: Possible terminal arrangements: for lower-demand systems, a 118 m long off-set terminal accommodates transfers between BRT services and regular city buses (top); for higher volumes, a longer platform is required (middle); and for high volumes, the trunk and feeder platforms can be split entirely (bottom).

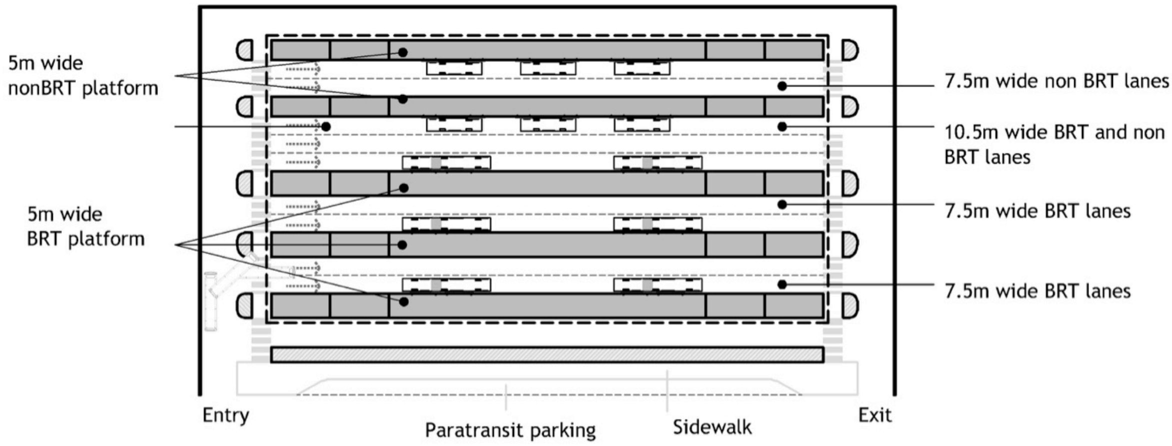


Figure 33: If bus frequencies and passenger volumes are high, terminals can include multiple platforms under a single roof.

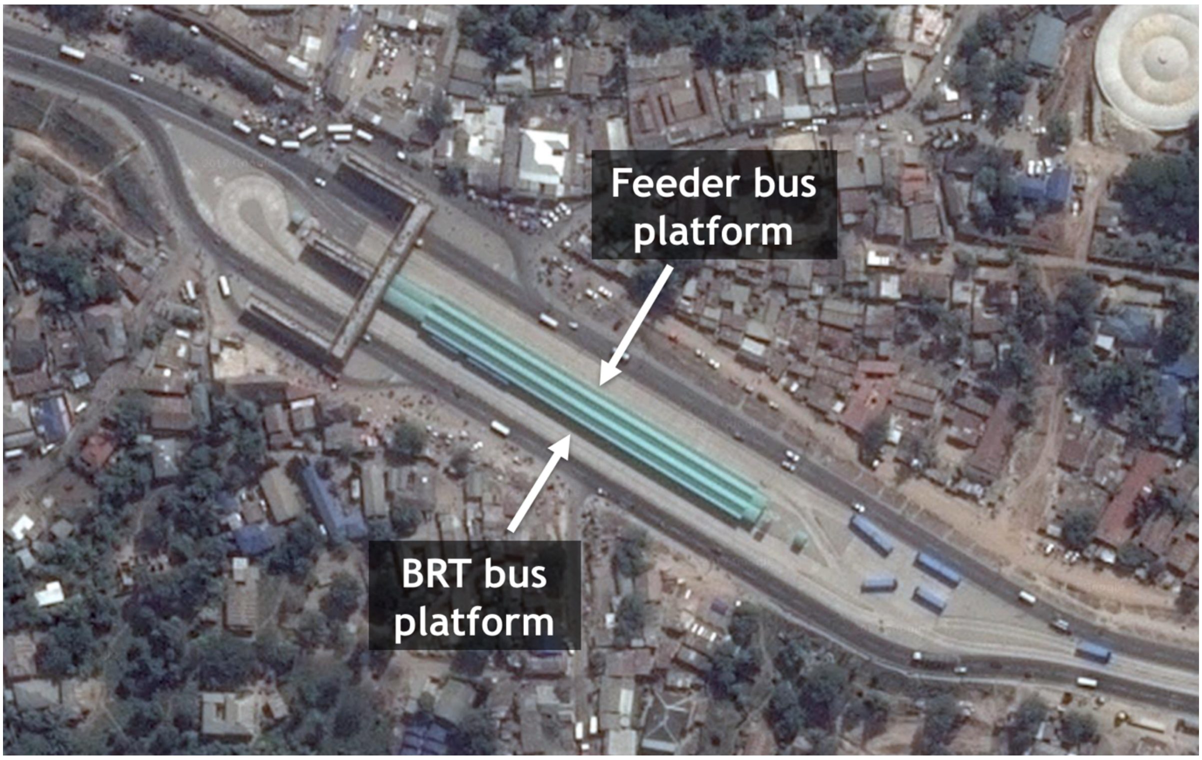


Figure 34: Dar es Salaam BRT system's Kimara terminal offers cross-platform transfers from BRT to feeder buses. The level of both platforms is the same to improve accessibility.

