SEPTEMBER 7, 2021

WAKE BRT

System Standards

CITY OF RALEIGH | DEPARTMENT OF TRANSPORTATION

TRANSIT

Raleighnc.gov/BRT

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GLOSSARY/LIST OF ABBREVIATIONS

AASHTO	American Association of State Highway and Transportation Officials
ADA	Americans with Disabilities Act
APTA	American Public Transit Association
AV/CV	automated and connected vehicles
AVL	automatic vehicle location
BAT	business access and transit
BRT	bus rapid transit
CAD	computer-aided dispatch
CCTV	closed-circuit television
CMS	central management software
CNG	compressed natural gas
FTA	Federal Transit Administration
GPS	global positioning system
GSI	green stormwater infrastructure
mph	miles per hour
MUTCD	Manual on Uniform Traffic Control Devices
NACTO	National Association of City Transportation Officials
NCDOT	North Carolina Department of Transportation
NCHRP	National Cooperative Highway Research Program
NEPA	National Environmental Policy Act
PAR	pedestrian access route
RFID	radio-frequency identification
SEPA	North Carolina State Environmental Policy Act
TCE	temporary construction easement
TOD	transit-oriented development
TSP	transit signal priority
TVM	ticket vending machine

1. INTRODUCTION

In 2016, Wake County voters approved a plan for focused investment in public transit, putting the implementation of the Wake County Transit Plan in motion. The original plan calls for building approximately 20 miles of transit lanes along four bus rapid transit (BRT) corridors within Wake County, to be implemented and operated by the City of Raleigh. These corridors comprise the current planned Wake BRT system. This document is the basis of design for the Wake BRT system and has been prepared in collaboration with project partners including the City of Raleigh, GoTriangle, North Carolina Department of Transportation (NCDOT), and other regional planning partners. Additional BRT corridor extensions in the region are currently being studied. Any future BRT extensions will be evaluated based on service characteristics for the inclusion into the Wake BRT system. The purpose of this document is to establish design guidelines and criteria that would be used for Wake BRT corridors, addressing factors that may affect the design of BRT and incorporating best practices for BRT implementation. The design standards developed include:

- Station spacing and siting
- Station facilities
- Roadway
- Technology
- BRT fleet and vehicles
- Identity and branding
- Service operations
- Green stormwater and infrastructure

Figure 1.1 GoRaleigh Station[1]

[1] GoRaleigh Station Image: https://downtownraleigh.org/getting-around/goraleigh-station

INTENDED AUDIENCE

This guide is intended to aid project stakeholders and design teams in planning and developing BRT facilities implemented and operated by the City of Raleigh. As design standards become more established within the Wake BRT system, current and future BRT project stakeholders may benefit from this guide as well, including design consultants, contractors, developers, public works administrators, and neighborhood and community organizations and leaders.

HOW TO USE THE GUIDE

This document establishes standards to be used for the four planned BRT corridors to be implemented and operated by the City of Raleigh (listed in Section 2: Existing Conditions). This document includes facility descriptions, graphic renderings, design diagrams, and technical drawings to help illustrate how various BRT transit facilities should be designed. The graphics and tables included herein have been created to align with the region's transit vision and assist in accommodating the interests and needs of the various communities BRT would serve. While the establishment of System Standards provides consistency in operations and user experience, design flexibility is often needed to work within a given environment. As new design standards are developed, this guide should be updated accordingly.

Additional documents are available that describe various policies, procedures, and design standards applied by jurisdictions in the Wake County transit service area. These include, but are not limited to:

- Americans with Disabilities Act (ADA) requirements.
- American Association of State Highway and Transportation Officials (AASHTO) *A Policy on Geometric Design of Highways and Streets.*
- American Public Transit Association BRT Design Standards.
- Town of Cary Standard Specifications.
- Town of Garner Standards.
- City of Raleigh Street Design Manual.
- National Association of City Transportation Officials (NACTO) Transit Street Design Guide.
- National Cooperative Highway Research Program (NCHRP) reports.
- Manual on Uniform Traffic Control Devices (MUTCD).
- The National Environmental Policy Act[2] (NEPA).
- North Carolina State Environmental Policy Act[3] (SEPA).
- North Carolina Department of Transportation (NCDOT) Roadway Design Manual.
- Title VI[4] of the Civil Rights Act.
- Wake County Major Investment Study BRT Design Standards.

These resources are referenced within these guidelines where applicable.

Additionally, each jurisdiction in Wake County has individual permitting procedures and requirements governing use and development of private property as well as the public right-of-way. The City of

[2] Federal Transit Administration NEPA overview: https://www.transit.dot.gov/regulations-and-guidance/environmental-programs/national-environmental-policy-act
[3] North Carolina Department of Environmental Quality SEPA overview: https://deq.nc.gov/permits-regulations/sepa
[4] FTA Title VI guidance: https://www.transit.dot.gov/regulations-and-guidance/civil-rights-ada/title-vi-guidance

Raleigh will work with each jurisdiction to ensure compliance with permitting requirements for each project.

BUS RAPID TRANSIT OVERVIEW

BRT is defined by the Federal Transit Administration (FTA) as high-capacity bus-based transit that delivers fast and efficient service. BRT may include dedicated lanes, busways, transit signal priority, off-board fare collection, elevated platforms, and enhanced stations. BRT has several distinguishing features, described in greater detail throughout this guide.[5]

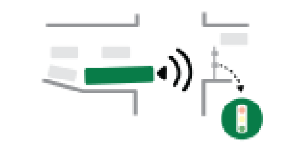
DEDICATED BUS LANES

BRT buses operate primarily in their own lane in traffic. Dedicated lanes prevent traffic delays even during rush hour, and they reduce the risk of collisions between buses and other vehicles, increasing safety for all road users.

Dedicated Lanes

TRANSIT SIGNAL PRIORITY

BRT buses can coordinate with traffic signals along the route to extend green lights and shorten red lights, reducing the amount of time buses spend idling at traffic lights. This increases service speed and reliability.



Transit Signal Priority

FREQUENT, ON-TIME SERVICE

With dedicated lanes and less frequent stops, BRT buses are better able to adhere to their posted schedules. BRT buses should also have onboard real-time location information so stations can display live, accurate updates for bus arrival time. BRT service is planned to operate with 15-minute frequency all day.

Frequent
On - time Service

OFF-BOARD FARE COLLECTION

Passengers should pay fares at stations instead of on the bus, speeding up boarding and reducing dwell time at stations. BRT fares should be the same as all GoRaleigh fares.

Off- Board
Fare Collection

ENHANCED STATIONS

BRT stations should include improvements to ticketing, scheduling, and boarding to enhance the passenger experience. Stations should also have raised platforms that reduce or eliminate the gap between the station and the bus, making boarding easier and more accessible for all passengers – including those using mobility devices.

Enhanced Stations

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[5] BRT Icons: https://raleighnc.gov/services/transit-streets-and-sidewalks/what-bus-rapid-transit-brt

SPECIALIZED VEHICLES

Wake BRT should have its own custom 60’ articulated buses with higher capacity than the buses typically used on local routes. BRT vehicles should also have doors on both sides and lower floors to allow for easier boarding.

Specialized Vehicles

UNIQUE BRANDING

Wake BRT should have its own unique branding to make buses and stations more visible and help passengers distinguish between BRT and other transit services.

Unique Branding

IMPLEMENTING SYSTEM STANDARDS IN CONTEXT

Every transit facility project is designed within the context of its physical space. Facilities are designed with passenger safety and comfort in mind. Facilities should also promote safe, efficient, and reliable transit service. To achieve that goal, this document contains general standards and guidelines that serve as a starting point for design development.

The City of Raleigh does not have a formal process to address variances from BRT standards. Appropriate roadway authority staff and the project agency should discuss, coordinate, and determine which features should be modified or eliminated in circumstances where project guidelines cannot be met. Projects should be reviewed, designed, and approved within the context of existing conditions. Existing agreements may also govern overall design elements at the project site.

2. EXISTING CONDITIONS

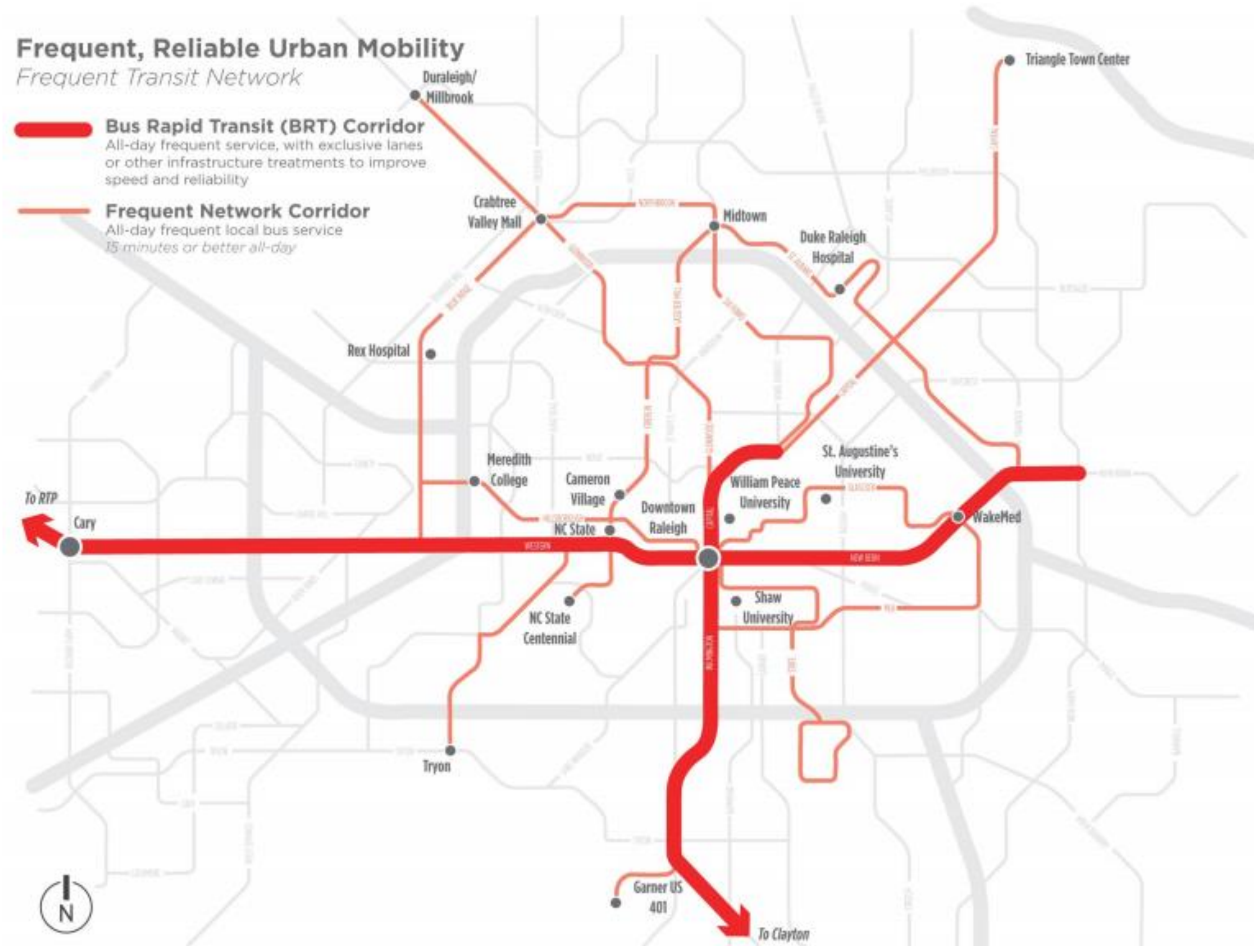

Figure 2.1 Wake County BRT Corridor Map[6]

LAND USE AND DEVELOPMENT

Figure 2.1 above shows proposed BRT corridors to be implemented and operated by the City of Raleigh, which will begin operation in a variety of land use contexts, including residential, commercial, institutional, and mixed-use areas, as well as downtown Raleigh, industrial centers, and healthcare facilities. Vacant lots may also be present adjacent to Wake BRT routes and/or stations. Land use patterns shape station nodes and impact pedestrian traffic and the transit environment. These patterns should be considered in selecting lighting, determining the placement of station elements, and developing other aspects of station design including pedestrian and bicycle access and various safety measures. Stations and support facilities should aesthetically and functionally complement the character of their surroundings, should be designed to take advantage of existing attractive site features and be compatible with surrounding land uses and development. Where consistent with land use policies, stations can form the nucleus for transit-oriented development.

