Montgomery County Department of Transportation

Flash Bus Rapid Transit (BRT) Guidelines

February 2024

This guide contains information intended to be used as an input during the design process; however, field verification, site condition assessments, engineering analysis, and design are necessary prior to implementing guidance contained herein.

Montgomery County Department of Transportation

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Chapter 1: Operating Characteristics

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Introduction

Flash Bus Rapid Transit's (BRT's) operating characteristics and performance, such as travel time, frequency, span of service, and reliability, are as crucial to the rider's experience as the physical attributes associated with BRT systems. The guidelines set in this chapter are informed by a review of BRT operations' best practices and local transit service guidelines. The presented operating standards are context-driven and may vary to accommodate three operating contexts: activity center, suburban, and regional settings. Table 1.1 summarizes Flash BRT's operating characteristics guidelines.

Table 1.1: Operating Characteristics Guidelines Summary

	Operating Context		
Service Parameter *(Description)*	**Activity Center**	**Suburban**	**Regional**
Travel Speed *(Corridor-Wide Average Operating Speed)*	▪ Avg.: 16 mph ▪ Alternative: 10% improvement over local service on the corridor	▪ Avg.: 18 mph ▪ Alternative: 12% improvement over local service on the corridor	▪ Avg.: 20 mph ▪ Alternative: 8% improvement over local service on the corridor
Route Length *(Route/Service Pattern Length)*	▪ Min.: 7 mi ▪ Max.: 15 mi	▪ Min.: 7 mi ▪ Max.: 15 mi	▪ Min.: 10 mi ▪ Max.: 20 mi
Station Spacing *(Average and Minimum Distance Between Stations on a Flash BRT Corridor)*	▪ Min. Avg.: 0.5 mi ▪ Max. Avg.: 0.75 mi ▪ Min.: 0.25 mi	▪ Min. Avg.: 0.75 mi ▪ Max. Avg.: 1 mi ▪ Min.: 0.35 mi	▪ Min. Avg.: 1 mi ▪ Max. Avg.: Based on Market ▪ Min.: 0.5 mi
Headway *(Average Interval Between Vehicles During a Time Period)*	▪ Peak Max.: 8 minutes ▪ Off-Peak Max.: 15 minutes ▪ Weekend: 15 minutes	▪ Peak Max.: 8 minutes ▪ Off-Peak Max.: 15 minutes ▪ Weekend: 15 minutes	▪ Peak Max.: 10 minutes ▪ Off-Peak Max.: 30 minutes ▪ Weekend: 30 minutes
Weekday Span of Service *(Start of the First Trip and End of the Last Trip on Weekdays)*	5:00 a.m. - 1:00 a.m.	5:00 a.m. - 1:00 a.m.	Based on Market
Passenger Load *(Number of Passenger by the Vehicle Seated Capacity)*	▪ Peak: 1.4 ▪ Off-Peak: 1.3	▪ Peak: 1.4 ▪ Off-Peak: 1.3	▪ Peak: 1. ▪ Off-Peak: 1.3
Service Reliability *(On-Time Performance)*	85% or higher	85% or higher	85% or higher

The Role of the Operating Guidelines

Enhanced stations, branded vehicles, and intelligent transportation systems (ITS) are features typically associated with BRT systems and are traditionally viewed as the foundation for a high-quality BRT corridor. However, an increased focus on operations, maintenance, and safety has been given lately to ensure that corridors with excellent physical attributes also deliver high-quality service to passengers. One example of this movement is the latest edition of the Institute for Transportation and Development Policy's BRT Standard. It now includes an operations section in its evaluation and scoring methodology to encourage high-quality system operations in addition to the already-scored design features. The operations evaluation deducts points from the design scoring due to low travel speeds, low frequency, poorly maintained infrastructure, and bus bunching.

The role of the Flash BRT operating guidelines is twofold: first, to give the Montgomery County Department of Transportation (MCDOT) a formal and transparent framework for planning and operating Flash BRT services; second, to communicate clear expectations for service delivery to customers and stakeholders. The guidelines set in this chapter are informed by a review of BRT operations' best practices and local transit service guidelines. The goal is to provide a balance of consistency and flexibility while addressing various public transportation needs across the county. As such, the operating guidelines are context-driven and may vary to accommodate three operating contexts: activity center, suburban, and regional settings.

The operating guidelines set the direction for Flash BRT service expansion and improvement while providing a framework for making decisions within the realities of limited resources. Regular service reviews and modifications are also key in managing Flash's operations and increasing its efficiency and effectiveness. Service reviews help identify trends, improvement opportunities, and any potential updates to operating guidelines set in this chapter. Additionally, MCDOT's ability to provide services that meet the operating guidelines set in this chapter is influenced by resource availability, from available funding for transit operations and vehicles, to the operating workforce. If resources become constrained, MCDOT will meet these guidelines as closely as possible and will work to achieve consistency as resources permit.

The Role of Flash BRT Within the Transit Network

The literature defines BRT as an integrated system of features, services, and amenities that improves bus transit's speed, reliability, and identity.[1] In this context, Flash BRT components and service should allow riders to identify it as a distinct bus service, faster and more reliable than the local bus. Montgomery County is served by a range of transit services designed to meet different purposes, markets, travel demand levels, and objectives. Operated by different transit agencies, these services include:

- MARC commuter rail
- Metrorail heavy rail
- Maryland Transit Administration (MTA) commuter bus
- Flash BRT
- Metrobus and Ride On express and local buses

Those transit options differ in terms of market, travel speed, frequency, and span of service, and stop spacing (Table 1.2). BRT routes typically operate throughout the day and on weekends and have higher frequencies in both peak and off-peak periods compared to typical bus services, aiming to serve a variety of riders and trip types. However, specific Flash BRT services may differ in some of those aspects. For example, commuter-oriented Flash BRT service patterns may operate only during peak periods, or service patterns running on access-controlled highways may have higher speeds and stop spacing.

Table 1.2: Montgomery County Transit Services typologies

Service	Market	Speed	Frequency	Span	Stop Spacing
Commuter Rail	Commuters	Very High	Low	Peak Period	Very High
Metrorail	All Trips	High	High	All Day	High
Light Rail	All Trips	Moderate	High	All Day	Moderate
Flash BRT	All Trips	Moderate	High	All Day	Moderate
Express Bus	Commuters	Moderate	Moderate	Peak Period	Moderate
Local Bus	All Trips	Low	Varies	Varies	Low

Adapted from: Countywide Transit Corridors Functional Master Plan (2013).

Flash BRT is part of a multimodal transit network. Metrorail is the backbone of the county's transit network, providing service to the county and the region. The planned Purple Line light rail will provide the next layer of transit service, connecting activity centers and Metrorail stations. The existing and planned BRT corridors would form the next layer of transit service. Local, limited-stop, and commuter bus routes and MARC commuter rail complete the county transit network.[2]

Flash BRT's role within the county transit network is varied. In addition to serving activity centers directly, BRT on the recommended transit corridors will serve as feeders to Metrorail and MARC stations. Segments of MD 355 and Georgia Avenue that Metrorail already serves also may be served by Flash BRT, which will

[1] National Academies of Sciences, Engineering, and Medicine. 2007. Bus Rapid Transit Practitioner's Guide. Washington, DC: The National Academies Press. https://doi.org/10.17226/23172.