5.8 Design of stations and interchanges

NaMATA will issue model station and interchange designs that should be followed on all BRT corridors. The designs will be available in CAD format and will provide functional layouts indicating the dimensions of key elements of the station interior and the station-bus interface. The architecture and aesthetic look of the stations may differ across the network, provided that station designs meets the functional requirements set out by NaMATA. Design competitions and/or engagement of local residents and relevant stakeholders are encouraged as a way to generate designs that reflect local culture and environment.

6. BRT vehicles

The NMA BRT will consist of trunk services operating exclusively in the dedicated BRT corridor as well as direct services that continue beyond the corridor to outlying areas. The service plan for each corridor will identify the fleet requirements for trunk-only and direct services, and the fleet will be procured accordingly. Buses offering direct services will require doors on both sides. Buses should meet modern emissions norms (i.e., at least Euro 4). However, the primary emission savings from BRT systems typically come from the reduction in kilometres travelled by personal motor vehicles rather than the marginal reduction in the emissions from each bus. Buses may also be designed with attractive external styling and high-quality interiors to project a smart image for the system. NaMATA will issue detailed vehicle specification for all BRT buses.

Table 5: BRT bus capacity.

Vehicle type	Vehicle length (m)	Capacity
Standard	12	70
Articulated	18	140
Bi-articulated	24	210

Figure 35: A 12 m standard BRT bus (left) and an 18-m articulated bus (right) in Dar es Salaam.

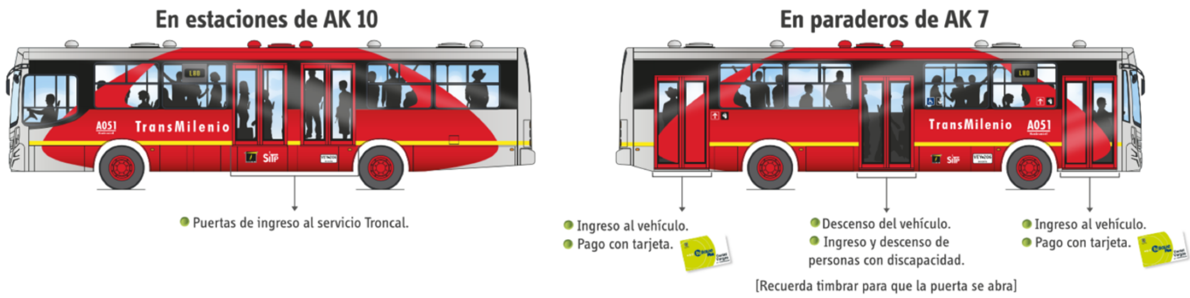


Figure 36: Example of a bus with driver-side doors to provide level boarding at BRT stations (left) as well as doors on the kerbside for direct services beyond the trunk corridors (right). Source: TransMilenio.