[6] Corridor Map: https://nmcdn.io/e186d21f8c7946a19faed23c3da2f0da/8bfec28a290449a7b10eb1fee3a0e264/files/TPAC/TPAC-Meeting-Files/2021-2.17/D--Wake-Transit-Plan-Update---Final-Report---Updated-2-14-2021---TPAC-Review-Draft.pdf

ROADWAYS

Roadway classifications are determined using the appropriate municipal and state roadway design manuals. Arterial BRT corridors would most often operate on major streets, including 4 and 6-lane avenues, one and two-way, and divided or undivided. Each classification of roadway has specific requirements for design speeds, right-of-way width, curb radii, and other standards. The following corridors are currently planned for BRT service in Wake County.

NEW BERN BRT

Heading east, this route begins in downtown Raleigh, continues past the WakeMed Raleigh Campus, and terminates in a low-density commercial and industrial area past Interstate 440.

Figure 2.2 WakeMed Campus[7]

NORTHERN BRT

This route follows Capital Boulevard or West Street from downtown Raleigh to Crabtree Boulevard. Final routing is yet to be determined at the time of this writing.

Figure 2.3 William Peace University Campus[8]

[7] WakeMed Image: https://www.wakemed.org/

[8] William Peace University Image: https://peace.edu/academics/academic-resources/core-curriculum/

WESTERN BRT

Heading west, this route would follow Western Boulevard to Cary Towne Boulevard, Maynard Road and terminate at the Downtown Cary Multi-Modal Center.

Figure 2.4 North Carolina State University Campus[9]

SOUTHERN BRT

The northern portion of this route would use South Wilmington Street, while the southern piece would use the S Wilmington Street extension (by new roadway construction)

Figure 2.5 Duke Energy Center for the Performing Arts[10]

[9] North Carolina State University Image: https://magazine.cals.ncsu.edu/the-power-of-giving-entrepreneur-and-philanthropist-and-cals-alum-carroll-joyner/

[10] Duke Energy Center for the Performing Arts Image: https://www.visitraleigh.com/listing/duke-energy-center-for-the-performing-arts/57123/

LAND USE CONTEXT

Planned BRT corridors in Wake County include a wide array of adjacent land use context. Land uses include high- to low-density residential and commercial areas as well as light industrial areas. Routes serve institutional uses including primary and secondary schools, colleges and universities, churches, and other institutions.

HIGH DENSITY

High density land uses along BRT corridors are typically located in city centers with high pedestrian volume. Transit facilities in these areas would require high levels of access and circulation as they often can experience the highest ridership levels on the corridor. Right-of-way can be limited with vertical adjustments constrained. Stations must be designed to maximize pedestrian movements and limit adverse impacts on storefront businesses. A high density land use is shown below in Figure 2.6.

Figure 2.6 High Density Land Use Example[11]

MODERATE DENSITY

Moderate density land uses along BRT corridors are typically located in areas just outside city centers and often in predominantly residential areas. Often, space at transit facilities is more available than in high density areas. While right-of-way may be more readily available, increased traffic speeds and reduced pedestrian activity may impact the implementation of BRT stations and exclusive runningway. A moderate density land use example is shown below in Figure 2.7.

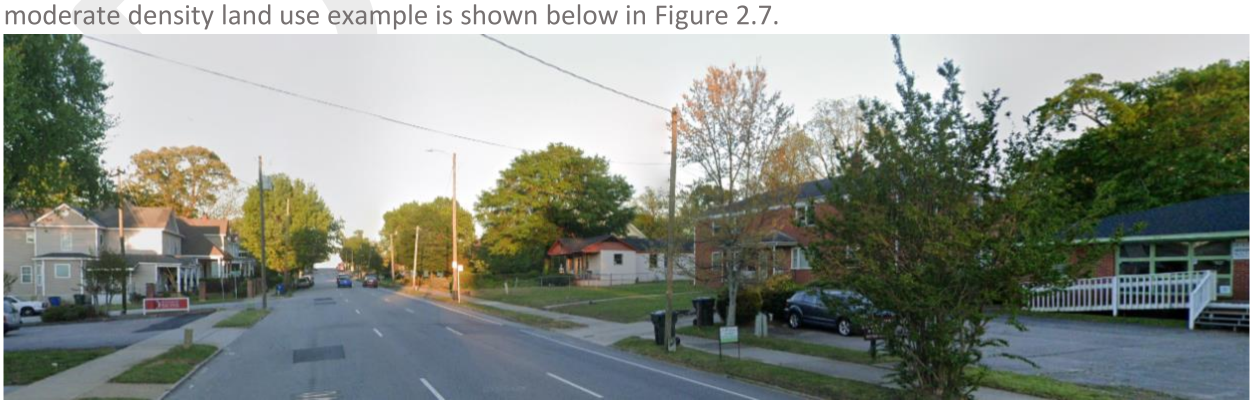

Figure 2.7 Moderate Density Land Use Example[12]

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[11] High Density Land Use: https://www.bing.com/maps

[12] Moderate Density Land Use: https://www.google.com/maps/@35.7800473,-78.6263516,3a,75y,109.67h,88.84t/data=!3m6!1e1!3m4!1sIHJB3KzmKZh6bh6Wk3KPkg!2e0!7i16384!8i8192

LOW DENSITY

Low density land uses along BRT corridors are typically located in areas farther from city centers with lower pedestrian volumes. Right-of-way tends to be less constrained, but low pedestrian volumes can reduce need for BRT exclusive stations and runningway. Low density locations often contain higher speed segments. Stations may require additional setbacks from roadways, constraining platform element placement. A low density land use example is shown below in Figure 2.8.

Figure 2.8 Low Density Land Use Example[13]

[13] Low Density Land Use: https://www.google.com/maps/@35.7977859,-78.5772489,3a,75y,65.63h,89.18t/data=!3m6!1e1!3m4!1srH6nSU5pEWxXqZLLoCe7Dg!2e0!7i16384!8i8192

3. STATION SPACING AND SITING

STATION SPACING

BRT stop spacing seeks to balance speed and access. Fewer stops allow for faster travel, but also reduce the number of destinations within a short walk. Table 3.1 below indicates general guidelines for application of BRT stop spacing and proportion of dedicated transit runningway based on surrounding land use context. A BRT stop is defined as a single platform in one direction of travel. Closer stop spacing is warranted in moderate to high-density areas with more trip generators, while in lower-density areas, speed is prioritized to ensure that BRT is an attractive alternative to driving. Moderate to high density areas are those with at least ten residents and jobs per acre, and low-density areas have less than ten people and jobs per acre.

Table 3.1 Station Spacing

Stop Spacing	**Moderate to High Density** (≥10 people and jobs per acre)	**Low Density** (<10 people and jobs per acre)
Minimum stop spacing	0.5 miles	1 mile
Maximum stops per mile	2	1
Dedicated Runningway		
Minimum percentage of all-day dedicated runningway	50%	N/A*

**Implementation of dedicated runningway for low-density segments would be context sensitive. Benefit/Cost analysis is recommended.*

STATION SITING

After the general location for a BRT station is identified through the corridor planning process, several factors influence the specific location of station platforms, including right-of-way needs, public input, adjacent property/business access, population and job density, community destinations, connecting transit routes, and nearby pedestrian and bicycle infrastructure.

STATION ORIENTATIONS

Five different station orientation categories, as referenced by NACTO[14][15][16], are used for station design. Each orientation describes the location context based on the roadway itself, as well as physical limitations or contexts. These categories are not mutually exclusive, as near-side, far-side, and mid-block describe proximity to an intersection, while split island and shared island stations reference the roadway layout.

[14] Near-Side, Far-Side, Mid-Block: https://nacto.org/publication/transit-street-design-guide/stations-stops/stop-design-factors/stop-placement-intersection-configuration/

[15] Split Island: https://nacto.org/publication/transit-street-design-guide/stations-stops/stop-configurations/in-street-boarding-island-stop/

[16] Shared Island: https://nacto.org/publication/transit-street-design-guide/stations-stops/stop-configurations/median-stop-left-side-boarding/

NEAR-SIDE

Near-side stations are described by platforms that are placed on the close side of the intersection to the direction of travel. Near-side stations allow for the bus to pull up to the station while in traffic prior to the intersection signal. If a bus pulls into the station during a green light cycle, allowing for boarding time, it may have to wait until the next cycle to proceed through the intersection. Limited transit signal priority (TSP) advantages can be implemented in this configuration. Figure 3.1 shows a schematic of a near-side station in relation to an intersection along the BRT corridor.

Figure 3.1 Near-Side Station[17]

FAR-SIDE

A far-side station is placed on the distant side of the intersection from the direction of traffic. These stations allow for buses to travel through the intersection before boarding. Additionally, if TSP is implemented, far-side stops allow buses to travel through the intersection during a green light, stop at the BRT platform, and depart without additional delay. Figure 3.2 shows a schematic of a far-side station in relation to an intersection along the BRT corridor.

Figure 3.2 Far-Side Station

[17] Station Siting Graphic: https://nacto.org/publication/transit-street-design-guide/stations-stops/stop-design-factors/stop-placement-intersection-configuration/

MID-BLOCK

Mid-block stations are located at a distance between intersections when the station is unable to be placed near intersections due to driveway access, on-street parking, or other operational safety concerns near the intersection. Mid-block stations ideally still allow for nearby access to key destinations. However, due to their greater distance from pedestrian roadway crossings, mid-block stations are typically proposed only where near-intersection platforms are not feasible, or where mid-block pedestrian crossing facilities are warranted. Figure 3.3 shows a schematic of a mid-block station in relation to an intersection along the BRT corridor.

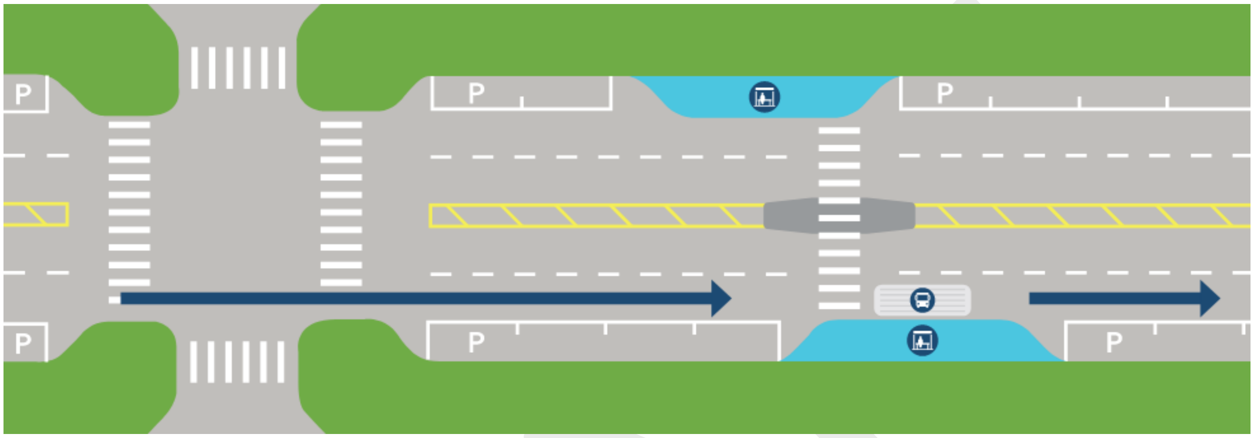


Figure 3.3 Mid-Block Station

SPLIT ISLAND

Split island stations are placed in the median of a dedicated transitway. With through traffic at the back edge of the platform, a protective edge behind the platform must be implemented to ensure the security of waiting passengers. Split island stations are typically associated with dedicated transitway roadway configurations. Figure 3.4 shows a schematic of a split island station in relation to an intersection along the BRT corridor.

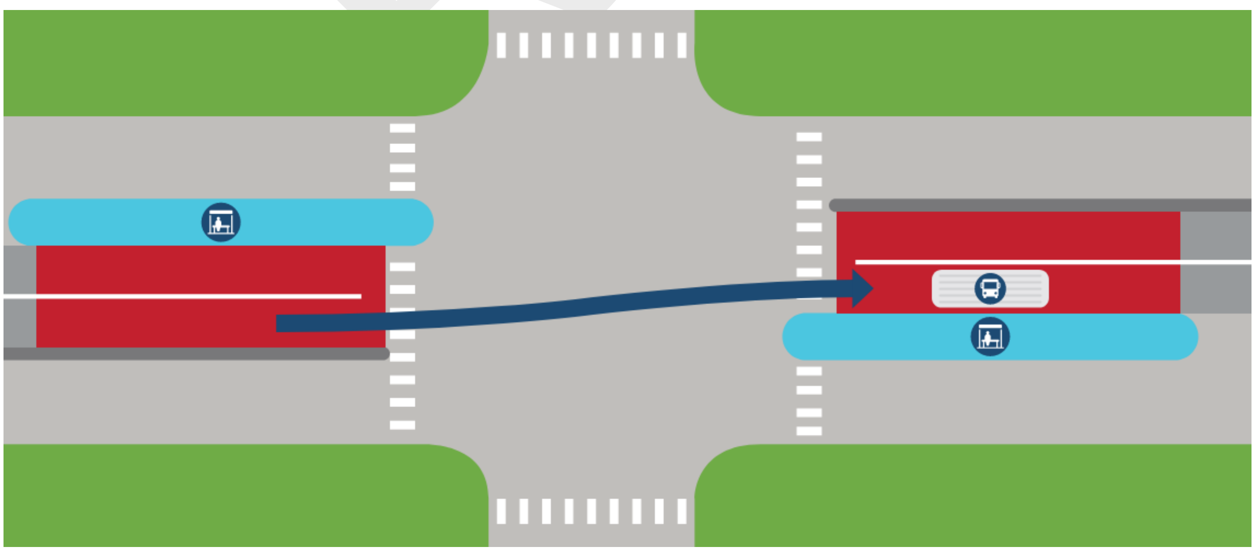


Figure 3.4 Split Island Station

SHARED ISLAND

Shared island stations are placed where transit routes require high capacity stops and have adequate right-of-way available to allow for both median-adjacent transit stops as well as passenger waiting space for a bi-directional platform. Sufficient passenger capacity and adequate rider pedestrian access are the primary considerations for this type of station. Buses are required to have left-boarding doors for this configuration. Figure 3.5 shows a schematic of a shared island station in relation to an intersection along the BRT corridor.