[2] M-NCPPC. 2013. Countywide Transit Corridors Functional Master Plan. Silver Spring, MD. https://www.montgomeryplanning.org/transportation/highways/documents/countywide_transit_corridors_plan_2013-12.pdf.

offer an intermediate level of transit service between Metrorail and local buses. In summary, Flash BRT corridors connect:[3]

- Rail stations, where physical and operating integration should be prioritized
- Multiple dense, mixed-use areas, where all station areas should prioritize pedestrian, bicycle, and transit access and park-and-ride lots should be discouraged
- Moderate-density residential areas to employment centers, where most station areas should prioritize pedestrian, bicycle, and transit access and park-and-ride lots may be appropriate at some locations but multimodal access should be provided
- Park-and-ride lots to employment centers, with vehicular and transit access prioritized at park-and-ride BRT stations

Operating Contexts

BRT is best suited to operate along mixed-use, densely populated corridors, serving a broad variety of urban and suburban environments in the United States.[4] It also can be introduced into some areas with large existing or developing suburban activity centers to attract automobile trips to transit. However, each urban area has specific needs, opportunities, and constraints that must be recognized. Thus, BRT corridors must be carefully customized to translate plans into operating characteristics adequate for the corridor operating context.

Since parts of Montgomery County have various land use characteristics and transit demand levels, Flash BRT corridors may require distinct operating guidelines to match those operating contexts. For example, Maryland Department of Transportation State Highway Administration (MDOT SHA) describes six operating contexts in Maryland, from urban cores to rural areas. Figure 1.1 compares operating context classifications developed by several entities or publications to the three operating contexts defined for these guidelines. These are:

- Activity Center: includes pockets of high-density development and well-connected roadway networks, as well as retail and office areas of suburban character typically found along or at the intersection of major arterials; activity centers feature many uses, including residential (multifamily and single-family), office, and retail facilities. According to Metropolitan Council of Governments (MWCOG), activity centers serve as the centerpiece of the region’s future development and includes existing urban areas, traditional towns, transit hubs, and priority growth zones.
- Suburban: has a moderate to low diversity of uses, primarily single-family residential development; office parks and small commercial strip retail are scattered throughout the area, along with neighborhood-level civic and cultural facilities

[3] Ibid.
[4] National Academies of Sciences, Engineering, and Medicine. 2007. Bus Rapid Transit Practitioner's Guide. Washington, DC: The National Academies Press. https://doi.org/10.17226/23172.

- Regional: includes areas of suburban development with lower density and rural areas; these areas include developments in large-lot residential clusters and a mix of agricultural uses and green space. Trip distances are long, as origins and destinations are few and far between

Figure 1.1: Flash BRT Operating Contexts

<table>
<tr><th></th><th colspan="7">Activity Center</th><th colspan="3">Suburban</th><th colspan="2">Regional</th></tr>
<tr><td>SHA</td><td>Urban Core</td><td>Urban Center</td><td colspan="3">Traditional Town Center</td><td colspan="3">Suburban Activity Center</td><td colspan="2">Suburban</td><td colspan="2">Rural</td></tr>
<tr><td>Federal Designations</td><td colspan="10">Urban</td><td colspan="2">Rural</td></tr>
<tr><td>ITE</td><td>Urban Core</td><td colspan="3">Urban Center</td><td colspan="2">General Urban</td><td colspan="4">Suburban</td><td>Rural</td><td>Natural</td></tr>
<tr><td>AASHTO Green Book, 7th Edition</td><td>Urban Core</td><td colspan="2">Urban</td><td colspan="2">Rural Town</td><td>Urban</td><td colspan="4">Suburban</td><td colspan="2">Rural</td></tr>
<tr><td>Florida DOT</td><td>Urban Core</td><td colspan="2">Urban Center</td><td colspan="2">Rural Town</td><td colspan="2">Urban General</td><td colspan="2">Suburban Commercial</td><td>Suburban Residential</td><td>Rural</td><td>Natural</td></tr>
</table>

Adapted from: MDOT SHA Context Driven Guidebook (2020)[5]

Although several factors play into defining and evaluating transit markets, the number of people and jobs is an established indicator of transit use potential in an area. Figure 1.2 shows the overall distribution of each operating context in Montgomery County, as defined by the population and employment density, as well as MWCOG's activity centers. The activity center's and MWCOG's activity center's context shows the highest density levels, with more than 20 people and jobs per acre. The density in the suburban context ranges between 7 and 20 people and jobs per acre, while the regional context has densities lower than seven people and jobs per acre. Since corridors often go beyond a single operating context, the operating context of a corridors or Flash BRT routes is defined as:

- Activity Center: connects or runs through at least two activity center areas (e.g., North Bethesda, or MD 355 between Bethesda and Shady Grove)
- Suburban: runs mostly through suburban operating context but may have one terminus at an activity center area (e.g., Veirs Mill Road)
- Regional: connects regional operating context to suburban operating context or peak-only Flash BRT routes (e.g., US 29 Flash Blue Route)