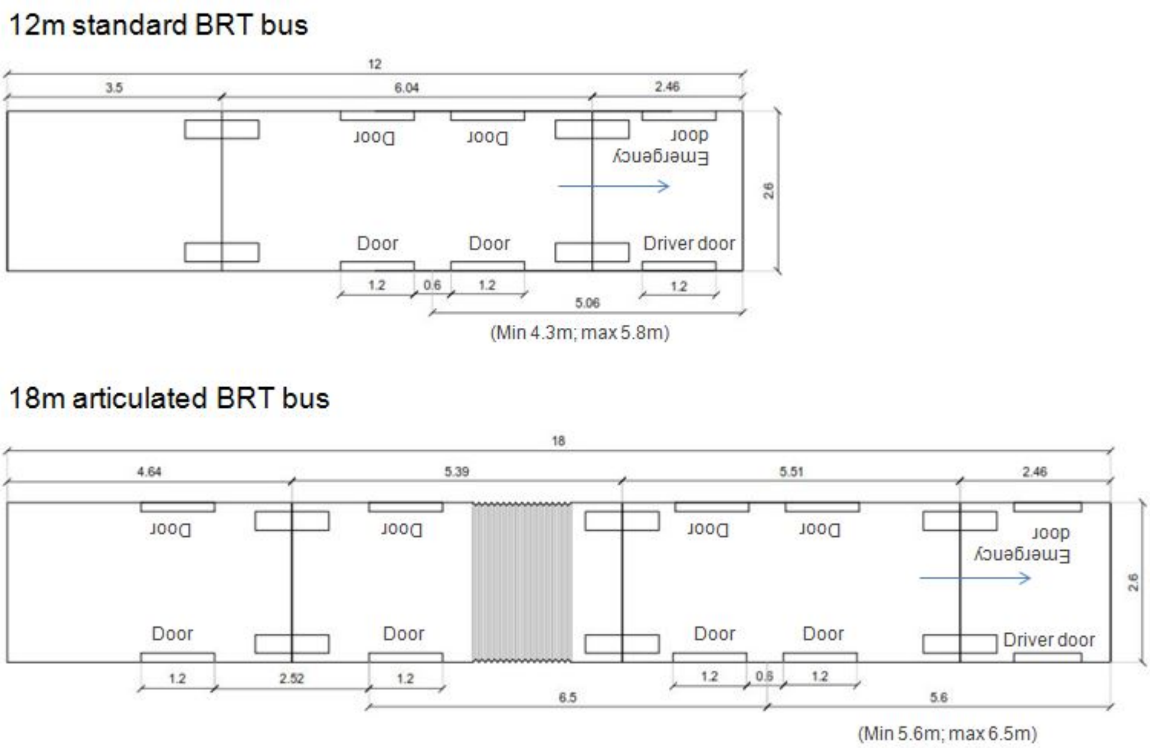


Figure 37: Bus door positions will be aligned so that different types of buses can dock at the same station. Station door positions will be coordinated with these docking positions.

7. Universal access

Transport should be easy for everyone to use. It is essential that the NMA BRT and complementary bus services incorporate best practices regarding design for persons with disabilities and special needs. This includes small children, people carrying heavy shopping or luggage, people with temporary injuries, and older people, who can all benefit from good design of BRT facilities and the wider pedestrian environment. The entire BRT corridor must be designed to provide seamless pedestrian connectivity, without abrupt level difference or changes in clear width.

7.1 Stations

Stations should incorporate the following elements:

- Tactile guides, including directional indicators and warning strips at platform edges.
- Accessible automatic barrier controls or manual gates operated by a station attendant.
- Route signs and information in Braille.
- Digital display systems with audio announcements.
- Platforms should be sized to allow for the inclusion of waiting wheelchair passengers close to other seating.

Station ramps must meet the following standards:

- Ramp gradients should not exceed 1:12.
- The materials selected for the surface finish of a ramp should be firm, levelled, and easy to maintain. The materials must also be slip resistant, especially if surfaces are likely to become wet.
- Handrails should be provided on both sides of the ramp.

Figure 38: Station ramps enable all users to access the system: Pimpri Chinchwad (left) and Dar es Salaam (right).

7.2 BRT vehicles

The interior of BRT vehicles must also be designed so that all persons can use them. The following access features must be included on all BRT vehicles:

- For BRT and feeder buses operating on service extensions beyond the dedicated BRT corridors, a lift must be provided on the left side of the bus to enable boarding from bus stops and from the ground level for seniors, wheelchair users, and other people with physical disabilities.
- Stanchions, grab bars, and hand-holds must be provided in contrast colour for balance and support for passengers to hold during bumps or sudden stops that the vehicle may encounter.
- Priority seating must be provided that is clearly identified as being reserved for people with disabilities, seniors, and mothers with small children, or pregnant women.

- Approximately 800 mm x 1200 mm of space on BRT vehicles must be dedicated for persons using mobility devices. This area must be located adjacent to vehicle entry doors to facilitate access from BRT stations.
- Stop request buttons must be installed at locations of priority seating and wheelchair positions.
- Auditory announcements of stop names and key destinations ensure that people who are visually impaired are facilitated to reach their destinations.

7.3 Bus stops on service extensions

BRT trunk buses in a hybrid system as well as feeder buses in a closed system travel beyond dedicated BRT corridors. Along these extensions, stops will be provided on the left side at the kerb. Bus stops should be placed adjacent to the linear line of travel so that the bus does not need to pull over to the left. Bus bays should be avoided because they increase travel time for bus users and the likelihood that bus passengers will stand in the street while waiting for the bus. The position of the bus stop should always leave accessible clear space for pedestrians behind the shelter. Bus stops should be built at a height of 150 mm (i.e., the same height as the surrounding footpath) to improve accessibility and safety if buses do not pull directly up to the kerb.

8. BRT Operations

Following implementation, BRT operations should be monitored closely to ensure good performance. BRT is more than the physical infrastructure of bus lanes and stations—reliable service and customer friendly operations are also essential to the success of the system.