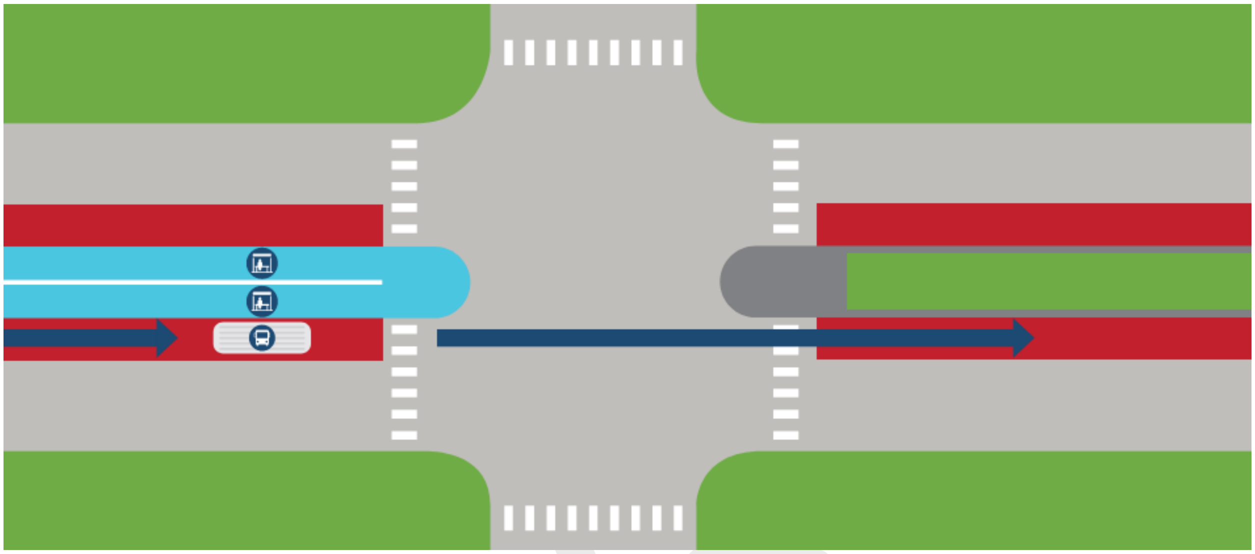


Figure 3.5 Shared Island Station

FACTORS INFLUENCING STATION ORIENTATION

The context of a station site influences where the station should be located. Far-side platforms are generally preferable from an operational standpoint, optimizing the potential for TSP to enable a bus to pass through an intersection without delay, and reducing dwell times after boarding. However, there are situations in which near side platforms better meet operational needs. In some cases, a mid-block platform may be appropriate when intersection-adjacent sites do not allow for adequate platform length.

Other factors that are considered in selecting a station site include the location of utilities, vertical roadway elements, access from local streets, and whether pedestrian guideway elements such as fencing or vertical separations would be needed for safety or other purposes. Space needs for the travel lane, curb and gutter, clear zone, through zone, furnishing zone, and tactile platform edge must also be accounted for in station site selection. When necessary, due to constrained right-of-way, this evaluation should also consider the possibility for a through zone combination with the clear zone. Full descriptions of each zone in the platform area can be found in the station facilities section.

4. STATION FACILITIES

PLATFORMS

Stations must serve users efficiently, safely, conveniently, and comfortably. . Station design should be compatible with the immediate vicinity of the station and reflective of the regional context and branding.

Stations should be standardized to the fullest extent practical to provide a consistent experience. This is essential for ensuring accessibility for all users. Standard graphic information systems are especially important. Some design elements can be modified based on ridership and neighborhood setting.

CONFIGURATION

There are several configuration types that would be used in Wake BRT. Stations can be located curbside, on a curbside island, or on a median island. Curb configurations occur on the edges of the mainline rather than the middle, like the medians. Islands describe where the platform is separated from the sidewalk by either vehicle or bicycle traffic lanes.

Level boarding (14" platforms) should be provided at all platforms to the fullest extent possible. Where level boarding is not feasible, individuals with disabilities may board the BRT vehicle by using a deployable bridge plate spanning the gap between the bus and the platform.

PLATFORM ZONES

Platform zones are specific areas at a station dedicated for different uses, such as boarding, drainage, walking, etc. These areas are distinguished for both design and practical applications. All platforms should include the following zones, as shown in Figure 4.1:

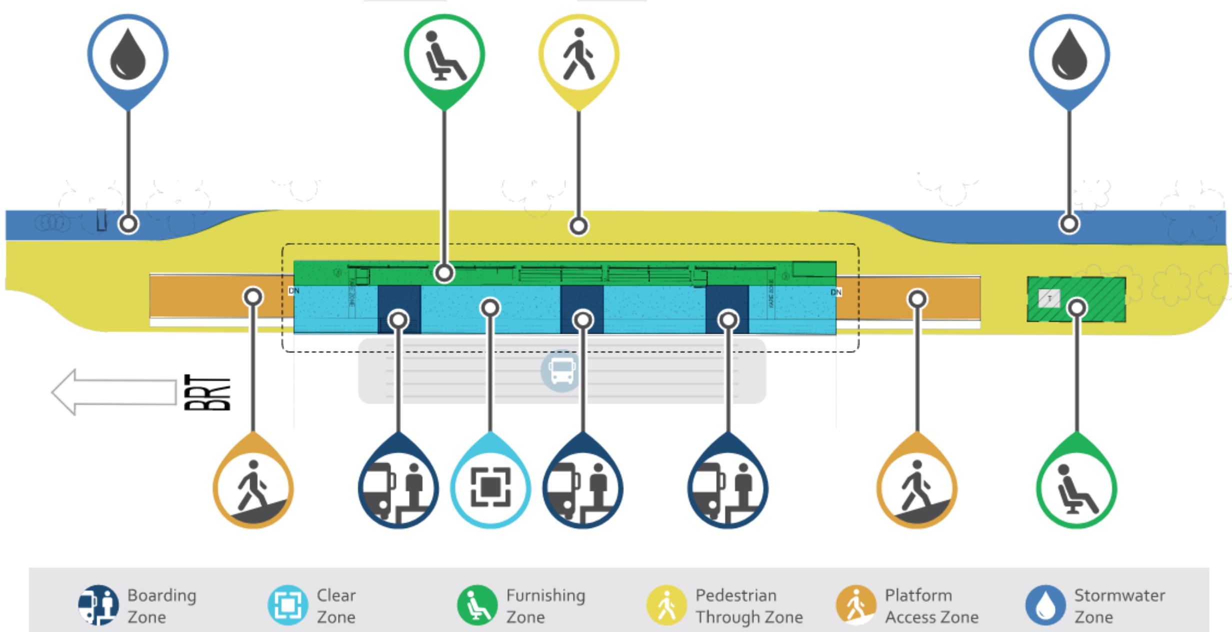


Figure 4.1 Station Zones

FURNISHING ZONE

The furnishing zone at the back of the platform includes permanent furniture items at the station such as seating, vending, and waste disposal. Spanning the length of the platform, riders would use this zone for waiting, vending, and disposing of waste. This zone is generally about 3 feet in depth and does not interfere with other pedestrian zones described below. Additionally, a furnishing zone will be included adjacent to the platform to accommodate bike parking.

CLEAR ZONE

This area describes the defined area where passengers wait to board and alight the bus. This zone should have adequate access from pedestrian sidewalks and trails adjacent to the platform. Detectable warning strips are located within the clear zone along the curbside edge of the platform. Waiting passengers should not enter the detectable warning area unless boarding or alighting the bus. Furniture, landscaping, and other vertical elements should not be placed here.

BOARDING ZONE

To improve consistency in ridership experience, a boarding zone should be explicitly established within the clear zone at each station to indicate to riders where they should enter the bus. The purpose of specifically and visually defining the areas in which riders would board helps to improve rider organization and understanding of the boarding process at each station. Though there would be multiple doors to board on the bus, certain doors should be specified for different ridership experiences. The front door should be the established point for wheelchair boarding and the back door should be the established point for bicyclist boarding. The boarding zone cross slope should not exceed 2% to meet ADA requirements. All doors should be indicated by station markings for operational consistency.

PEDESTRIAN THROUGH ZONE

The pedestrian through zone provides continuous access through the station area. Located behind the station platform, this zone should feature a clearly designated pedestrian access route (PAR) and allow pedestrian traffic to travel uninhibited by the BRT platform and BRT riders. Depending on the station type, there should be several locations in which pedestrians would be able to exit the pedestrian through zone to enter the platform itself.

PLATFORM ACCESS ZONE

The platform access zone describes the ramps on either side of the platform on which pedestrians would enter the station area. The zone contains ADA accessible ramps and railings, allowing for all riders to access the station without obstacle.

STORMWATER ZONE

The stormwater zone indicates the area in which landscaping features are placed to collect runoff from the shelter, platform, and adjacent walkways and assist in drainage infiltration purposes. This area is not meant to be used by riders.

DIMENSIONS

Where permissible within local roadway standards, platforms should be 14 inches above the roadway surface to accommodate level boarding. All platforms must facilitate drainage to the runningway with a minimum one to maximum two percent cross slope. A platform cross slope steeper than two percent is not allowed in any direction except on ramps.

Length is dependent on station typology but ranges from 75 feet in the middle of the route to 140 feet at terminal stations. Most stations are at least 75 feet to accommodate movements of a 60-foot articulated bus. Terminal stations should be 140 feet to accommodate two 60-foot buses with 20 feet of maneuvering space. In specific situations, a 65-foot bus platform may be used when space is extremely limited. Table 4.1 shows design, desired, and constrained dimensioning for stations. Figure 4.2 shows a typical station with dimensions in plan view.

Platform width is also dependent on typology. Widths are typically 10 feet or more, with some stations requiring a minimum 12 feet. Larger widths are more common at stations with greater access to right of way. As with station length, extreme space limitations may allow for a 9-foot width in urban and sub-urban areas.

Table 4.1 Station Dimensioning

Criterion	Design Standard	Desired Standard	Constrained Guideline
Curb height	14”	N/A	Minimum 6”
Platform length	75’ 140’ at terminal stations	N/A.	Minimum 65’ Minimum 130’ at terminal stations
Platform width	12’	10’ minimum.	Minimum 9’ in urban areas

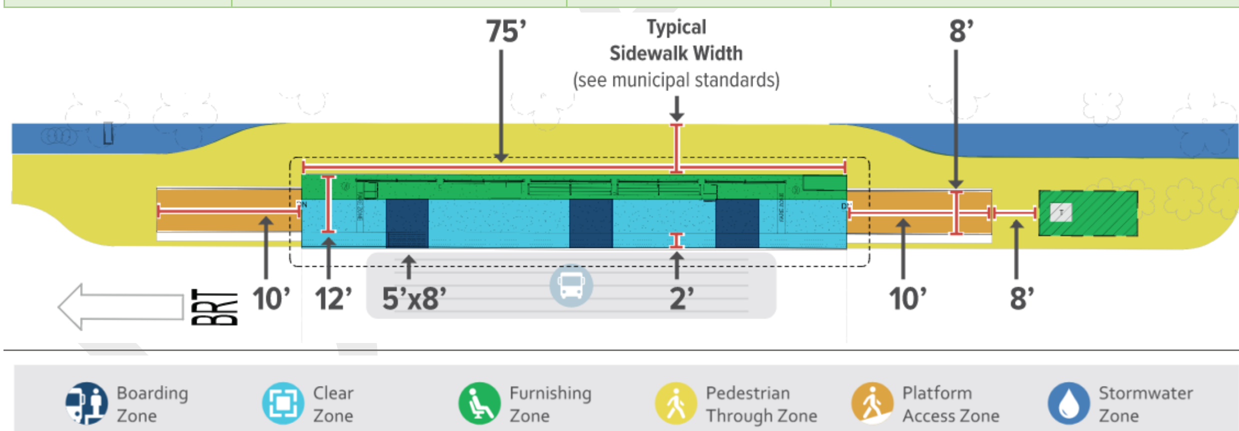


Figure 4.2 Station Dimensioning

RAMPS

All station ramps must adhere to ADA standards. However, each station has more specific dimensions depending on the configuration. Across all types, ramp lengths are typically 10 feet with a 6-foot minimum landing per ADA standards when required, but many stations require longer ramp dimensions for slope criteria. Ramp widths are typically 8 feet including railing foundations with larger widths occurring at stations with available space.