[5] https://experience.arcgis.com/experience/3476e680584c49e48303fe6d52ceeda9

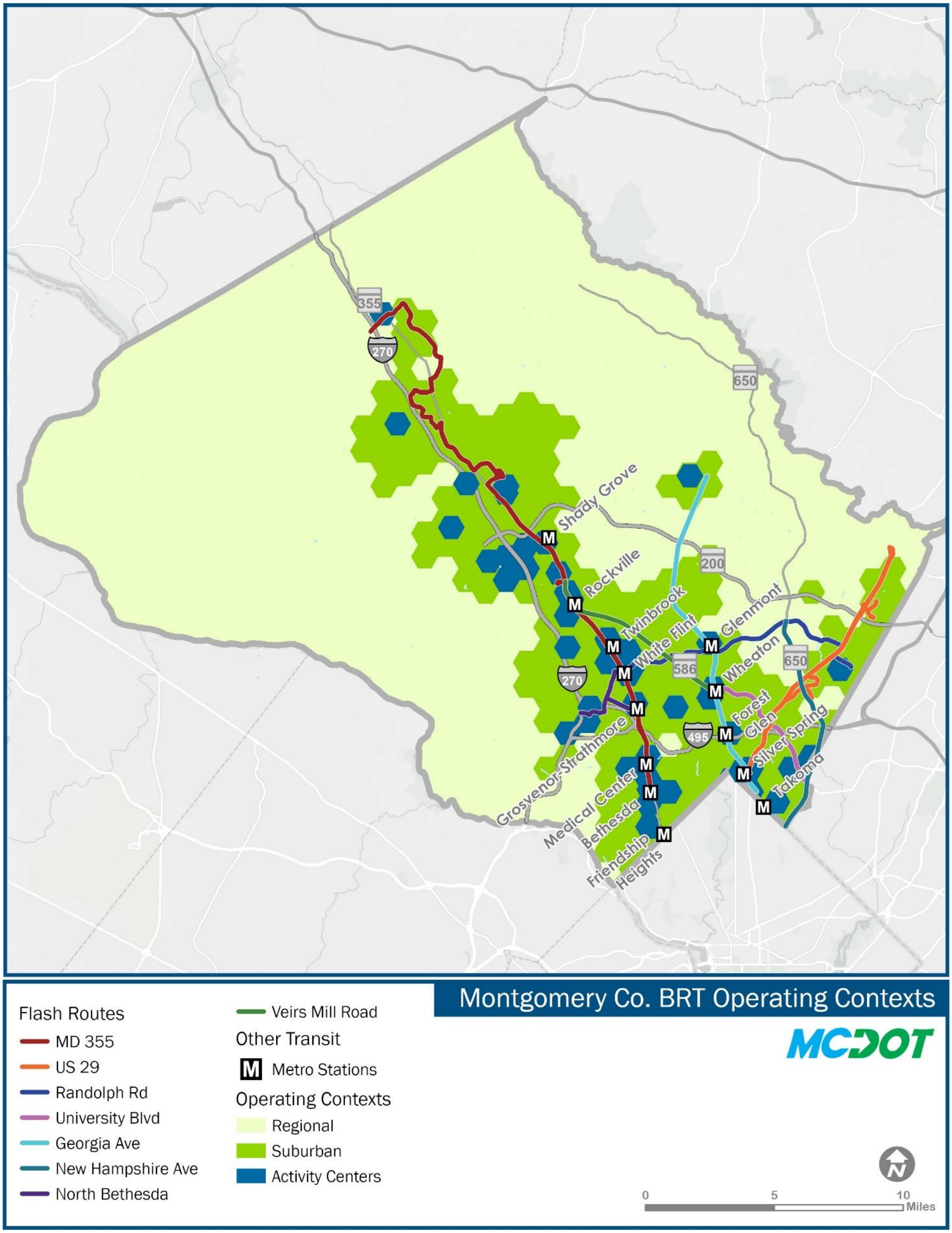


Figure 1.2: Montgomery County Operating Contexts

1.Travel Speed

1.1 Description

Travel speed refers to the corridorwide average operating speed, which includes dwell times and is the result of the total corridor length divided by the total corridor travel time. As it impacts the travel time required to make a trip, it is a key metric for customers. The more competitive the speed, and therefore the travel time, is compared to other modes, particularly the car, the more attractive the BRT service will be, particularly in suburban settings.

Several factors impact the operating speed a BRT service can reach. Those factors on suburban roads include the maximum authorized speed, the distance between stations, the dwell times at stations, the number of intersections and traffic signals per mile along the corridor, as well as traffic congestion mitigation strategies such as dedicated runningways, TSP, and queue jumps. Since those factors work together, they should not be considered in isolation. For example, selecting a route with lower speed limits may limit the station spacing that can be supported without greater detriment to operating speeds, especially if there is a high intersection and traffic signal density.

Flash BRT service should be rapid. Higher speeds are one of the main goals of many of BRT's physical attributes and technology strategies. Priority treatments, such as dedicated runningways, transit signal priority (TSP), and queue jumps, aim to mitigate the impact of general traffic on BRT operations, speeding it up. Operational strategies such as limited-stop patterns can also increase average operating speed by reducing dwell time.

1.2 Key Considerations

- Operating speeds reflect the type of runningway, station spacing, and service pattern.
- Type and length of runningways. At-grade dedicated lanes without a physical separation provide BRT vehicles priority but is still impacted by traffic signals, the potential for road construction, and the potential for unauthorized use of the facility (e.g., stopped or parked vehicles). Curb-aligned lanes also introduce potential right-turning traffic and parking maneuvers delays. Mixed-traffic operations introduce potential travel time variability due to traffic congestion and variability in traffic volumes from one hour or day to the next.[6] Finally, the longer the dedicated runningway, the greater the potential for travel time savings.
- The geometry of the dedicated lanes. In some instances, it may be necessary to narrow a BRT right-of-way to fit the facility through a pinch point.
- The location of the dedicated lane. In corridors with a mixture of BRT and conventional transit buses, the curb lane may become too slow for effective BRT operations due to the frequently stopping conventional services. Also, in mixed-traffic situations, the curb lane tends to be the slowest lane due to right-turning traffic. However, in situations where BRT is the only transit operating in a corridor, and is operating in a dedicated lane, the curb lane can be an effective option. The median lane can allow more efficient operations than the curb lane in some situations,

[6] National Academies of Sciences, Engineering, and Medicine. 2007. Bus Rapid Transit Practitioner's Guide. Washington, DC: The National Academies Press. https://doi.org/10.17226/23172.

as it allows the BRT vehicles to avoid right-turning traffic and conventional buses making frequent stops.

- Rules of the road. Transit agencies should consider adopting special speed limits for vehicles passing through stations without stopping. This is particularly important in situations where a skip-stop or express service is operating through a station with waiting passengers Standard operating speeds that apply to the full facility will be the simplest to enforce. For example, a maximum operating speed of 50 miles per hour between stations and 30 miles per hour in station areas. Additional consideration should be given to speeds traveled between stations, especially through intersections. Many BRT systems that operate along a designated right-of-way may interface with other modes of transportation at intersections, therefore increasing the likelihood of conflict. To address this safety concern, certain cities have found it beneficial to decrease travel speeds through intersections. While it initially may affect overall travel time, these cities have found the difference minimal.
- Traffic engineering and transit signal priority (TSP) treatments, including queue jumps, reducing left turns or crossing movements across a runningway. Travel time savings associated with TSP in North America and Europe have ranged from 2 to 18 percent, depending on the length of corridor, particular traffic conditions, bus operations, and the TSP strategy deployed. A reduction of 8 to 12 percent has been typical, while the reduction in bus delay at signals has ranged from 15 to 80 percent.[7]
- Stations spacing. See Section 3. Station Spacing.
- Boarding protocols to reduce dwell. See Fare Collection and Boarding Protocols.
- Operating cost savings potential. If the travel time savings is enough to reduce route's cycle time to the point where fewer vehicles are required to maintain a set frequency, there is savings in operating costs.

1.3 Guidelines

Literature shows that limited-stop BRT operations on city streets can achieve overall speeds between 15 and 20 miles per hour, while ranging between 25 to 35 miles per hour on entirely segregated runningways.[8] For the Flash BRT, operating speeds should be at least 10 percent greater than local service on the corridor or the travel speeds indicated in Table 1.3.

[7] Transit Cooperative Research Program. 2010. Bus and Rail Transit Preferential Treatments in Mixed Traffic. Washington, DC: The National Academies Press. Available at: https://www.trb.org/Publications/Blurbs/163890.aspx.
[8] Transit Cooperative Research Program. 2003. Bus Rapid Transit, Volume 1: Case Studies in Bus Rapid Transit. Washington, DC: The National Academies Press. Available at: https://onlinepubs.trb.org/onlinepubs/tcrp/tcrp_rpt_90v1fm.pdf.

Table 1.3: travel speeds guidelines

	Operating Context		
Service Parameter	Activity Center	Suburban	Regional
Travel Speed	▪ Avg.: 16 mph ▪ Alternative: 10% improvement over local service on the corridor	▪ Avg.: 18 mph ▪ Alternative: 12% improvement over local service on the corridor	▪ Avg.: 20 mph ▪ Alternative: 8% improvement over local service on the corridor

2.Route Length

2.1 Description

Route length refers to how long a Flash BRT route is. The design of a transit route impacts its attractiveness and usefulness. BRT routes tend to have little circuity and serve demonstrably high levels of demand, aiming to minimize trip time and improve productivity. Route length is one of the design elements of a BRT route, and as a general rule, longer routes have greater travel time savings potential but may be more susceptible to reliability issues.

2.2 Key Considerations

- Route length relates to other bus priority strategies. Literature indicates that savings of five minutes or more on a typical trip can affect mode choice.[9] Therefore BRT routes should be long enough to result in travel time savings of five minutes or more for a significant share of the potential riders. These savings can be estimated considering local buses and auto travel times, for example, and savings due to bus priority strategies such as TSP, queue jumps, dedicated runningways, etc.
- The route should serve a high number of origins and destinations. In addition to being fast and long enough so that riders can experience and perceive travel time savings, routes need to reach a high number of activity centers, denser residential areas, and other transit infrastructure and modes. Shorter routes may not serve a sufficient number of destinations to be cost-effective.
- BRT services and infrastructure can function distinctly, meaning that BRT route may operate both on and off the corridor with the physical infrastructure such as TSP and enhanced stations. This approach may optimize customer benefits by minimizing transfers, for example, versus infrastructure costs. However, the route length guidelines refer directly to the route operating where there is infrastructure built.
- Long routes are prone to reliability issues and segments with lower demand. Longer routes are more susceptible to delays compromising schedule-recovery times and impacting

[9] National Academies of Sciences, Engineering, and Medicine. 2007. Bus Rapid Transit Practitioner's Guide. Washington, DC: The National Academies Press. https://doi.org/10.17226/23172.

reliability. Long routes, particularly in suburban operating environments, may have segments where demand is lower.