8.1 Fare collection

Efficient fare collection is an essential component of a modern public transport service. The NMA BRT system will make use of off-board fare collection with electronic smart cards to improve customer experience and reduce revenue leakage. Off-board fare collection eliminates delays such as those caused when buses halt between bus stops to allow a conductor to sell tickets to all of the passengers on the vehicle. They also eliminate the need for passengers to fish for change on a moving vehicle. The NMA BRT fare collection system will be linked to popular forms of mobile money, such as M-pesa and Airtel Money to enable customers to recharge their smart cards. System designers should also explore possibilities for incorporating emerging fare collection media such as near field communications (NFC) systems.

Figure 39: Off-board fare collection is used across many high capacity BRT systems, including systems in Dar es Salaam (left) and Mexico City (right).

Manned service booths where customers can buy tickets, recharge smart cards, or make general enquiries should be provided at stations. Service booths should be positioned near station entrances, away from the barrier controls to provide adequate space for customer queueing and circulation of passengers entering and leaving the station. With large-scale adoption of electronic smart cards, the requirement for service booths can be reduced, freeing up station space for passenger circulation.

8.2 Access control

The NMA BRT system will have automatic barrier control at BRT stations to reduce the amount of time needed to verify fare payments. The system will utilise automatic barrier controls that provide for fast ticket or electronic smart card scanning and user throughput.[8]

Platforms should incorporate space for one wide gate suitable for wheelchairs and multiple regular gates. The minimum width between stanchions is typically 550-600 mm for a standard gate and 1,080 mm for a wide (disabled) gate, while the stanchions themselves are typically 300 mm wide. The number of gates required at each station should be determined taking passenger demand into account.

[8] Barrier controls options include turnstiles and flap gates. The tripod-shaped turnstiles used in many older rapid transit systems have lower operating and maintenance costs compared to flap gates. However, tripod gates are not universally accessible to persons with disabilities and users with strollers and heavy luggage. On the other hand, flap-gates offer faster throughput because users can simply walk through the gate without applying physical force to turn the tripod unit. Furthermore, advanced detection systems prevent the gates from closing when a stroller or suitcase is still passing through the gate and can stay open if another legal passage is detected.

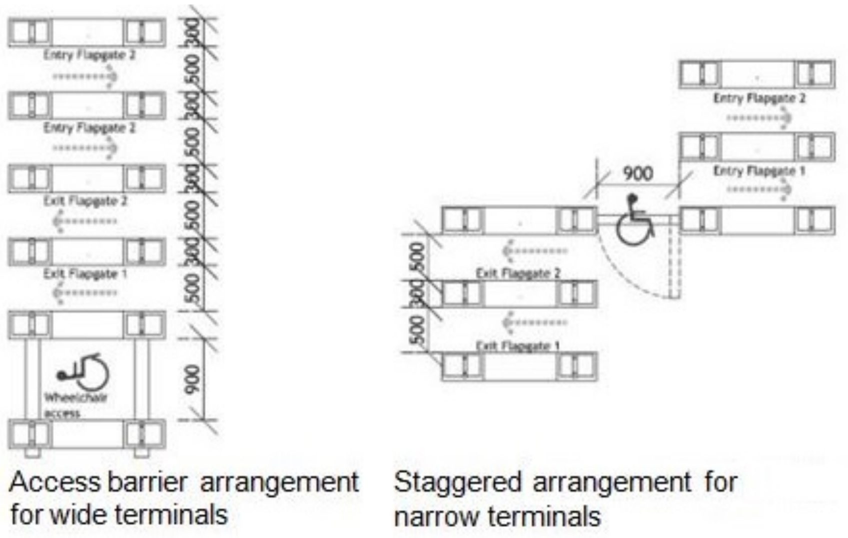


Figure 40: Barrier control arrangements for BRT stations. A staggered arrangement is preferred for narrow stations.

8.3 Passenger information

One of the barriers to using public transport is customer uncertainty about when the next bus will arrive. Providing real time information in the form of voice communications and variable message signs at stations can eliminate this uncertainty for BRT users. The NMA BRT system will incorporate the following real-time information services:

- **At stations and terminals**: visual and audio announcements of when the next bus will arrive and the destination or route number of the bus.
- **On buses**: real-time audio and visual announcements of the next stop and the final destination of the route.

In addition to the real-time information, the following static information must be provided:

- **At stations and terminals**: Network map, fare chart, directions, system map, station locations, and an area map with surrounding landmarks.
- **On buses**: Line diagrams and network map.

Multi-lingual real-time and static information in Kiswahili and English is preferred to allow for easy comprehension by all users.

8.4 Corridor management

BRT services will be planned according to passenger demand to prevent overcrowding during peak hours. Real-time monitoring and feedback from an IT-enabled control centre can help bus drivers stay on schedule.