SURFACE AND EDGE TREATMENTS

Surface and edge treatments should be placed along the full length of the platform with varied coloration at boarding zones. All platform surfaces should be non-skid and use durable, weather-resistant materials. The tactile warning plates at the platform edge must be fabricated with high-strength concrete, urethane, or other approved materials. The plate must accept the deployable ramp of a BRT vehicle if it is used and be sufficiently textured to be detected by users with visual impairments without impeding passage for wheelchairs. Tactile warning plates must be compliant with ADA requirements, which currently stipulate a width of 24 inches from the clear zone on tangent or curved platforms. A potential example of a tactile surface used on a station is shown below in Figure 4.3.

Figure 4.3 Tactile Warning Plate Example[18]

STATION TYPOLOGIES

Typologies have been developed by the City of Raleigh with references to both land use contexts and station orientations. Land use context, discussed in Section 2: Existing Conditions, impact the typology choice by providing the setting for the station chosen. High density uses tend to have station typologies that are designed for more compact spaces or higher pedestrian counts. Low density uses typically are prescribed station types that allow for pull-outs or don't have as much pedestrian space. Each typology has different configurations, dimensional specifications, amenities, and uses, among other criteria. Table 4.2 shows a detailed description of the typologies.

[18] Tactile Warning Image: http://www.whsupply.com/products/ada-tactile-systems

Table 4.2 Station Typologies

	Urban Core	Sub-Urban/Intermodal	Peripheral	Split Island	Shared Island
Configuration	Curbside (in-lane or pull-out)	Curbside (in-lane or pull-out)	Curbside (pull-out)	Median island (in-lane)	Median island (in-lane)
Platform length	75' typical, *65' minimum*	75' typical, *65' minimum*	75' typical, *65' minimum*	75’ typical, *65' minimum*	75’ typical, *65' minimum*
Platform width	10' preferred, *9' minimum*	10' preferred, *9' minimum*	*12' minimum*	*10' minimum*	*12' minimum*
Level Boarding (14”)	Yes	Yes	No	Yes	Yes
Boarding type	Right side typical	Right side typical	Right side typical	Right side typical	Left side typical; right side optional
Accessed via	Sidewalk (2 end ramps), rear mid-platform access	Sidewalk (2 end ramps), Intermodal: + rear mid-platform access	Sidewalk (through platform)	Crosswalk (1 ramp)	Crosswalk (1 ramp)
Ramp length	10' typical + 6' landing	10' typical + 6' landing	N/A	14' typical + 6' landing	14' typical + 8' landing
Ramp width	6' preferred, *5' minimum*	6' preferred, *5' minimum*	N/A	*6' minimum*	8' preferred, *6' minimum*
Rear edge condition	Open, accessible	Suburban: privacy screened Intermodal: open, accessible	Open, accessible	Protected edge	N/A, boarding both sides

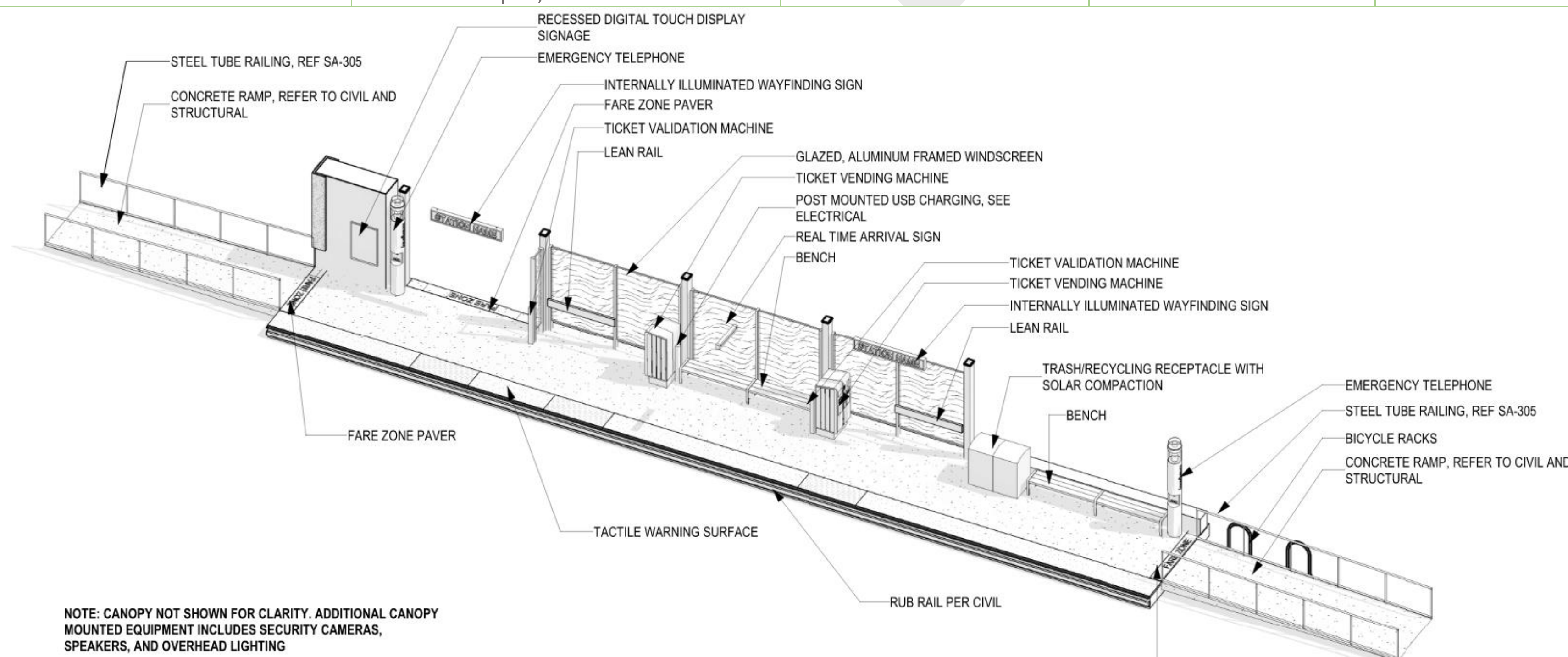


Figure 4.5 Station Amenities Layout

DESIGN KIT OF PARTS

Each transit station should contain a design kit of parts of repeatable elements, components, and materials. These elements are placed at every station for both utility and consistency. Providing amenities and other useful features helps improve the rider experience of BRT. Additionally, whenever possible, it is crucial for a transit agency to provide a consistent rider experience across all stations with the focus of equity. Below is a list of station elements included in the design kit of parts:

- Fare Kiosk
- Ticket Validator
- Paid Fare Zone
- Bench Seating
- Lean Rail
- Trash/Recycling Receptacle
- Emergency Phone
- Interactive Route Map
- Local Information/Wayfinding
- Community Messaging
- Real-Time Information
- Closed-circuit television cameras
- Annunciators
- USB Charging Ports
- Bike Racks
- Step Up Platform Access

Station elements in the design kit of parts are shown separately in Figure 4.6, and in a generic station context in Figure 4.5 previously.

Figure 4.6 Design Kit of Parts

CUSTOMIZABLE ELEMENTS

Providing consistent BRT elements at all stations is important. However, some elements do not need to be identical, and they can be customized to accommodate locations of greatest use, need, or space.

Specific examples include the use of step-up platform access at urban and intermodal stations as well as bike parking at intermodal stations adjacent to multi-use paths. Other examples include community artwork, landscaping, and additional station seating. Placemaking goals and initiatives would rely heavily on these customizable elements to make the area unique and prominent.

Customizable elements that exceed standard expenses are not eligible for federal funding and may require additional local funds or resources for installation and maintenance. If a customizable element is requested by an area stakeholder, the installation and maintenance must be agreed upon by the transit design team, the City of Raleigh, and area stakeholders.

5. ROADWAY

BRT corridors would primarily be constructed on existing roadways in Wake County and should conform to NCDOT and local street and transit standards as applicable; roadway design should follow the required standards of the governing roadway authority. Special attention should be given to providing convenient and safe at-grade accommodations for transit customers crossing roadways on foot, in mobility devices, or on bicycles.

RUNNINGWAY TYPES

BRT vehicles would operate in the roadway via three major runningway types: business access and transit (BAT) lanes, transitway, and mixed traffic lanes. The runningway types determine the need for roadway improvements, pavement markings, platform configuration, and other criteria. Careful consideration should be made for how buses would enter and exit bus-only roadways to allow clear delineation for bus traffic and general traffic.

Whenever possible and reasonable, separation should be added between BRT and general-purpose lanes. Median islands are a preferred method for separation, but pavement markings are also a reasonable alternative. At median stations, protection should be considered for both adjacent travel lanes and pedestrians.

BUSINESS ACCESS AND TRANSIT LANE

BAT lane operation would primarily consist of a bus and right-turning vehicle exclusive lane located on the outermost lane in both directions without physical separation. The BAT lane should be indicated by pavement lettering and signage. Figures 5.1 and 5.2 show a one-way and two-way BAT lane runningway typical section, respectively.

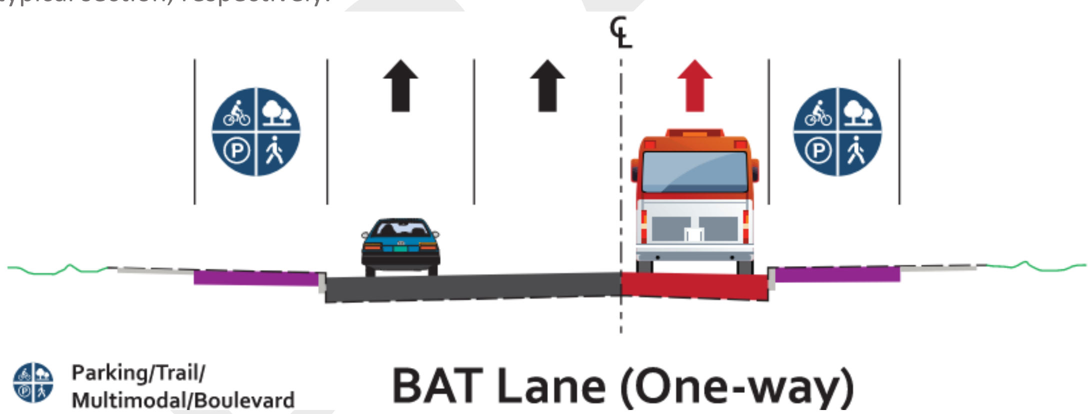


Figure 5.1 BAT One-Way Lane Typical Section

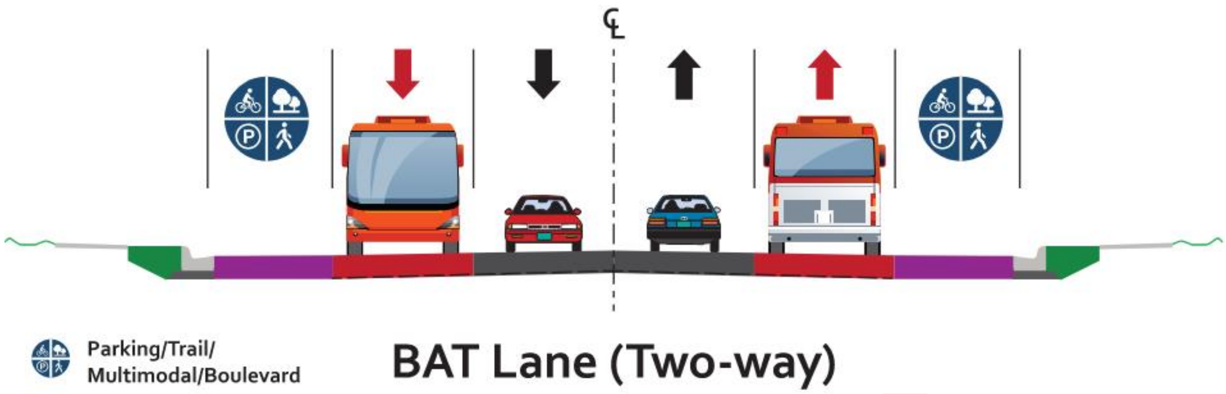


Figure 5.2 BAT Lane Two-Way Typical Section

TRANSITWAY

In a transitway, lanes should be physically separated from the general purpose traffic lanes by medians or platforms. Bus traffic in opposing directions would run in adjacent lanes. All other vehicle travel except for emergency vehicles should be prohibited in these lanes. The BRT lane should be indicated by overhead signage, pavement lettering, and red pavement marking spanning the entire transitway lane for a determined length adjacent to transitway intersections. Figure 5.3 shows a general transitway typical section.