2.3 Guidelines

The guidelines are meant to apply branding as Flash BRT between two distinct termini, excluding branched systems or local services segments of BRT corridors. However, this does not preclude having a ‘short turn’ provision as part of the service plan for a BRT route. Table 1.3 defines a minimum and maximum route length for distinct operating contexts.

Table 1.3: Route Length Guidelines

	Operating Context		
Service Parameter	Activity Center	Suburban	Regional
Route Length	▪ Min.: 7 mi ▪ Max.: 15 mi	▪ Min.: 7 mi ▪ Max.: 15 mi	▪ Min.: 10 mi ▪ Max.: 20 mi

Location-specific consideration may justify route lengths outside of the set guidelines, particularly in terms of the minimum length of routes connecting activity centers. Operating characteristics such as high frequency play a greater role in customer convenience in these circumstances. Regarding longer routes, as they are more susceptible to reliability issues, the potential impact of traffic and the physical attributes of the corridor are important factors to consider when examining routes longer than the set guidelines.

3.Station Spacing

3.1 Description

Station spacing is the calculated average distance between stations on a Flash BRT corridor. One of the most important considerations in system design and operating plan, the distance between stations relates to both access time and travel time. The goal is to make the station as easy to access as possible and as close to nearby origins and destinations as possible, decreasing access times. However, if stations are too close together, deceleration and acceleration times reduce bus speeds. Therefore, BRT station spacing should try to strike an optimal balance between convenient walking time to access the service and convenience for riders in the form of higher speed and capacity.

3.2 Key Considerations

- The actual distance between any two stations can vary, depending on several factors. While the average station spacing should fall within the set guidelines, factors such as the topography, roadway grid design, and land use influence the location of stations.
- Stations should prioritize access to major origins and destinations, such as residential complexes, employment centers, educational and health facilities, and shopping, cultural or recreational centers.

- The presence or potential for first/last-mile and other transit connections should be considered. BRT stations should allow and facilitate access and transfer to and from other modes, including a well-connected sidewalk network, bicycle infrastructure, and other transit stops and stations.
- Stations should be located where there is adequate space to accommodate the infrastructure of a BRT station. See the Station chapter for further station site guidelines.
- Where the bus operates in mixed traffic, locate stations so buses do not have to re-merge into traffic, maintaining their place in the traffic queue.

3.3 Guidelines

Flash BRT stations should be located in accordance with an overall BRT station spacing objective for the corridor, serve key origins and destinations along the route, and allow for transfers to other transit routes and modes. The guidelines in Table 1.4 set a range of minimum and maximum average distances between stations that represent a good balance of the key considerations for each operating context. Minimum distances between adjacent stations are defined to account for cases where strong, closely-spaced trip generators may warrant closer spacing. Outside of these guidelines, the exact location of a station along a corridor is highly site-specific.

Table 1.4: Station Spacing GUidelines

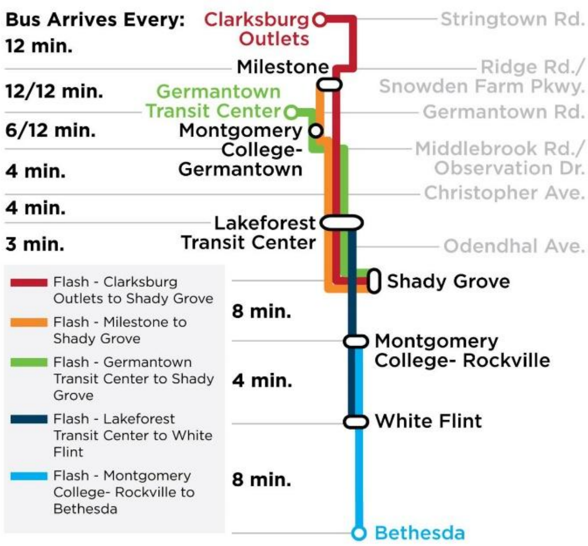
	Operating Context		
Service Parameter	Activity Center	Suburban	Regional
Minimum Average Station Spacing	0.5 miles	0.75 miles	1 mile
Maximum Average Station Spacing	0.75 miles	1 mile	Based on Market
Minimum Distance Between Adjacent Stations	0.2 miles	0.25 miles	0.5 miles

4.Frequency of Service

4.1 Description

Service frequency refers to how often a BRT vehicle picks up passengers at a station. Frequency is typically measured as headway, which is the amount of time between transit vehicle arrivals at a stop. Frequency can vary depending on the service type, and there are many considerations for determining the level of service, such as the population served, the purpose of the route, the expected level of ridership, resources available, and more. Frequent service buses in the US often have 10- to 15-minute headways. Flash BRT routes typically fall under an all-day, high-frequency type of service. Still, peak-only, commuter-oriented service types may also be provided. Therefore, the frequency of service will vary depending on service typology and the operating context, with service between activity centers typically more frequent and less frequent in the regional context. Generally, service with a higher frequency is more useful and attractive to riders because there is a shorter wait time between buses and overall travel times. Ride On Reimagined, a comprehensive, forward-looking assessment of the bus network, redefined how transit operates in Montgomery County, setting guidelines for both Ride On and Metrobus services. Flash BRT guidelines here defined are in line with those outlined by Ride On Reimagined.

Figure 1.3: MD355 Flash BRT service patterns and Headwav



4.2 Key Considerations

- The frequency of service can vary along a corridor. The frequency of BRT service is contextually sensitive and varies depending on the surrounding land use. Typically, the trunk of a BRT corridor sees the most frequent service, while smaller branches experience less frequent service. Where Flash BRT service is supplementing existing Metrorail service, frequencies may be slightly lower.
- Shorter headways are more expensive. Shorter headways require more vehicles and drivers to operate. Depending on the context of the route, a route with shorter headways may not experience a proportional increase in ridership without an appropriate density and ridership demand.
- Shorter headways mean shorter wait times and higher capacity. Shorter headways mean more buses are operating on the same route providing customers with shorter wait times between buses and higher capacity during its service span. Higher capacity is particularly useful in and between activity centers where demand is higher.
- Longer headways can cause crowding during peak periods. Buses that arrive less frequently have the potential to cause crowding both on platforms and on buses, especially during peak periods of travel. Longer headways mean longer periods for passengers to accumulate at individual stations, and buses may even need to pass stations if capacity is reached.
- Longer headways can deter riders, even during low-demand periods. Long headways can make it time-consuming for passengers to get from one location to another. Longer headways are less attractive because it is difficult for riders to coordinate their schedule with the time that the bus will arrive. For example, a BRT route that serves metro connections may be utilized throughout the day (by shift workers, etc.), but if service decreases during the mid-day period, riders might be less inclined to consider BRT as a viable option.
- Flash BRT is a premium service and must operate under a maximum headway that maintains that status. A BRT route is attractive to customers because of the speed and frequency with which it can get riders to their destination. Riders must be able to differentiate BRT from a standard bus route in the system, and high frequency is a key differentiator.