Recovery vehicles will be operated under contract to either NaMATA or the bus operating company. These will be able to access the busway to overtake and tow away a disabled bus. Passengers on a disabled bus stopped between stations may be evacuated onto a replacement vehicle or out of any danger area (for instance if the bus is on fire).

Figure 41: The Dar es Salaam BRT system employs an automatic vehicle location system to optimise bus headways.

9. Non-motorised transport access

The entire BRT network must be designed to provide seamless pedestrian connectivity, making it easy for passengers to reach BRT stations. BRT designs should promote safe, at-grade pedestrian access, employing universal design techniques that ensure accessibility for BRT passengers and other road users. Continuous footpaths must be constructed along all streets. Intersections require pedestrian elements such as crosswalks, median refuge islands, and pedestrian signals. Pedestrian crosswalks can be constructed as raised zebra crossings at the same height as nearby footpaths. The BRT system should be accessible to all special-needs customers, including those who are on wheelchairs, parents with strollers, and other load-carrying passengers.

9.1 Footpaths

Footpaths must meet the following standards:

- Footpaths should include the following components:
  - A 0.5 m margin next to the property line (the "frontage zone").
  - At least 2 m of clear space for walking (the "pedestrian zone"). For footpaths with heavy pedestrian volumes, more clear width should be provided.
  - 1.0 m of space for landscaping, lights, bus shelters, signs, property ramps, and other street furniture (the "furniture zone") (Figure 42).
- Footpaths should be no higher than 150 mm above the carriageway level.
- Bollards should be installed to protect footpaths from vehicle encroachment, leaving a clear width of at least 1.2 m for wheelchair access. Strategic placement of street furniture and landscaping could also be place at the edge of the carriageway in lieu of bollards to protect footpaths from encroachment.
- Footpaths should have a smooth surface—asphalt or concrete.

- Footpaths should be designed without abrupt level differences, especially at property entrances and intersections. Abrupt and frequent kerb cuts that require pedestrians to constantly step up and down discourage people from using footpaths. Unavoidable level differences must be bridged with ramps that offer full access to persons with disabilities.
- For persons with visual impairments, tactile paving can be installed to indicate locations where vehicles and pedestrians interact.

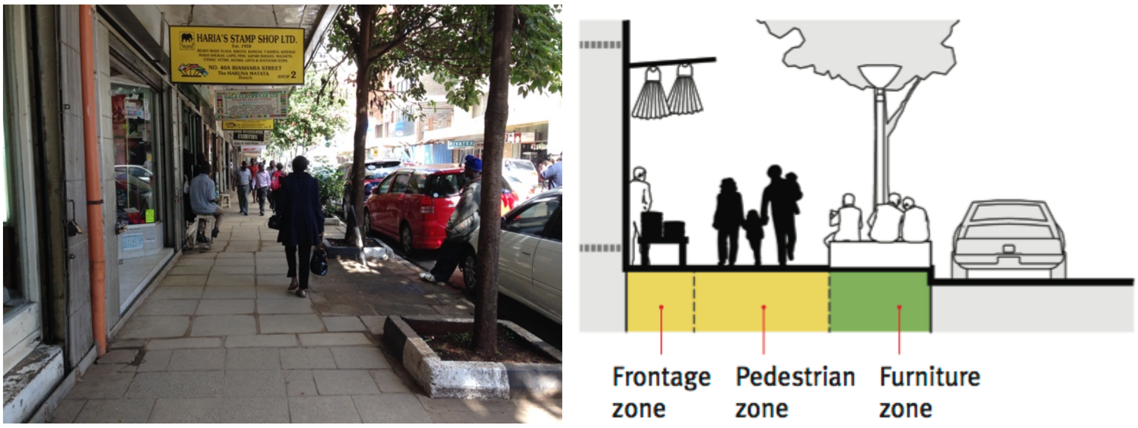


Figure 42: Footpaths along the BRT corridors should follow the zoning system, providing adequate clear space for pedestrian movement.

9.2 Pedestrian crossings

Well-designed crossings allow pedestrians to cross busy streets safely and conveniently. As discussed in section 5.4, BRT stations require safe, at-grade crossings to facilitate convenient access to the system. Besides crossings at stations, BRT corridors should offer at least one midblock crossing opportunity between each pair of stations. As with station crossings, these midblock crossings should be designed as raised zebra crossings at the same level as the adjacent footpath. At-grade crossings are recommended along all urban sections along the BRT. They will require traffic management through signalisation to manage traffic flow and pedestrian movements.

9.3 Bicycle infrastructure

Dedicated cycle tracks should be provided along BRT routes to enhance connectivity and safety for cyclists and to expand the catchment area of BRT stations. In general, cycle tracks should be physically separated from mixed traffic to provide a clearly defined, safe space to travel. To ensure a smooth riding surface, cycle tracks should be constructed in concrete or asphalt (not paver blocks). The BRT corridor can double as a new spine of the bicycle network, especially if none exists. At major stations and terminals, secure cycle parking should be provided in the paid area of the station.