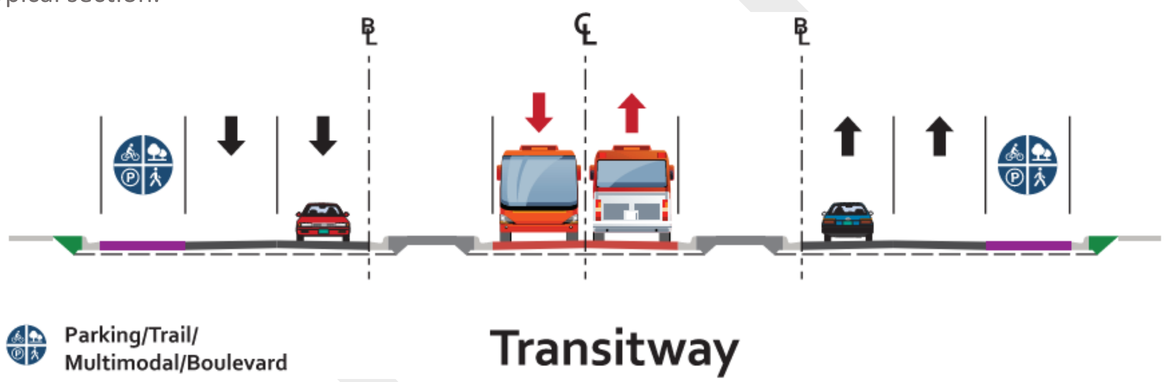


Figure 5.3 Transitway Typical Section

MIXED TRAFFIC

In some corridors, BRT vehicles would operate in mixed traffic segments. No reconstruction would occur on the roadway itself and buses should use existing travel lanes mixed with normal traffic. Figure 5.4 shows a mixed traffic typical section.

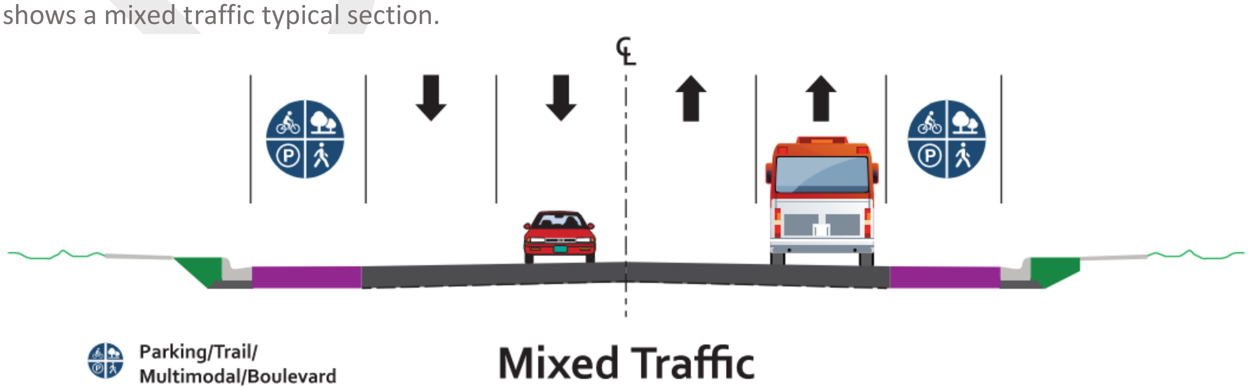


Figure 5.4 Mixed Traffic Typical Section

POSTED SPEED LIMITS

Roadway posted speed limits are a significant factor related to BRT platform design. Most roadways where BRT would operate have posted speeds of 35 to 45 miles per hour (mph). The posted speed limit impacts and informs platform design development with particular attention to NCDOT clear zone standards. If clear zone standards cannot be met, coordination is needed with NCDOT to achieve a safe an accessible platform design. Table 5.1 shows BRT platform clear zone requirements.

Table 5.1 Clear Zone Requirements

Posted Speed Limits	Platform Clear Zone Width	Total Clear Zone Width
35 mph or less	8'	14' (BAT lane designated as clear zone)
45 mph or greater	12'	20' (NCDOT memo allows approved structures 12' from face of curb)

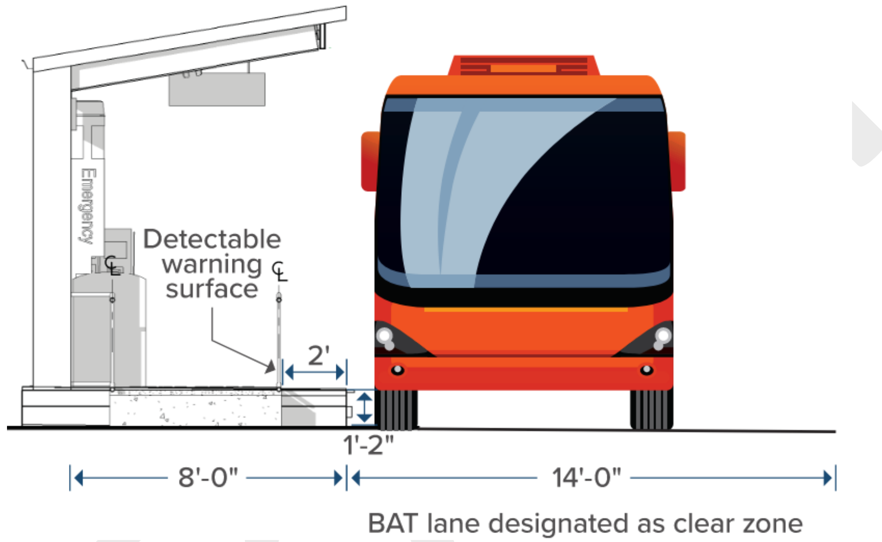


Figure 5.5 Typical Urban/Sub-Urban/Intermodal/Split Island/Shared Island Platform

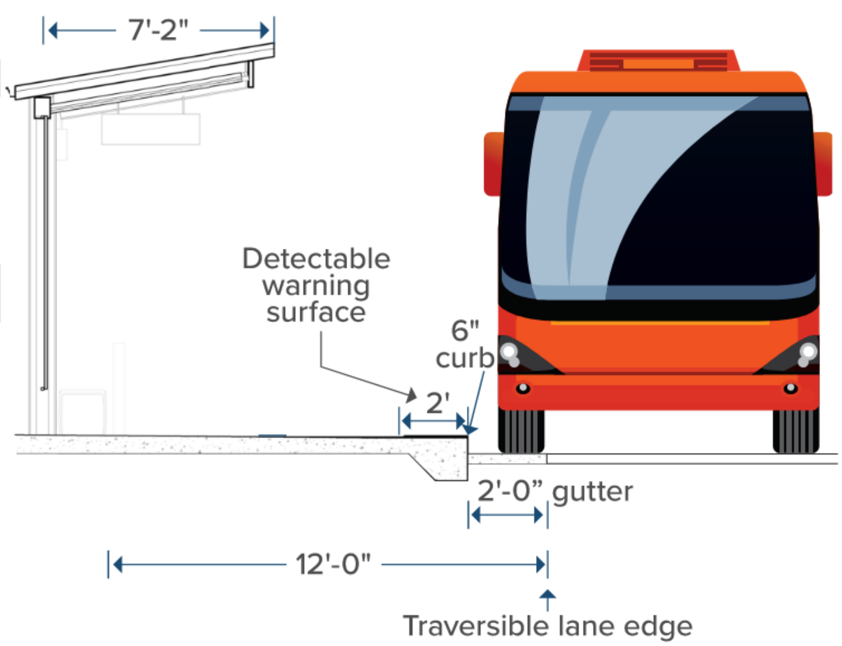


Figure 5.6 Typical Peripheral Platform

DESIGN CRITERIA

As stated previously, design criteria should adhere to the standards of the governing roadway entity. In most cases, NCDOT guidance directs design, so state standards should be used. Otherwise, coordination with municipalities is necessary to develop standards. Design criteria include lane width, horizontal and vertical clearance, cross slope, clear zone, and other factors. In many cases, BRT design should include roadway modifications to accommodate stations and BAT lanes, among other changes.

Lane widths may vary from 11' to 12'. Auto turn software should be used to verify adequate space when analyzing turning movements and platform locations with the proper design vehicle. In addition, ADA requirements should be considered when determining longitudinal grade of the roadway at platform locations.

QUEUE JUMPS

Queue jump lanes combine short**,** dedicated transit facilities with a leading bus interval or TSP. This allows buses to easily enter traffic flow in a priority position. Applied thoughtfully, queue jump treatments can reduce delay considerably, resulting in travel time savings and increased reliability. A bus head-start can significantly improve bus performance by routing vehicles through congested intersections ahead of traffic. An example of a queue jump is shown below in Figure 5.7.

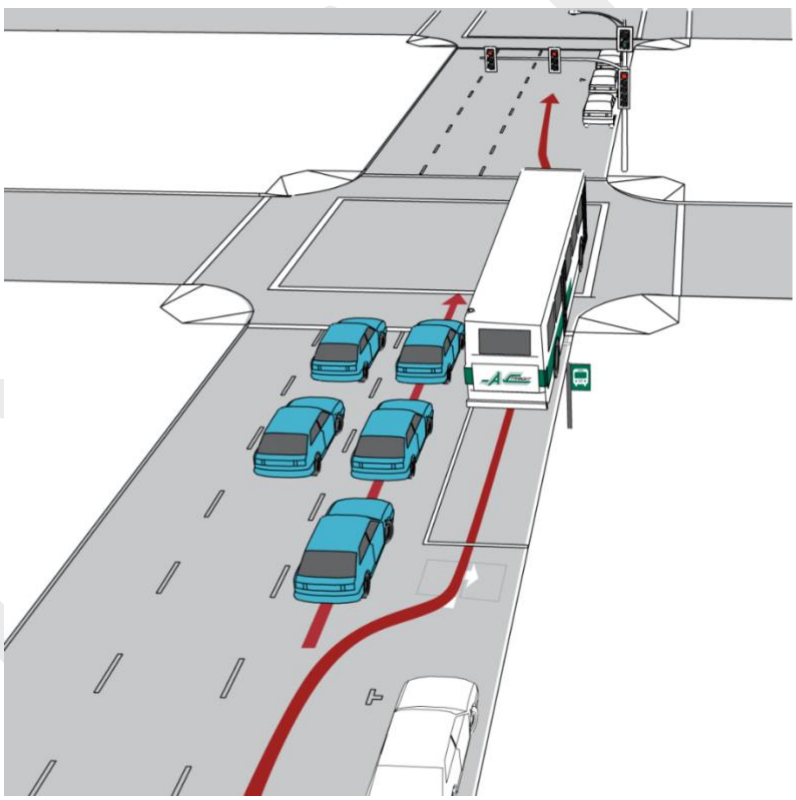


Figure 5.7 Queue Jump[19]

[19] Queue Jump Graphic: https://www.actransit.org/?attachment_id=38165

Queue jumps should be applied on signalized streets with low or moderately frequent bus routes, especially where transit operates in a right lane with high peak hour volumes but relatively low right turns. In some locations, implementing restrictions may be necessary.

Specialized transit-only signals are triggered by approaching BRT vehicles equipped with TSP in queue jump lanes that allow buses to pass through the intersection without additional signal delay.

Queue jumps can be applied at near-side, far-side, or non-stop configurations. At near-side stops, the bus completes loading before rolling forward onto a loop detector that gives priority. At far-side or non-stop locations, the bus receives priority signal treatment and proceeds either into a far-side stop or ahead of the traffic flow.

Before implementation, coordination with appropriate roadway authorities should take place to ensure consistency with existing roadway and traffic standards.

RIGHT-OF-WAY REQUIREMENTS

In many cases, to accommodate stations and other station area elements, additional right-of-way may be needed along the corridor. There are several types of right-of-way acquisition, but in the most basic sense, the process results in either permanent or temporary usage of the land.

PERMANENT ACQUISITION

Right-of-way that would be continuously used in both the construction and operation of the BRT should be permanently acquired. This land is purchased at fair market value price by a governing public entity. Due to the permanency of the acquisition, the land can later be used by the agency for other purposes, such as station rehabilitation or additions, or transit-oriented development (TOD). Reducing the amount of land needed for BRT operation is beneficial for lowering project costs and delays. Due to the high public profile of typical BRT projects, property acquisition through eminent domain should only be used judiciously.

TEMPORARY CONSTRUCTION EASEMENTS (TCE)

Alternatively, land can be temporarily used for specific purposes of construction along a BRT corridor. Easements provide more space for staging and equipment needed for safe construction. Unlike permanent acquisition, this land cannot be permanently altered and must return to its original state once construction has finished. However, because it is a temporary transaction, this is cheaper than permanent acquisition.