4.3 Guidelines

The guidelines establish a maximum headway (or minimum frequency) for service during weekday peak periods and all other times and days of service (Table 1.5). The recommended peak period maximum headways for BRT are:

- Peak-period maximum headways are 8 minutes for the BRT trunk in or between operating context of the activity center, and suburban
- In regional operating context or peak-only service patterns, the maximum headway is 10 minutes
- Weekend (Saturday and Sunday) maximum headways follow the off-peak standard of a maximum of 15 minutes in or between the operating context of the activity center and suburban and 30 minutes in the regional operating context.

Off-peak maximum headways are 15 minutes, except for overnight service. Demand for overnight service can be significantly lower than during peak periods or midday service. Due to the reduced demand and the reduced frequency of service on regular routes and Metrorail, Flash BRT can operate on far reduced frequencies or not at all during overnight hours.

For a BRT route to maintain visibility and utility, FTA guidance is that the maximum off-peak headway is no more than 30 minutes. Service provided at a frequency less than twice every hour means the service will no longer be a practical option for many riders, and it may apply undue hardship to any riders who miss the scheduled departure time. Therefore, even on corridor segments with multiple routes with a combined headway of at least 10 minutes, each route should still operate at a minimum frequency of 30 minutes.

> The Federal Transit Administration (FTA) has offered standards for the national provision of a BRT service. FTA says BRT must have 10 min peak headways for New Starts funding. Additional recommendations state that BRT should have headways no greater than 15 minutes in the off-peak and 30 minutes off-peak on any branches of the system.

Ride On Reimagined also defines frequency guidelines for BRT services, as well as other service types. Ride On Reimagined set BRT frequency between 8 and 15 minutes, framework/high-capacity routes (Ride On Extra) and express routes would run at a frequency of 10 to 15 minutes, the frequency of commuter routes would be of 30 minutes on weekdays between 6:00 and 9:00 a.m. and 3:00 and 7:00 p.m., and finally, coverage/local routes would run at a frequency of 15 to 30 minutes on weekdays and 30 minutes on weekends.

Table 1.5: Frequency of Service Guidelines

	Operating Context		
Service Parameter	Activity Center	Suburban	Regional
Frequency of Service	▪ Peak Min.: 8 minutes ▪ Off-Peak Max.: 15 minutes ▪ Weekend: 15 minutes	▪ Peak Min.: 8 minutes ▪ Off-Peak Max.: 15 minutes ▪ Weekend: 15 minutes	▪ Peak Min.: 10 minutes ▪ Off-Peak Max.: 30 minutes ▪ Weekend: 30 minutes

5.Span of Service

5.1 Description

The service span of a route is the time that it operates from the first stop on the first trip of the day to the last stop on the last trip of the day. The service span typically varies by route and day of the week, taking into account peak commuting times, typical rider demographics, the utility of the route, and other similar factors.

Montgomery County's Ride On Reimagined Study outlines a number of different goals for service planning, including an evaluation of the current route structure, connectivity, span, and frequency of service. The study will also address the County's priorities to improve racial equity and prevent climate change. Within these priorities, the County provides a number of ways to quantify how each will be addressed. Specifically, as the priorities relate to the span of service, the County recommends a greater provision of all-day service to implement targeted equity actions, which will result in improved service to underserved areas of the county. Additional benefits the County is considering when looking at the span of service of bus routes (particularly for Flash BRT) are the expanded reach of the system, connections to other transit modes, and the switch from single-occupant vehicle (SOV) trips to transit trips.

5.2 Key Considerations

- Increased passenger convenience. An increased span of bus service will attract more riders to the service because it offers increased flexibility for customers to navigate their schedules, and it is also more likely able to accommodate shift workers (those who work non-traditional hours).
- Cost-effectiveness depends on demand. Demand for Flash BRT service can guide when a route should operate, particularly if farebox revenue is a key contributor to agency funding. If demand doesn't exist during a certain time of the day, late night or early morning, for example, then it is acceptable that Flash BRT not operate during those times or operate at lower frequencies.
- Allow for transfers with other lines. The span of service of a Flash BRT line should be coordinated with other modes of transit to provide opportunities for transfer between modes and increased accessibility throughout the region. Flash BRT service in Montgomery County also should

consider WMATA Metrorail's service span, particularly at stations near Metro stations, to facilitate transfers. Alternatively, if demand is present for trips after Metro operating hours, particularly on the branch of Flash BRT that operates adjacent to the Metro, BRT could offer a viable alternative to extend service availability.

5.3 Guidelines

Spans of service should be context sensitive. For Flash BRT routes operating in activity centers and suburban operating contexts:

- Flash BRT spans of service should match other frequent transit services. Metrorail service spans on weekdays and weekends which are generally 5:00 a.m. to 1:00 a.m., with some slight variation.

Shorter spans are acceptable for routes not connecting to rail (MARC, Metrorail, and the future Purple Line light rail), especially in less-dense suburban areas. In these locations, shorter spans would be more cost-effective, as the land use also may not support longer spans, such as late-night service.

- The guidelines for regional BRT are highly contextual and based on demand and other readily available transit services. Riders are attracted to BRT for the efficient and frequent trips; however, with low demand or other viable transit options, Montgomery County may find it challenging to support a BRT route with long spans of service at this level.

The trunk of the BRT system would likely have a span of service that supports higher use and ridership, but branches to the system should have, at minimum, the span of the most frequent/premium local bus routes. The BRT system provides a premium service regardless of its classification as trunk or branch service and, therefore, should perform better and offer more frequent service than local routes.

Similar to frequency of service guidelines, Ride On Reimagined sets guidelines for spans of service. These are:

- BRT routes would operate between 5:00 and 1:00 a.m.
- Framework/high-capacity routes would run from 5:00 a.m. to 7:00 p.m. on weekdays and from 7:00 a.m. to 7:00 p.m. on weekends.
- Express routes would run on weekdays and Saturdays from 5:00 a.m. until midnight and 6:00 a.m. and 10:00 p.m. on Sundays.
- Commuter routes would run between 6:00 and 9:00 a.m. and 3:00 and 7:00 p.m. on weekdays.
- Coverage/local routes would run from 5:30 a.m. to 11:00 p.m. and 6:00 a.m. and 11:00 p.m. on weekends.
- Passengers would be able to request Microtransit (Flex) service between 6:30 a.m. and 7:30 p.m. Monday through Saturday, and Sunday service would be informed by demand.

6. Passenger Load

6.1 Description

The passenger load describes the number of passengers on a vehicle at a given time between stops. The load is derived from the boardings and alightings at each stop. Passenger load is a key metric that describes passenger comfort and provides a way to quantify the level of service being provided on the route. This is not to be confused with the boarding process on buses and how that impacts service.

It is important to strike a balance between cost-effectiveness, passenger comfort, safety, and dwell times. An ideal passenger load allows riders to move about comfortably and safely on board a bus and navigate boardings and alightings efficiently. Considering the fact that passenger load is reflective of the level of service being provided, it is important to balance the comfort of passengers with the cost-effectiveness of the route; a passenger load that is too small may maximize passenger comfort but will also minimize cost-effectiveness. In addition to reducing rider comfort and safety, high passenger loads increase dwell time and thus decrease travel speed.