Figure 43: Dedicated cycle tracks should be provided along BRT corridors to enhance safety and improve access for BRT passengers (left). Cycle parking should be provided in the paid area of major BRT stations and terminals (right).

10. Inter-modal integration

For the NMA BRT to function as part of a coherent public transport network, passengers need to be able to transfer easily from one mode to another. Integration does not merely mean placing stations for multiple public transport modes close together. Rather, it involves the detailed design of inter-modal stations. Detailed guidance on the integration of BRT with existing paratransit services will be developed as part of an industry transition plan. The physical design of intermodal facilities will be guided by the following principles:

- Walking paths will be short and direct with minimal level difference for transferring passengers. Direct cross-platform interchanges are preferred.
- Adequate clear space for passenger movement will be provided to prevent bottlenecks.
- Passenger areas will be protected from sun and rain.
- Robust public information will be provided to enable users navigate the areas.

Some inter-modal facilities, such as boda boda stands and cycle parking, can be developed at multiple major stations along a BRT corridor. Convenient inter-modal facilities should be developed wherever the BRT corridor passes near a commuter rail station, matatu terminal, or intercity bus terminal. Intermodal stations may require an additional turning point for feeder services or enhanced crossing facilities. Designers of associated projects should liaise with NaMATA at the beginning of projects regarding the location of stations that require additional space for transfers.

Figure 44: Passengers on Medellín's Metro plus BRT corridor can easily access the city's elevated metro line without leaving the paid area of the station.

Figure 45: High-quality feeder stations in Dar es Salaam (left) and Bogotá (right) provide transfer opportunities for BRT passengers.

11. Depot design

BRT depots should include areas for refuelling, cleaning, repairs, administration, and parking. Depots are generally located at or adjacent to terminal facilities so that depot parking can be used for BRT vehicles coming out of service during off-peak periods.

The location of a depot is often dependent upon the economical acquisition of sufficient property, but depots generally should be sited immediately adjacent to a BRT corridor to reduce the number of "dead kilometres" that buses operate to reach a corridor end point. The geometric design of the depot entry should be designed in conjunction with that of the BRT corridor. The interior layout should allow for convenient manoeuvring of buses.

The size of the depots and terminals depends on the number of vehicles that will be based at the depot. As a rule of thumb, a depot for 100 standard buses requires approximately 2 hectares. Depot surfaces should be constructed in concrete rather than asphalt for better durability.

Figure 46: BRT depot facilities in Dar es Salaam (left) and Bogota (right).

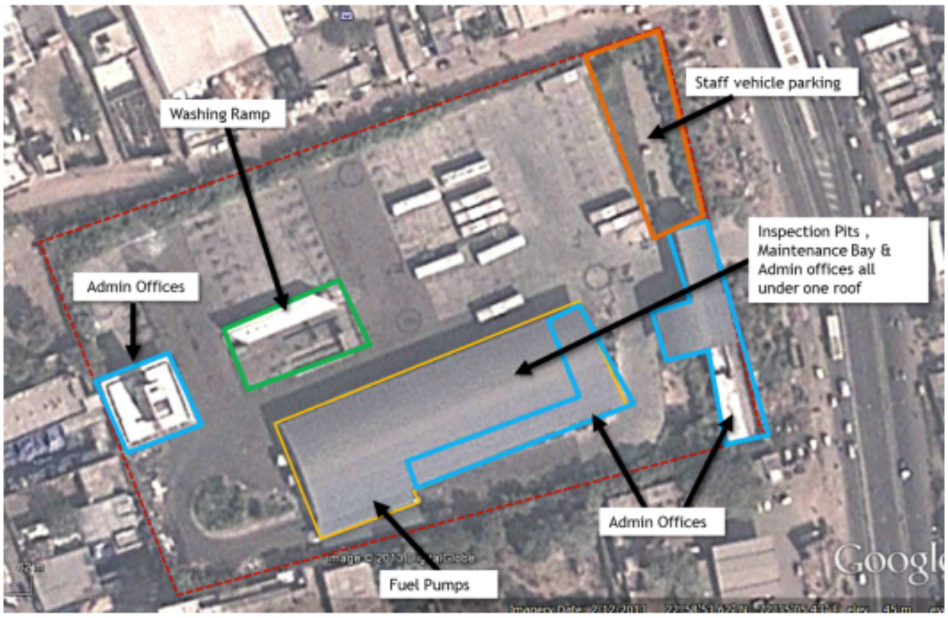
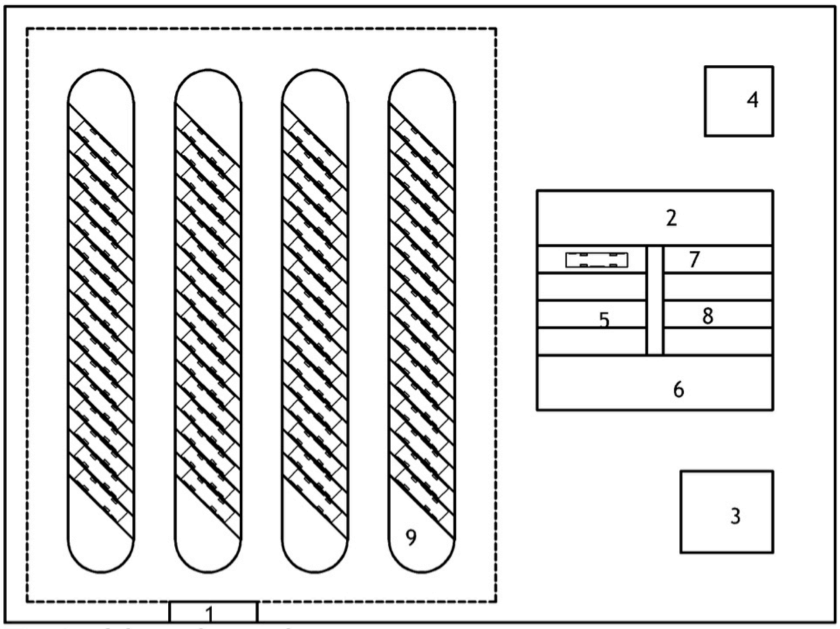