Figure 5.8 BRT Station Construction[20]

MULTIMODAL CONNECTIVITY

One priority of transit service is to provide access for as many riders as possible. To support this, stations should be designed to be accessed via several modes of transportation, such as walking, biking, and local bus service; stations must have adequate multimodal access points and connections to nearby multimodal facilities. Components such as bike parking and multiple station entrances are crucial for promoting a greater range of multimodal connectivity. Where possible, stations should be designed to accommodate other micro-mobility travel modes including electric scooters and on-call transportation services. Intermodal stations are designed to promote multimodal connectivity, with a typical intermodal station shown below in Figure 5.9.

Figure 5.9 Intermodal Station

[20] BRT Station Construction Image: https://www.sfexaminer.com/news/van-ness-brt-construction-impact-set-to-increase/

Access to adjacent multi-use paths should be incorporated in BRT system designs. To increase usage and access by pedestrians and bikers, these paths would connect stations to important routes and features, as well as provide greater access for different modes throughout the corridor. Paths would include combined space for bikes and pedestrians on a wide trail separated from the roadway.

While dedicated bike lanes are preferred, in certain conditions, bicycles and buses may share lanes. These dedicated lanes, called shared bus and bike lanes, are primarily used in locations where separated bike and bus traffic is not feasible or reasonable but have high bicycle traffic. Shared bus and bike lanes offer a compromise between having the refuge of a separated bicycle space and on-street biking. General traffic cannot use shared bus and bike lanes, so bus and bicycle traffic volumes must be considered when analyzing their potential usage. An example of a shared bus and bike lane is shown in Figure 5.10.

Figure 5.10 Shared Bus and Bike Lane[21]

[21] Shared Bus and Bike Lane Image: https://nacto.org/publication/transit-street-design-guide/transit-lanes-transitways/transit-lanes/shared-bus-bike-lane

6. TECHNOLOGY

BRT operations rely on a wide variety of technology. Some of the technology is essential to the functionality of the system, while other applications are amenities intended to improve rider experience. All elements of technology are part of a wider network, which requires standardization to ensure compatibility with other aspects of the system. Standardization also ensures equity between different stations and routes. Device uniformity also increases ease of use and wayfinding by using systems riders already have familiarity with.

COMMUNICATIONS INFRASTRUCTURE

Technology implemented as part of a BRT system requires a robust communications infrastructure capable of transmitting large amounts of information over high speeds and distances. Fiber optic cable would meet these needs and provide opportunities for future expansion. Fiber optic trunkline should be installed along BRT routes. Branch fiber should then connect the trunkline to signal cabinets or communications cabinets, where the fiber would be terminated.

Communications cabinets should be installed at each station next to an electric cabinet. Due to the large size of the cabinet and limited space on the platform, cabinets should be installed off the platform. Cabinets should be placed with enough clearance that the doors can open fully and do not disrupt activity in the surrounding area. Visual screening and/or artistic/branding treatments of the cabinets should be used to minimize aesthetic impacts.

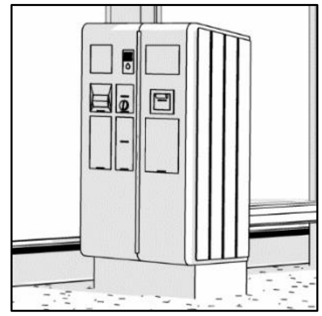
Devices on the network should also be monitored for malfunctions and outages. A centralized hub where all technology is monitored combined with clearly defined responsibilities and procedures reduces confusion and down time. Additionally, a compatible monitoring system should issue real-time reports whenever a device malfunctions so repairs and maintenance can be conducted as needed.

STATION TECHNOLOGY COMPONENTS

BRT stations should have the following amenities:

- Ticket Vending and Fare Validation Machines
- Emergency Telephones
- Closed-Circuit Television Cameras
- Real-Time Information
- Touch Screen Kiosks with Wi-Fi
- USB Charging Stations
- Smart Trash/Recycling Receptacles
- Public Address
- Flashing Beacons

TICKET VENDING MACHINES

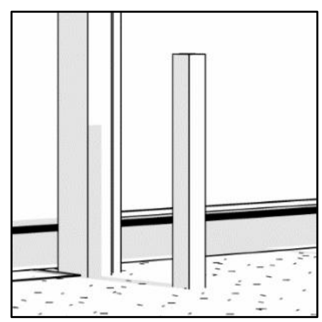


To speed up boarding times, fare vending and validation should occur at the station platform rather than on board vehicles. Two ticket vending machines (TVMs) and two fare validators should be present at each BRT station except where ridership projections or space constraints may limit TVMs and validators to one. Fare validation should take place at a separate location than the fare vending to minimize wait times and crowding. The location of ticket vending machines and fare validators is shown outlined in orange below. TVMs and fare validators should be equipped with cameras facing the transaction area and shall be placed in visible areas of the platform and oriented to minimize impacts to station circulation.

All fare vending and validation equipment should be compatible with existing regional transit fare technology and infrastructure. TVMs with closed-circuit television cameras installed in the machine should be managed and standardized as the monitored cameras below. Purchasing fares at TVMs should match processes used in existing fare vending. Fares purchased at BRT stations should be accepted at other transit locations and vice versa. TVMs should meet regional and BRT branding and design standards and ADA requirements.

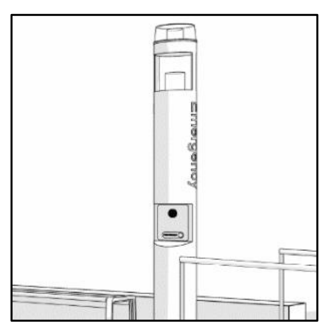
TVMs should sell paper tickets with magnetic strips as well as radio-frequency identification (RFID) smart cards compatible with fare validators at stations and on vehicles. Riders with existing RFID smart cards would be able to check the balance and add funds to their cards at TVMs. In addition to single ride fares, all fare types, such as duration-based passes, should be sold at TVMs. Fare discounts, such as those for youth or seniors, should also be available at TVMs. Ticket vending machines would accept payment in the form of cash, debit, or credit cards.

FARE VALIDATION



Fare validation machines should be compatible with existing regional transit technology, such as those on-board vehicles. Fare validators would be capable of reading magnetic strip cards and RFID smart cards used as fare for BRT or local buses. After reading the fare, the validator would indicate if the transaction was successful or not with audio and visual cues. These cues should match indicators on existing local fare validation systems. Design and branding of fare validators should conform to regional, BRT, and ADA requirements and standards.

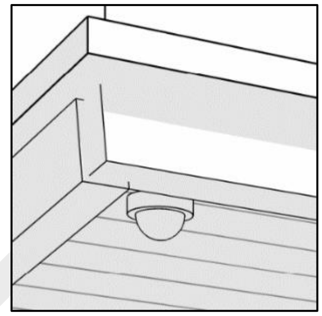
EMERGENCY TELEPHONES



To increase safety at platforms and the surrounding areas, emergency telephones should be installed at each BRT station. Areas around the emergency telephone should be clear of obstacles and other devices so they can be accessed quickly.

The emergency telephones should be labeled clearly and distinctly to avoid accidental use. Using the telephones should be simple, such as a single button press. Emergency telephones should meet ADA requirements.

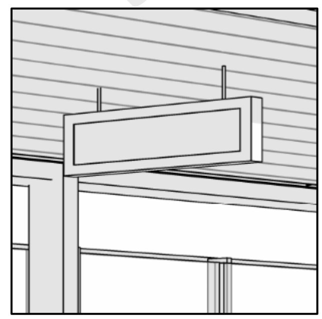
Calls from emergency telephones would be sent to a designated operator facility that can route calls to appropriate safety personnel. All calls should be recorded and kept for an established retention period.



CLOSED-CIRCUIT TELEVISION (CCTV) CAMERAS

For safety and security, two CCTV cameras should be installed into the shelter ceiling at each station. The placement of the CCTV cameras should provide full 24/7 coverage of the platform. Specifically, areas to be covered include the TVMs and any areas prone to falls, such as rear stair access to the platforms and along the front of the platform curb. Station lighting and CCTV placement should be coordinated for night coverage. CCTVs should be compatible with existing local CCTV infrastructure.

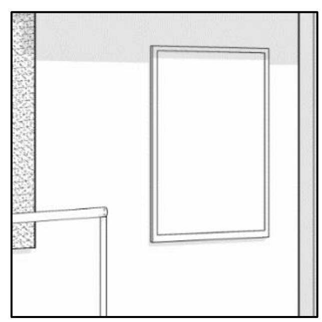
CCTV footage should be available for live monitoring and as recorded footage. Recorded footage should be stored at a centralized control center for 30 days before deletion. All footage should be tagged with date, time, and location information. Live footage would also be immediately available for the operators of the emergency telephones.



REAL-TIME INFORMATION

Real-time information signs provide estimated arrival time of buses based on dynamic vehicle location. Other Real-time information signs should display upcoming bus routes along with the estimated arrival time via a Variable Message Sign. Typical sign placement within the platform is shown in Section 4: Station Facilities.

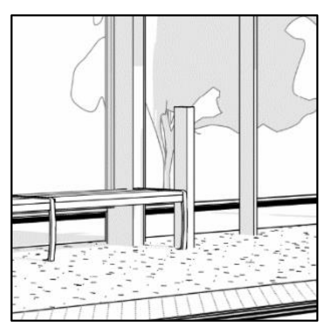
Accessible push buttons located near the real time display should prompt an announcement via speaker of the information displayed on the real-time signs. The push buttons and signage should conform to ADA standards.



TOUCH SCREEN KIOSK WITH WIFI

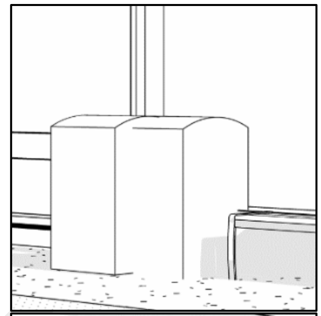
Interactive touch screens provide tools and information such as wayfinding and local events to users. These screens are separate from real-time signs, which only provide arrival times of buses; however, if desired, these screens can also be formatted to provide the same real-time data in addition to other information. These signs should be located away from fare vending, fare validation, and boarding zones so as not to interfere with normal operations. Signs should match regional and BRT branding as well as ADA requirements.

Touch screens should come equipped with a modem to provide free Wi-Fi for those waiting at the station. The Wi-Fi should be coordinated with the service provided aboard the buses to avoid the need for users to re-authenticate their connection when boarding.



USB CHARGING STATION

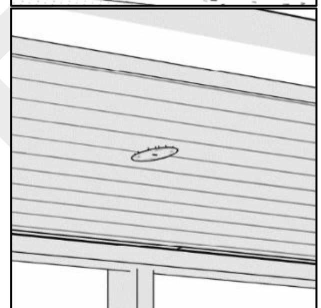
Power outlets with USB charging ports should be included at stations for riders to charge their phones or other devices.



TRASH AND RECYCLING RECEPTACLES

Each transit station should be equipped with trash and recycling receptacles to keep the surrounding areas clean and pest-free. The receptacles should automatically compact waste to prevent overflow and lower the frequency of waste collection. Smart receptacles should be used to track usage and capacity to improve collection efficiency and could be solar powered.

All waste receptacles should be clearly labelled as either trash or recycling. Any design features should match regional branding and design standards.



PUBLIC ADDRESS

Public address speakers should be installed in the canopy of each station shelter. Pre-recorded voice messages should convey real-time bus arrival information at regular intervals. Speakers may also be used for other information, such as changes to routes, safety reminders, or service alerts.

FLASHING BEACONS

Flashing beacons are placed at stations and illuminate when a vehicle is arriving or approaching the stop. Beacons should work in tandem with real-time signs and annunciators so that arrival information is consistent for passengers. Flashing beacons should follow regional design standards and branding.[22]

[22] Flashing Beacon Example: https://www.metrotransit.org/c-line-steps-closer-to-rapid-bus-reality

TRANSIT SIGNAL PRIORITY (TSP)

TSP reduces wait time for transit vehicles by changing signal behavior. TSP can be used to extend, truncate, or reallocate the green signal phase as well as truncate the red signal phase. TSP can be given conditional or unconditional priority throughout a corridor. Conditional priority applies TSP only if the transit vehicle is delayed by a certain, defined amount of time. Unconditional priority occurs when the transit vehicle signal is given priority 100 percent of the time, reducing transit vehicle delays, but may adversely impact cross traffic by increasing the amount of time those signals receive a red light. Signal behavior may be managed at a centralized hub, or independently at each intersection.

The priority control system shall consist of vehicle equipment, intersection equipment and a Central Management Software (CMS). The software should allow authorized local and remote users to set and read all user-programmable features and retrieve data collected by the system.