6.2 Key Considerations

- Headways essentially define the passenger load. How frequently a bus arrives plays a significant role in how many passengers are on board. The more frequently a bus arrives, likely the fewer passengers are on board than if the same bus were to arrive only half as frequently.
- Shorter headways are more expensive. Shorter headways can reduce passenger load by spreading the same number of passengers throughout more buses; however, operating more buses on the same route costs more. Costs should be optimized to make BRT an attractive service with comfortable rides for passengers while also not becoming cost-prohibitive.
- Passengers are more willing to tolerate crowded conditions for short trips. Studies have shown that passengers are willing to tolerate more crowded conditions for short to moderate-distance trips on rapid services. Because BRT is faster and more convenient than local service, more crowding will generally be tolerated.
- Social Distancing. COVID-19 introduced the concept of social distancing to public transportation vehicles, and passenger load is the primary consideration in light of a pandemic. Metrics for the number of passengers who can safely ride a bus should be considered for any route as recommended by local, state, or national authorities during a health emergency.

6.3 Guidelines

Because vehicle size, aisle width, seating arrangements, and floor height, along with the size, number, and arrangement of doors, all influence vehicle passenger capacity, the guidelines for load are expressed as a multiplier of the number of seats. This reflects the fact that, like trains, BRT passengers will stand for both short- and moderate-distance trips. Thus, the target load of a BRT vehicle is comprised of both the number of seats and standing customers. These numbers represent the optimized number of passengers by service period to maximize comfort and cost-efficiency.

- In peak periods, the maximum target load should be 1.4 passengers per seat[10]
- In a bus with 40 seats, the target load is thus 56
- In a bus with 60 seats, the target load is thus 84
- In the off-peak periods, the maximum target load should be 1.2 passengers per seat
- In a bus with 40 seats, the target load is thus 48
- In a bus with 60 seats, the target load is thus 72

7. Service and Travel Time Reliability

7.1 Description

Reliability is one of the most important characteristics of a high-quality transit service. Reliable services arrive on time or within consistent intervals between buses on a given route, also referred to as on-time performance or schedule adherence. Service reliability is, therefore, associated directly with customer waiting time at stations. On the other hand, travel time reliability relates to how confident a customer can be about the time required for their trip. The less reliable the travel time, the longer the extra time customers plan for their trip to prevent being late.

7.2 Key Considerations

- Bus priority strategies are a means of improving the reliability of BRT services on urban streets. Dedicated runningways, TSP, and queue jumps are key in reducing delays caused by other vehicles and improving service and travel time reliability.
- While greater BRT implementation (capital) costs tend to lead to the reduction and consistency of travel times, faster travel times reduce operation costs for any given bus volume.
- Reliability is important to both BRT customers and operators. Improved travel time consistency means that regular customers can begin their trips at the same time every day and expect consistent travel times, and transit operators can reduce the amount of recovery time built into their schedules, which can lead to operating and maintenance savings.
- Runningways should ideally be implemented where and when congested conditions are common. If dedicated runningways are present only in part of the corridor, they should ideally be present in the most congested segments. Similarly, part-time bus lanes should be active during the most congested times, typically peak hours. Nevertheless, runningways can be implemented where traffic and right-of-way allow their implementation.
- Regional service is dependent on other transit services offered. Schedule adherence facilitates transfers to other modes and services.

[10] Higher loads may be tolerated for short distances where it is not practical to add more vehicles to reduce loads.

7.3 Guidelines

Service reliability is assessed based on on-time performance. A trip is considered on time if the bus departs no more than one minute early or five minutes late. If a route uses headway-based scheduling, on-time performance is relative to the target headway rather than a fixed schedule. On-time performance for Flash BRT is 85 percent or higher, regardless of the operating context.

Table 1.6: Service and Travel Time Reliability Guidelines

	Operating Context		
Service Parameter	Activity Center	Suburban	Regional
Service Reliability (on-time performance)	85% or higher	85% or higher	85% or higher

8.Fare collection and Boarding Protocols

8.1 Description

How a passenger boards a Flash BRT vehicle and pays the fare is an important part of the user experience. Simplifying the procedure not only results in a better experience for the customer but also speeds up the boarding process, which reduces dwell times and boosts travel speed. All-door boarding is one of the most effective ways to reduce dwell times. In all-door boarding, riders who have prepaid may board and validate their fare at all doors.

8.2 Key Considerations

- Reduce boarding times. Off-board fare payment is one of the most effective ways to reduce bus dwell time. Based upon peer analysis, 20 seconds is the recommended dwell time for buses on a full BRT system, which is difficult to achieve if all-door boarding and/or off-board fare payment is unavailable.
- Improve overall travel speed. Shorter headways reduce dwell times by speeding the boarding process. With buses running more frequently between stops, queue lines are comparatively reduced, and overall travel time for the route is improved.
- All-door boarding is a key aspect. All-door boarding allows passengers to board more efficiently, theoretically halving the boarding time of a bus with front-door boarding only.
- Stopping rules. It may be appropriate to state that regular BRT services will stop and open doors at all stations, while special peak period express routes will stop only at designated stations.

8.3 Guidelines

All door boarding often relies on alternative operating policies for passengers to have smart cards with needed balance or a cash payment receipt from a station vending machine. Although onboard cash fare payment will be allowed, off-board fare payment with cash is encouraged and facilitated by ticket vending machines (TVM) at every Flash station. Due to the high number of passengers that will need to board for each trip, fare payment is most efficient when done off-board so that queuing and payment can be completed prior to bus arrival. Alternative fare enforcement also is likely used in these cases, considering Flash BRT is a barrier-free system. A validator should be placed at every door.

Integration with existing fare systems is highly recommended. Streamlining and integrating BRT fare systems with existing systems will help streamline the customer experience and make the service more attractive and easier to use. The Flash BRT service is already integrated with WMATA's fare payment system, thereby simplifying passenger payments between systems. Any BRT line implementation should also follow this practice.

9. Other Services Sharing a BRT Corridor

9.1 Description

Most BRT corridors are implemented on streets and corridors with existing heavily traveled bus routes. Although the development of the BRT service will involve restructuring existing bus routes along the corridor, some existing routes will likely still overlap the BRT corridor, even if just for a short segment. Additionally, in some operating contexts, the BRT station spacing may justify the maintenance of parallel local bus services, making more frequent stops. Therefore, guidelines are needed for other services sharing a corridor or interfacing with BRT services.

9.2 Key Considerations

- Existing bus routes on a BRT corridor may need to be restructured. Local routes should feed rather than duplicate the BRT service to the extent possible. In addition to transfers where services cross the corridor, BRT termini stations can serve as focal points for connecting bus services.

- BRT can accommodate express and local services in a single facility. A BRT corridor can include service patterns that service every station and patterns skipping certain stops. Although non-BRT services may share a corridor with BRT services on the curb lane, those routes should service distinct bus stops, ideally located after a BRT station, to minimize delays. Having BRT and local buses at the same stations would require longer facilities and potentially greater station costs.

- The operating rules should clearly state when buses are allowed to pass other buses or vehicles on the BRT route or runningway. On most existing facilities, buses are allowed to pass other buses in station areas only where passing lanes are provided. The only other passing that is permitted is around disabled vehicles or maintenance vehicles, and this is only at certain designated maximum speeds.

- Coordination and communication between entities are key when various transit services operated, regulated, and administered by different government entities share a corridor. For instance, a major arterial might have school buses, commuter buses, intercity buses, private express buses, and local buses. Restricting the use of BRT runningways leverages corridor improvements leading to a more efficient operation.

9.3 Guidelines

Guidelines for services sharing a BRT corridor are set for three types of services, parallel local services, limited-stop services, and feeding and cross services.