Figure 47: BRT depots should incorporate areas for bus parking, refuelling, washing, repairs and maintenance, and administration.



1. Gate and visual inspection area
2. Administration area
3. Refuelling area
4. Vehicle washing and cleaning
5,6. Major repairs
7,8. Minor repairs and maintenance
9. BRT vehicle parking

Figure 48: Typical bus depot layout.

12. Safety

Since dedicated BRT corridors segregate buses from smaller vehicles, the NMA BRT system can contribute to a significant reduction in minor as well as major crashes. With appropriately designed pedestrian facilities, conflicts between motor vehicles and pedestrians can fall as well. Safe design of BRT requires attention to the following safety elements:

- **Physical segregation of BRT lanes**. Physical barriers between the carriageway and BRT lanes help prevent conflicts between mixed traffic and BRT buses. Railings are advisable to prevent random pedestrian crossing movements along the corridor. However, breaks in the railings should be provided at regular intervals to facilitate safe crossing behaviour.
- **Intersection design**. The layout of intersections should facilitate safe user behaviour. Channelisation using medians and pedestrian refuge islands can help reduce crossing distances, streamline traffic flow, and reduce avoidable conflicts.
- **Pedestrian crossings**. BRT corridors require safe pedestrian crossings at regular intervals. Pedestrian crossings should be built at grade to ensure that they are accessible to all users. Crossings require adequate markings and signage. Motor vehicle movements must be managed, either through signalisation in the case of crossings located at junctions, or through physical traffic calming elements at mid-blocks. Mid-block crossings should be constructed as table-top crossings that are raised to the level of the adjacent footpath. Bollards, if provided should have minimum spacing of 1m to allow mobility aid users such as wheelchairs to pass through unhindered.
- **Footpaths and cycle tracks**. The corridor design must provide for safe movements for pedestrians and cyclists through the length of the corridor. Wide, continuous footpath and cycle tracks are important to provide access to BRT stations and to offer access to other road users.

- **Driver training**. Adequate training is required to orient and sensitise drivers to BRT corridor safety issues.
- **Level boarding**. Precision docking of buses and level boarding is essential for the buses so that there is minimum horizontal and vertical gap between bus platform and bus chassis (Figure 25), which can be bridged through manual hinged ramp.
- **Traffic management**. During the initial phase of BRT operations, in order to sensitise vehicle users and promote safe road user behaviour along a corridor, traffic wardens should be stationed at major junctions and pedestrian crossing points along the entire corridor. The primary duty of these guards will be to prevent motorised vehicles from entering the corridor, ensuring that vehicles give priority to BRT buses at intersections, and providing safety to pedestrians who wish to cross the road or access a BRT station.

Once the system is operational, the BRT control centre should monitor all traffic incidents along the corridor to document safety issues and identify solutions.

13. Performance evaluation

Once a BRT system is operational, the following checklist can be used to evaluate whether management practices along the corridor are contributing to good performance.