The in-vehicle equipment shall operate without requiring any action from the vehicle operator or occupants once power is applied. The system shall be intersection-centric, where configuration of system operation parameters shall be completed on the intersection equipment and not require interaction with the vehicle equipment.

Signal controllers equipped with TSP technology should be implemented at each signalized intersection along the BRT corridor where feasible, including at existing signals. The controllers should be equipped with both priority and preemption capabilities, even if those TSP methods are not planned for use at the intersection at that time. Signal timing, including conditional TSP requests, is controlled and operated by the governing roadway jurisdiction. Specific TSP equipment ownership and maintenance responsibilities are agreed upon with each individual road authority.

Figure 6.1 Traffic Signal[23]

[23] Traffic Signal Image: https://www.bizjournals.com/triangle/news/2020/12/23/bus-rapid-transit-raleigh-wake-county-usdot-funds.html

7. BRT FLEET/VEHICLES

VEHICLES

The BRT fleet should be comprised of 60-foot articulated buses with five total doors: three on the right and two on the left. Doors on both sides are provided to increase loading and unloading flexibility, increasing potential for a variety of bus stop configurations. BRT vehicles should not include fare collection equipment on-board, as BRT fare collection would occur off-board. Loading and unloading could occur at stops on either side of the bus, allowing for center platforms. BRT vehicles will include deployable ADA ramps at the frontmost door of either side of the vehicle (Figure 7.1) and kneeling capabilities to achieve ADA-accessible boarding.

Figure 7.1 Deployable Ramp[24]

In addition to the standard 60-foot articulated bus, 40-foot buses may be added to the fleet. Current GoRaleigh bus fleet utilizes compressed natural gas (CNG) for propulsion. Additional CNG buses are planned for procurement on the New Bern Corridor. However, consideration for additional propulsion types, including electric and diesel, should allow for increased flexibility in fleet operations. In addition to bus specifications, necessary maintenance, storage, and operations modifications would need to be made at garage facilities and along the corridor to support the chosen fuel type.

AVL/CAD TECHNOLOGY

Automated Vehicle Location / Computer-Aided Dispatch (AVL/CAD) technology should be used on buses. AVL/CAD software is a widely implemented vehicle feature that connects riders and transit providers to GPS locations and data of vehicles in a transit system. This helps passengers with planning when there are delays, gives operators more information on where unexpected slowdowns occur most frequently and helps operators coordinate changes in real time.

STORAGE AND AMENITIES

Riders who use bicycles to access the BRT should have interior storage of their bikes available. To avoid users stepping off station platforms in non-designated locations, bike racks at the front of the bus would not be available.

[24] Bus Without On-Board Validators Example: https://www.goldcoasttransit.org/how-to-ride/specialized-guides/accessibility

Figure 7.2 On-Board Bike Storage[25]

To improve experience for riders, several amenities should be included on BRT vehicles. Wi-Fi, USB charging ports, and wheelchair securement should be available on all buses.

Passengers using wheelchairs should use self-securing technology on buses which uses a rear-facing device that allows riders to secure themselves with a button. This feature increases passenger independence while alleviating the need for transit operators to assist, which speeds up efficiency and decreases loading time. This improvement from typical wheelchair securing procedures would improve accessibility, equity, and operating efficiency.

Figure 7.3 Wheelchair Securement Technology[26]

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[25] On-Board Bike Storage Image: https://www.bordersbuses.co.uk/bike-friendly-buses

[26] Wheelchair Securement Image: https://www.qstraint.com/quantum

EMERGING TECHNOLOGIES

As vehicle technologies continue to evolve, GoRaleigh should consider incorporating advanced technologies in future bus procurements. Such technologies include:

- Lane detection systems
- Smooth acceleration and braking systems
- Collision avoidance systems

Additionally, it is widely expected that precision docking technology will continue to develop and would at some point be widely used. In several cities across the country, automated and connected vehicles (AV/CV) are being demonstrated in revenue service. AV/CV technology will continue to evolve and find new markets. Finally, although they are not yet widespread, battery electric bus use is increasing. As battery technology evolves and the range between charges increases, it is anticipated that battery electric bus technology will become an increasingly-used propulsion system.

Many technologies are not yet widely used in the transit industry, and as such they will not be discussed in detail. However, standards documents are living documents and are frequently updated as circumstances warrant. Future versions of this document would discuss these technologies as they become more prevalent in the transit industry.

8. IDENTITY AND BRANDING

- [Informed by identity/branding workshop]
- Fleet branding
- Station branding
- Real-time information format
- Wayfinding
- Public art

9. SERVICE OPERATIONS

DEFINITIONS

The following definitions are drawn from the Wake County Transit Plan Major Investment Study - BRT Design Standards and Performance Measures document[27] and are used to inform and guide the development of Wake BRT: System Standards related to bus service and operations.

- BRT service is bus service that operates within the BRT infrastructure and is branded as BRT service. While branded vehicles may operate outside of the BRT infrastructure, the standards and targets set in this document do not apply outside of the infrastructure.
- A standard sets the minimum investment required to achieve the desired characteristics of BRT.
- A measure is a reference point against which performance is evaluated. Measures are evaluated against a target.
- A target is the defined value set for individual measures. For example, the target for productivity is 25 passengers per revenue hour.

This section focuses primarily on operations standards for BRT service and is intended to communicate the customer-facing characteristics of BRT routes. Measures and targets would be primarily internally focused and should be the subject of a separate System Policies memorandum.

SPAN OF SERVICE

Span of service denotes the minimum hours of operation for a BRT during a typical weekday, Saturday, or Sunday. The span of service includes a definition of the portions of the day defined as the morning and afternoon peaks when frequency on BRT services may be higher to accommodate demand. Span of service for a particular BRT route may be extended beyond the minimum standard based on the transit agency's ridership and productivity guidelines.

Proposed minimum standards for span of service on BRT routes are shown in Table 9.1.[28]

Table 9.1. Span of Service

Span of Service	Weekdays	Saturdays	Sundays
Total span of service[29]	5 AM – 12 AM	6 AM – 12 AM	7 AM – 12 AM
AM/PM peak	6 AM – 9 AM; 3 PM – 6 PM	N/A	N/A

[27] Wake County Transit Plan Major Investment Study - BRT Design Standards and Performance Measures document. Accessed February 2020 from http://goforwardnc.org/wp-content/uploads/2018/11/Wake-MIS-BRT-Design-Standards-Performance-Measures-FINAL.pdf.

[28] Note: FTA guidelines for a BRT project to qualify for New Starts funding state that the project "must provide short headway, bidirectional service for at least a fourteen-hour span of service on weekdays and a ten-hour span of service on weekends." FTA will consider projects that provide weekday-only service for Small Starts, including the same requirement for a minimum span of service of 14 hours for the weekdays.
Source: APTA Recommended Practice: Bus Rapid Transit Service Design. Accessed February 2020 from https://www.apta.com/wp-content/uploads/Standards_Documents/APTA-BTS-BRT-RP-004-10.pdf.

[29] Total span of service is as defined in the Wake County Transit Plan Major Investment Study - BRT Design Standards and Performance Measures document. Accessed February 2020 from http://goforwardnc.org/wp-content/uploads/2018/11/Wake-MIS-BRT-Design-Standards-Performance-Measures-FINAL.pdf.

SERVICE FREQUENCY

Service frequency describes the minimum number of trips per hour operated by a BRT. Frequency can also be expressed as a headway, or the average time between trips during a given period. Service frequencies often differ by time of day, as well as the service day (weekday/Saturday/Sunday).

Proposed minimum standards for service frequency on BRT are shown in Table 9.2.

Table 9.2. Service Frequency

Service Frequency	AM/PM Peak	Midday/Evening	Early/Night/Sat/Sun
BRT service[30]	4 trips per hour (15-minute headway)	4 trips per hour (15-minute headway)	3 trips per hour (20-minute headway)

CAPACITY AND LOADING

Capacity refers to the total number of passengers that can be accommodated on a single BRT vehicle. Seated capacity indicates the number of passenger seats available on a single BRT vehicle; total capacity indicates the maximum number passengers that can be accommodated (including seated passengers and standees).

Vehicle load refers to the percentage of a vehicle's seated capacity that is used on any given trip. Loading standards are based on the maximum acceptable average load across a given time period. The maximum acceptable average load may differ between peak and off-peak periods, as shown in Table 9.3.

Table 9.3 Vehicle Loading Standards

Vehicle Loading Standard	Peak	Off-Peak
Maximum acceptable average load (BRT service) [31]	120% of seated capacity	100% of seated capacity

LOCAL SERVICE

An important factor in designing BRT projects is determining whether the BRT service would operate as a stand-alone route, or whether BRT stations and guideway features would be shared by underlying or connecting local bus routes. Wider station spacing offers the opportunity to deliver faster trips for BRT buses, with the trade-off of necessitating the provision of local bus service for customers who may not be able to walk to BRT stations. Underlying local service will be analyzed once BRT route and service begins along each corridor.

[30] BRT service frequency is as defined in the Wake County Transit Plan Major Investment Study - BRT Design Standards and Performance Measures document. Accessed February 2020 from http://goforwardnc.org/wp-content/uploads/2018/11/Wake-MIS-BRT-Design-Standards-Performance-Measures-FINAL.pdf.

[31] BRT loading standards are as defined in the Wake County Transit Plan Major Investment Study - BRT Design Standards and Performance Measures document. Accessed February 2020 from http://goforwardnc.org/wp-content/uploads/2018/11/Wake-MIS-BRT-Design-Standards-Performance-Measures-FINAL.pdf.

Figure 9.1 GoRaleigh Bus[32]

CONNECTIONS AND TRANSFERS

When BRT service is implemented, the service plan should assess opportunities for improved connections with other local routes outside the corridor. Where possible, nearby routes could be extended to connect at major BRT stations, offering customers a convenient transfer to the BRT network. At the same time, routes that substantially duplicate BRT service or that operate in nearby parallel corridors could receive reduced service levels, as the BRT service would be expected to attract many riders. These service planning decisions should be made based on a detailed understanding of the ridership and operating context of each BRT corridor.

[32] GoRaleigh Bus Image: https://goraleigh.org/goraleigh-fares-passes

10. GREEN STORMWATER AND INFRASTRUCTURE

INTRODUCTION

PURPOSE

If the facilities of a roadway are not appropriately planned and designed to accommodate water runoff during storm events, then the safety and mobility of a street can be compromised for all users, especially non-motorized users who often times have to travel in close proximity to the water runoff. Puddles or streams can impede walking, biking, and wheelchair access to non-motorized roadway users, especially to users accessing transit facilities.

In an effort to prevent the loss of safety and mobility opportunities for transit users during storm events, the purpose of this report is to review national best practices for Green Stormwater Infrastructure (GSI) in transit station and bus stop design and identify how those practices can be incorporated into the design of the Wake BRT program.

BACKGROUND

Section 502 of the Clean Water Act defines green infrastructure as "...the range of measures that use plant or soil systems, permeable pavement or other permeable surfaces or substrates, stormwater harvest and reuse, or landscaping to store, infiltrate, or evapotranspirate stormwater and reduce flows to sewer systems or to surface waters." More specifically, Green Stormwater Infrastructure is specifically designed to address water runoff from storm events.

In contrast to single purpose "gray stormwater infrastructure" (conventional piped drainage and water treatment systems), Green Stormwater Infrastructure reduces and treats stormwater at its source and provides additional economic, social, and environmental benefits for all roadway users.

GSI BEST PRACTICES ADJACENT TO TRANSIT FACILITIES

Green Stormwater Infrastructure components should be incorporated into transit facility design when adequate space is available to address stormwater concerns. Some of those components include:

- Boarding bulbs and islands (opens up curb space for adjacent GSI features)
- Bioswales
- Pervious Strips
- Green features on transit facility roofs
- Pervious pavements at key locations
- Tree trenches

BOARDING BULBS AND ISLANDS

Bus bulbs are curb extensions that align the bus stop with the parking lane, allowing buses to stop and board passengers without leaving the travel lane. Bus bulbs help buses move faster and more reliably by decreasing the amount of time lost when merging in and out of traffic.

New curb space created using bus bulbs can be re-purposed to provide green streetscape improvements such as bioswales or planters to improve streetscape and stormwater recapture.

Key Features:

- The curb extension must be long enough to accommodate passengers boarding and alighting by the front and rear doors of the vehicle.
- Strategic planning can aid in crossing safety and traffic calming

Application:

- Can be applied in both mixed-flow and dedicated transit lane conditions
- Can be installed at near or far-side of an intersection, or at mid-block stops
- Requires a street cross section with on-street parking or other curbside uses between curb extensions (cannot extend the curb into a general purpose lane).