- Parallel local services operate at lower speeds; therefore, these services should give priority to BRT buses. The number of local bus routes and stops on BRT corridors should be reduced as much as possible and clear rules around passing and lane use must be clearly defined.
- Limited-stop services can increase speed and capacity on a BRT corridor while adding complexity to the system from the customers' point of view. Passing provisions at stations ease limited-stop operations on BRT corridors.
- Feeding and cross services bus stops should be planned to ease transfers between these services and the BRT service. See Station Area Chapter for more information.

10. Service Reviews

10.1 Description

Service review refers to a regularly recurring formal performance review of a route against established benchmarks so that corrective actions can be taken. While excellent service delivery and customer service are goals of transit service in general, this is even more important in a BRT service since it is branded as a premium service. Also, where possible, operators should receive additional training about BRT-specific goals and other training as applicable.

10.2 Key Considerations

As part of the Ride On Reimagined Study, Montgomery County, with help from stakeholders and the public, developed a set of goals and measures to guide the project and develop a vision for transportation in the county. The three underlying goals of safety and Vision Zero, environmental and climate resiliency, and economic development and equitable access all have established measures for routes in the system that closely align with BRT system best practices nationwide. Measures of ridership, revenue hours, bus trips per capita, deadhead-to-revenue time ratio, and others are used to review the performance of the associated BRT routes.

Transit agencies should set policies and deploy appropriate supporting tools when implementing a BRT system. While the basics of training a person to operate a transit bus are common between BRT and standard bus transit, some areas are unique to BRT. Operators should be trained on best practices specific to BRT routes; for example, when a BRT line relies on a shoulder lane, training is necessary to prevent potential conflicts. Additionally, operators and communications supervisors should be trained to understand and support active headway management to ensure that minimum headways are met.

10.3 Guidelines

Table 1.7 outlines key performance indicators (KPIs) specific to BRT routes, including but not limited to ridership, customer satisfaction, service reliability, performance, access, and more.

Table 1.7: BRT Key Performance Indicators

Category	KPI	Description	Benchmark	Frequency	Data Source
Ridership	Ridership	Daily passenger boardings by route by time period (daily, peak, off-peak, weekend)	Route-specific	Monthly	APC
Ridership	Ridership Trends	Percent change in daily boardings	Route-specific	Quarterly	APC
Ridership	Passenger-Miles Traveled	Daily passenger-miles traveled (PMT) by route by time period (daily, peak, off-peak, weekend)	Route-specific	Monthly	APC, CAD/AVL
Service Reliability	On-Time Performance	Percentage of on-time by timepoint by period (daily, peak, off-peak, weekend)	85% or higher	Monthly	CAD/AVL
Performance	Travel Time	Absolute travel time (including dwell) by segment (timepoint to timepoint) and direction by period (daily, peak, off-peak, weekend) Travel time ratio to baseline/reference time	Route-specific 2.4 or lower	Monthly	CAD/AVL
Performance	Travel Time Reliability	Variability in travel time by segment (timepoint to timepoint) and direction in weekday AM and PM peak periods	2.7 or lower	Monthly	CAD/AVL post-process
Performance	Productivity	PMT per revenue vehicle hour-square-foot	0.4 or higher	Annually	APC, CAD/AVL post process, NTD reporting
Customer Satisfaction	Customer Satisfaction Rating	Ratings on service attributes	Above local service average	Periodic	Periodic rider survey
Customer Satisfaction	Customer Service Feedback	Number of positive and negative feedback comments	Route-specific	Quarterly	Customer calls, emails, etc.
Access	Mode of Access	Percent of access mode by station	Station-specific	Periodic	Customer survey

10.3.1. Ridership

Total daily passenger boarding is an important metric for measuring the success of a BRT line. Ridership will be collected and reported to the National Transit Database (NTD) as required by the FTA.

10.3.2. Ridership Trends

Ridership trends consider total daily passenger boardings over time as a way to measure the change in route performance. This KPI is primarily used to establish and examine trends in a BRT corridor or route.

10.3.3. Passenger Miles Traveled

Passenger miles traveled (PMT) is an important baseline metric for assessing service systemwide and is required to be reported to the NTD, typically on a quarterly basis, derived from Automated Passenger Counter (APC) technology. APCs are able to provide stop level ridership data (boardings/alightings) by route direction. PMT feeds various other metrics that can also be used to determine the effectiveness of a BRT line, including PMT per revenue vehicle-mile and PMT per mile of route.

10.3.4. Customer Satisfaction Ratings

Customer satisfaction ratings, determined through a periodic satisfaction survey, are important for determining the level of service being provided to customers. BRT offers a distinctive customer experience, including increased passenger amenities, station comfort, and system speed; customer satisfaction ratings help determine if these services are appropriately provided and realized.

10.3.5. Customer Service Feedback

Any feedback received from customers, positive or negative, provides insight into the service being provided. Feedback, be it positive or negative, is not collected at regular intervals but rather as determined by passengers reporting feedback. This information should be used to supplement periodic customer system surveys.

10.3.6. On-Time Performance

BRT offers a premium service to customers, of which the on-time performance reflects through reliability and consistency. Once a route has begun operation, on-time performance (OTP) should be reported beginning in the second quarter. OTP should be reported for each departure and time point in each direction as well as on a route-wide basis and it is recommended that the classification of trips into time periods (peak/off-peak) align with the travel time KPI. The generally accepted definition for “on-time” is no more than one minute in advance of the scheduled time and less than five minutes late of the scheduled time.

10.3.7. Travel Time

Travel time is a principal measure for assessing the performance of a BRT route, because a fundamental motivation for bus rapid transit is to improve this attribute of service. APC data can be used to determine bus travel time between stations and can also be used to determine dwell time; this data should be reported monthly.

10.3.8. Travel Time Reliability

Travel time reliability addresses schedule certainty for a passenger once they are aboard a bus. Reliability of this metric means that a passenger can be certain of their travel time when riding a BRT line. The classification of trips into time periods (peak/off-peak) should align with the on-time performance and travel time metrics.

10.3.9. Productivity

Productivity is a metric that combines PMT and revenue-square-foot-hour of service to compare a route to itself and also directly to other routes and modes. By looking at the floor area in square feet of a vehicle operating on a BRT route, such generalizations are possible because the baseline is square footage, not vehicle or mode specific. Measuring productivity allows an agency to assess whether BRT resources are being deployed effectively in the network.

10.3.10. Mode of Access

The mode of access metric measures how customers reach a BRT route. The mode can be obtained via onboard surveys and the list of mode options provided to customers should be extensive. Mode of access can be used to determine the nature of a route (commuter, etc.) and also if any first/last mile improvements can be made. This metric should not be used to determine route effectiveness as it generally is reflective of service options and land use.

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Chapter 2:

Station Platform Design

Chapter 2 – Stations and Platform Design

Introduction

Stations are both the first and last impressions that customers have of a bus rapid transit (BRT) system, and therefore set the tone for the entire rider experience. This section presents the Montgomery County standard for Flash BRT stations, supporting a high-quality, consistent user experience while providing flexibility for space-constrained station areas. For the purposes of this section, platforms are defined as the area immediately adjacent to where BRT vehicles stop to pick up and drop off passengers, and generally include amenities like benches and weather shelters. Stations include additional components adjacent to the platform such as pathways to/from the platform and additional amenities such as bicycle racks. Some amenities may be located directly on the platform or elsewhere at the station, depending on the location and available space. The term “station area” is used to describe the greater context in which a station is located and may include additional infrastructure or property that is outside of the control of the Montgomery County Department of Transportation (MCDOT).