Table 6: Performance evaluation criterion

Topic	Criteria	Data source
Multiple routes	The corridor has two or more services.	System map
Control centre	The system has a functioning control centre that monitors bus movements, responds to incidents real-time, controls the spacing of buses, and trip data for each bus, including distance travelled and speed.	System map
Hours of operations	The system offers late night and weekend service.	Agency data
Commercial speeds	The system offers commercial speeds of at least 20 km/h.	AVL data
Passenger throughput	Passenger throughput.	AFC data
Passenger boardings	Number of daily passengers.	AFC data
Load factor	Passenger kilometres travelled divided by bus kilometres travelled.	AFC data
Transfer rate	Passenger boardings divided by linked passenger trips.	AFC data
Enforcement of right-of-way	Effective enforcement measures prevent unauthorised entry of mixed traffic into the busway.	Manual observation or monitoring with cameras
Significant gap between bus floor and station platform	The horizontal and vertical gaps between the station platform are at most 10 cm and 5 cm, respectively).	Manual observation
Overcrowding	No more than 25 per cent of peak hour buses experience loads of over 5 passengers per sq m (calculations based on passenger volume data).	AFC data
Maintenance of the busway, buses, stations, and technology solutions	BRT facilities are clean, free of litter, and in a good state of repair.	Manual observation

Frequency	Each service operating on the BRT corridor has a frequency of at least 8 buses during the peak period and 4 buses off-peak.
Express, limited and local services (for high demand systems)	The system offers limited or express services that skip some stations.

14. Checklist for BRT infrastructure design review

Category	Element	Mandatory	Recommended
Station interiors	BRT station platform same as BRT bus height	X	
	Docking ledge (200-250 mm) with rubber beading	X	
	Small railing or barrier on both the edges of the ledge for safety		X
	Automated sliding doors	X	
	RFID tags for sliding door operations	X	
	Vertical alignment marker (flag) on the station edge for bus docking	X	
	Kassel kerbs		X
	Electricity connections	X	
	Lighting arrangement	X	
	Universal power supply facility	X	
	Solar panels for station electricity		X
	Fixtures for PIS displays	X	
	PIS displays	X	
	Tactile flooring	X	
	Passenger seating	X	
	Stop line and entry/exit arrows to guide passengers at the station automated doors	X	
	Sufficient number of docking bays based on demand	Y	
	Station name displayed - internal	X	
	Station name displayed - external	X	
	Corridor map displayed	X	
	Route-wise headway information displayed inside stations	X	
	Station kiosk for off-board fare collection		X
	Ticket prices displayed		X
	Local area wayfinding map displayed		X
	Station doors/shutters at main entry for security at night	X	
	Concrete surfacing installed in bus lanes (at least near bus docking areas at stations)	X	X
	Passing lanes (wherever applicable)		X
Corridor design **Intersections**	Corridor segregation	X	
	Footpaths on either side of the corridor	X	

	Pedestrian refuge islands between bus lanes and mixed traffic lanes	X	
	Table-top crossing in mixed traffic lanes at midblock locations with speed bumps ahead of the crossing	X	
	Zebra markings	X	
	Lane segregation at bus station installed	X	
	Designated stopping bays for auto rickshaws/ cycle rickshaws share autos near stations (wherever applicable).		X
	Terminal entries and exits are designed properly	X	
	Wide and safe universally accessible footpaths along the corridor.	X	
	Wide and safe universally accessible footpaths on access roads to corridor at least up to 500 m from stations.	X	
	Sufficiently wide bicycle lanes along the corridor-wherever applicable		X
	Corridor enforcement signage	X	
	Bus lane segregation up to the junction	X	
	Minimum 1.2 m wide pedestrian refuge islands at medians on all arms	X	
	Pedestrian zebra markings	X	
	Signals installed	X	
	Simplified two-phase signals (Right turns across the busway prohibited or squareabout designs)		X
	Concrete surfacing of busway on all approaches	X	
	Signals installed and programmed for new signal cycle	X	
	Accessible ramps installed on all corners and refuge islands	X	
Operations and management	Standard operating procedures established	X	
	Drivers training	X	
	Traffic wardens training	X	
	Security guards training	X	
	Fare collector (off board or on board) training	X	
	PIS testing: buses and BRT stations	X	
	Operations schedule	X	
	Route rationalisation		X
	Headway of any BRT route on the corridor is less than 20 min as per service plan		X
	Integrated ticket with easy transfers		X
	System logo is put on all the BRT buses	X	
	Appointment/ identification of field officers to monitor – bus and bus station cleanliness, no breakdowns, maintenance	X	
	Central control centre installation and testing	X	
	Bus cleaning and maintenance facilities	X	
	GPS testing and verification	X	

	Station door operations testing and verification	X	
	Station UPS testing and verification	X	
	Bus lane enforcement notification (traffic police)	X	
	Terminal supervisors and starters	X	
Communications	Route map	X	
	Customer information on changes in services	X	
	System website		X
	Communications officer		X
	Grievance redressal system	X	
	ID cards for system staff	X	