Source: NACTO Transit Street Design Guide

Diagram Components:

1. At stops adjacent to crosswalks, provide at least 10 feet of clear sidewalk space, ahead of transit vehicle at near-side stops and behind the transit vehicle at far-side stops.
2. If shelters are placed on boarding bulbs, they must be placed clear of front- and back-door boarding areas.
3. (Optional) Include green features like bioswales or pervious strips to improve streetscape and stormwater recapture.

BIOSWALES

Bioswales are vegetated, shallow, landscaped depressions designed to capture, treat, and infiltrate stormwater runoff as it moves downstream. Above ground, bioswales can look like a flower garden. Below ground, bioswales have an engineered subgrade design to filter pollutants out of stormwater runoff.

Bioswales are considered the most effective type of green infrastructure facility in slowing runoff velocity and cleansing water while recharging the underlying groundwater table.

Source: City of Raleigh (Sandy Forks Road)

Key Features:

- Designed to capture and breakdown pollutants
- Typically sized to treat the water quality event, also known as the "first flush," which is the first and often most polluted volume of water resulting from a storm event.
- The engineered subgrade is designed so that captured water readily moves down through a sandy soil media to filter out pollutants.

Application:

- Installed where water is unable to infiltrate and percolate downward through the existing soils at an adequate rate.
- Can be installed into bulb-style transit stops to improve the passenger waiting experience. However, this would require special consideration to maintain accessible loading and clear sightlines for transit operators.
- Incorporating stormwater facilities at transit stops introduces new opportunities for mutual benefits and inter-agency collaboration, unlocking new project funding sources and leveraging complementary resources.
- Have flexible siting requirements, allowing them to be integrated with medians, cul-de-sacs, bulb outs, and other public space or traffic calming strategies.

Source: NACTO Urban Street Design Guide

Advantages / Benefits:

- Mitigate runoff from impervious surfaces
- Remove sediment and pollutants to improve water quality (remove 90% or more of suspended sediment)
- Reduce runoff rate and volume in highly impervious areas; reduce runoff velocity
- Provide for groundwater recharge if design and site soils provide sufficient infiltration
- Good option for small area retrofits – replacing existing drainage ditches
- Good retrofit opportunities for residential or institutional areas of low to moderate density
- Linear configuration works well with highway or residential street applications

Disadvantages / Limitations:

- Sediment/pollutant removal sensitive to proper design of slope and maintaining sufficient vegetation density
- Not recommended for locations with low infiltration rates because standing water could cause issues on streets and sidewalks in an urban environment
- Higher maintenance than curb and gutter systems
- Possible re-suspension of sediment
- Require O&M agreements

PERVIOUS STRIPS

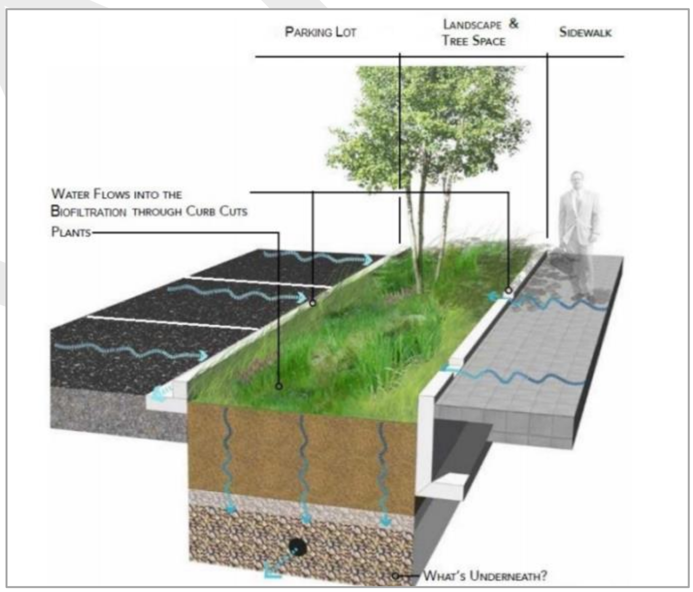
Pervious strips are long, linear landscaped areas or linear areas of pervious pavement that capture and slow runoff. If developed on a favorable underlying subsurface soil, a pervious strip can provide some infiltration. However, pervious strips provide much less infiltration than bioswales.

Advantages / Benefits:

- An inexpensive initial step in urban stormwater management.
- Removes sediment and pollutants to improve water quality (remove 90% or more of suspended sediment).
- Long, linear spaces may be integrated with urban agriculture programs.

Disadvantages / Limitations:

- Unlikely to provide enough capacity for treatment of a street's full water quality event
- Require O&M agreements



Source: San Diego County

Application:

- Integrate pervious strips with sidewalks, medians, curbs, and other features. Depending on the desired configuration, pervious strips may treat either sheet flow or more channelized flow. Pervious strips require long, continuous spaces to treat and filter pollutants.
- Install a perforated pipe at the base of the facility to collect the treated runoff.
- Use a maximum 2% gentle side slope to direct flow into the facility.
- Protect adjacent subsurface infrastructure by maintaining a minimum clearance, installing waterproof liners as separation barriers, or by constructing a deep curb to separate the roadbed subgrade or parallel utility line from the facility.
- For additional runoff control on slopes exceeding 4%, consider the use of adjustable weirs, berms, or check dams, or modified catch basins that feed into the bioswale or permeable system.

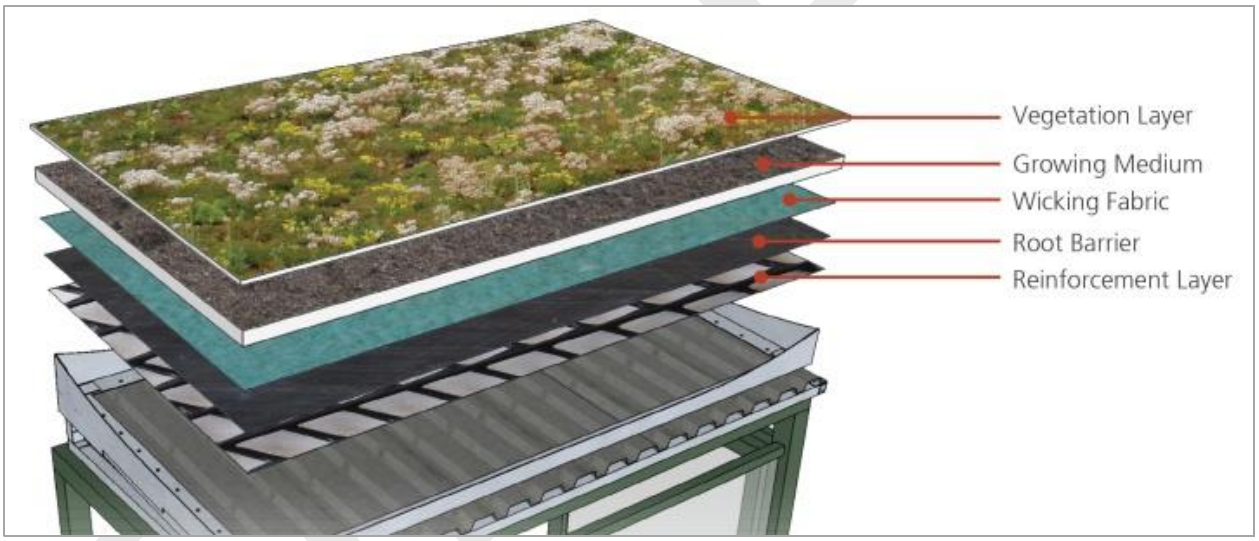
- Reduce irrigation requirements of pervious strips by utilizing pervious pavements and native plants. Native landscaped areas are generally preferable because they would generate less runoff and can help mitigate the urban heat island effect. Native plants increase biodiversity, act as a pollinator habitat, and are well-adapted to the regional climate, increasing their chances for survival.

GREEN FEATURES ON A TRANSIT FACILITY'S ROOF

Transit facility roofs provide location opportunities to install green features and help reduce water runoff during storm events. Green roofs offer many benefits—they help to ease the summer heat and reduce the amount of rainwater that makes its way to the sewer. When we capture rainwater or slow the flow to storm drains, we can reduce the pollution and flooding that impacts our streams and rivers.

Advantages / Benefits:

- Eases the level of summer heat
- Reduces the amount of rainwater runoff that can inconvenience transit users
- Reduces the amount of rainwater runoff that makes it to the sewer



Source: PhillyWatersheds.org

Key Features:

The layers on a green roof system help manage rainwater and protect the building underneath. A general example of these layers includes the following:

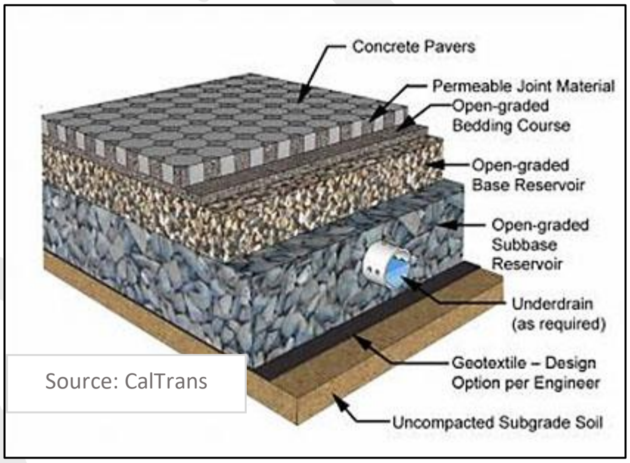
- Vegetation layer – comprised of a variety of plant species to protect the young green roof plants and soil from blowing in the wind. A photodegradable wind net would protect the newly planted roof.
- Growing medium – a lightweight soil that can support plant growth. The soil is often deeper in the corners above the bus shelter steel legs, where more weight can be supported.
- Capillary fabric – an engineer fabric is added to enhance water retention.
- Root barrier – a barrier used to protect the roofing from roots and mechanical damage.
- Reinforcement layer **–** a water-resistant corrugated steel roof to both protect from the elements and facilitate drainage of excess water from the back of the shelter. A rigid mat above the metal

roof creates a flat surface to support the rest of the green roof layers and a plastic sheet above the rigid mat holds the majority of rainwater in the soil.

PERVIOUS PAVEMENT

Pervious paving allows stormwater to infiltrate through the paved surface to an underlying crushed rock base where it is either stored or infiltrated. This effectively treats, detains, and infiltrates stormwater runoff where landscape-based strategies are restricted or less desired.

Treatments should be tailored to their specific climate and available maintenance capacities. Pervious pavement is not advised for portions of the roadway that will have frequent, direct contact with buses or other heavy vehicles. Therefore, pervious pavement could be used for other aspects of a Complete Street such as sidewalks, street furniture zones, parking lanes, and/or gutter strips.



Source: CalTrans

Application:

- Verify the structural stability of the sub-grade materials to handle potential vehicle usage and loading. For example, some decorative pavers may be more susceptible to shifting than others and are thus more appropriate for use in pedestrian and bike-only areas.
- Pervious pavement should drain within 48 hours.
- Pervious pavements must be designed to account for the native subsoil infiltration rate. The depth of the pervious layer, void space, and the infiltration rate of the underlying soils result in the desired storage volume and intended drain time of the facility.
- Prior to installation, verify that underlying native soils are not contaminated. A full geotechnical evaluation is required to determine the permeability, height of the water table, and depth to bedrock. Many urban areas have significant swaths of unclassified urban fill that may cause issues if not remediated.
- Utilize an underdrain system to treat overflow, or if partial infiltration is preferred, to convey remaining runoff to the municipal sewer system.
- Pervious pavements often require ongoing cleaning (vacuuming or power washing) to remove silt from the void spaces to maintain infiltration performance.
- Selection of pavements, such as permeable pavers, permeable concrete, permeable asphalt or other materials, should be based on engineering constraints and the surrounding street context
- In cold climates, salt should be applied in moderation to reduce contamination of the subsoil. Plowing should be done carefully, and abrasives, such as sand or cinders, should be avoided to preserve the integrity of the pavement system. Also, use biodegradable, non-corrosive de-icing agents such as BX36, GEN3, and BetaFrost.
- The drain rock layer must be clean and wrapped in filter fabric.

- Protect the adjacent subsurface infrastructure by maintaining minimum clearances, installing waterproof liners as separation barriers, or constructing a deep curb to separate the roadbed subgrade or parallel utility line from the facility.

GSI CONCLUSION & APPLICATION TO WAKE BRT

The City of Raleigh has a policy supporting GSI on road construction projects wherever possible. Information about this policy can be found on the City of Raleigh's website:

- https://raleighnc.gov/SupportPages/green-stormwater-infrastructure
- https://raleighnc.gov/business/content/PlanDev/Articles/DevServ/DrawingsStandardDetailsIndex.html#paragraph--221806

It is important to apply GSI features to the highest extent practicable. Implementing GSI features helps conserve natural resources, reduce flooding risks, improve the water supply quality, and increase property values. Feasibility and stormwater management benefit analysis must be completed at each specific runoff location based upon the connection to the proposed stormwater network.

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