Key objectives for station and platform design include:

- Providing a superior customer experience during which users feel safe, comfortable, and have access to the information they need in real time
- Complying with and (in some cases) exceeding state and federal accessibility requirements to support and encourage ridership by users of all abilities
- Promoting the visibility of Flash BRT station while also maintaining and enhancing their architectural quality and unique identity

1. General Guidelines and Standards

Flash BRT station and platform standards consider and incorporate several guidelines and standards set by regional and national entities. MCDOT is committed to meeting all legally mandated requirements for accessibility, and to meeting or exceeding the best practices for transit design established by regional, state, and national agencies. A brief discussion of relevant guidelines and standards is included in this section, with specific recommendations incorporated into the station and platform discussions that follow.

1.1. Americans with Disabilities Act (ADA)

Bus transportation facilities are governed by several different sections of the ADA, with the most recent regulations adopted in 2010. Relevant sections include, but are not limited to, 209 (Passenger

Loading Zones and Bus Stops), 218 (Transportation Facilities), 402 (Accessible Routes), 405 (Ramps), and 406 (Curb Ramps).

An accessible boarding area must be provided, typically measuring a minimum five feet long (parallel to the curb) by eight feet wide (perpendicular to the curb). This includes five feet of width for a wheelchair waiting area, plus additional width to deploy a wheelchair ramp to serve the waiting area (typically three feet). Longer ramps may require additional length (ADA Accessibility Guidelines §810.2.2).

1.2. Public Right-of-Way Accessibility Guidelines (PROWAG)

The U.S. Access Board began developing new Public Right-of-Way Accessibility Guidelines (PROWAG) in 1999 and finalized them in August 2023. PROWAG generally expands upon ADA guidelines, with a specific focus on sidewalks and streets, crosswalks, curb ramps, pedestrian signals, on-street parking, shared-use paths, and other components of public rights-of-way.

Many sections of the guidelines can be applied or connected to transit stations/stops such as sections R302 (Pedestrian Access Routes), R305 (Detectable Warning Surfaces), R308 (Transit Stops and Transit Shelters), R407 (Ramps), R409 (Handrails), and R410 (Visual Characters on Signs). For transit stations/stops with passenger loading zones, section R310 also should be considered. An illustration of a basic transit stop from PROWAG is shown below in Figure 2.1. Although PROWAG does not specify accommodations for all-door boarding, it would be best practice to apply components such as detectable warning strips along the length of the platform if all-door boarding is used. Where ramps are expected to be deployed from the bus (typically at the front door), extra clearance may be needed to meet ADA standards for maneuverability.

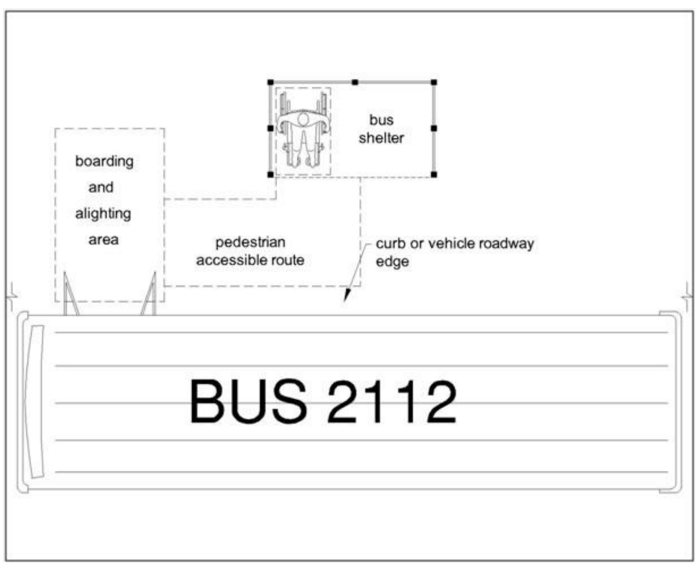


Figure 2.1: Boarding Connection Illustration (PROWAG R308.1.3.2 Connection)

1.3. National Association of City Transportation Officials (NACTO)

NACTO's Transit Street Design Guide[1] provides a range of best practices for bus and rail transit stations/stops located on city streets. Typical dimensions for a standard bus stop are illustrated in Figure 2.2.

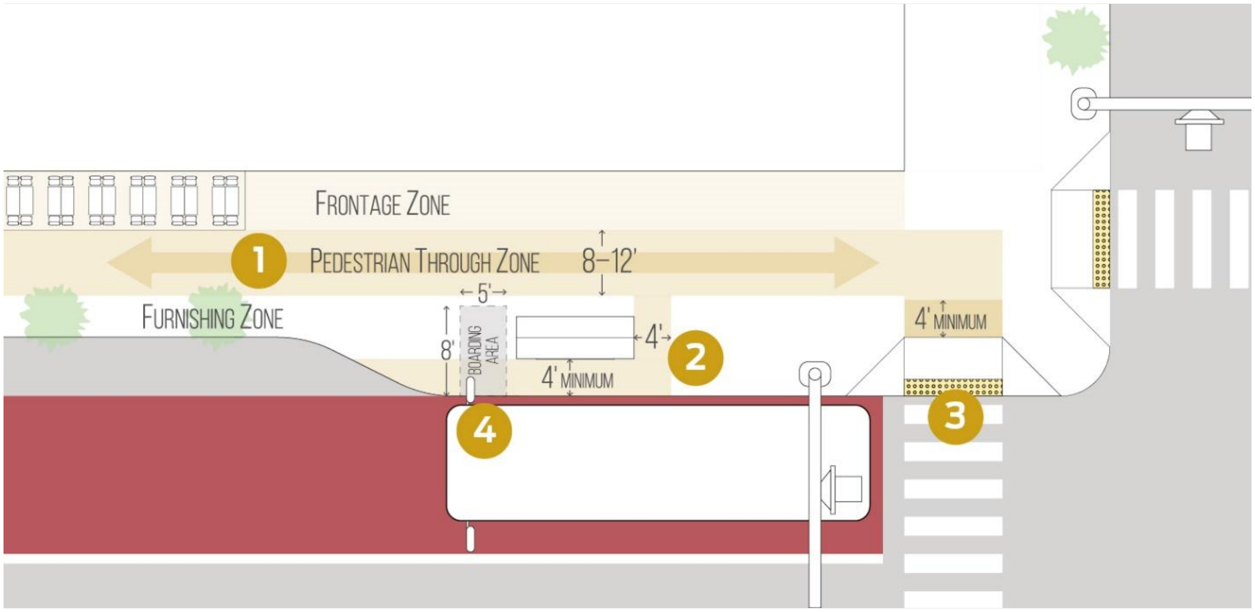


Figure 2.2: Transit Platform Component Widths (NACTO)

The most common types of bus stops are pull-out stops, where buses exit the flow of traffic to serve a stop along the shoulder of a road in street space that is frequently allocated to parking. Longer zones are needed to facilitate ingress and egress to these types of stops. Platform lengths are listed in the table below.

Table 2.1: Minimum Platform Length for Pull-Out Stops by Vehicle Type

Stop Position	40' Bus	60' Bus	2 x 40' Bus	2 x 60' Bus
Near-Side	100	120	145	185
Far-Side	90	100	125	165
Far-Side (Right Turn)	140	160	140	230
Mid-Block	120	145	185	210

NACTO recommends in-line bus stops (where buses service the stop without exiting the flow of traffic) for their operational and accessibility benefits, such as reduced dwell times and because they

[1] https://nacto.org/publication/transit-street-design-guide/

free up sidewalk space for circulation and other purposes. Figure 2.2 above illustrates a bus stop configuration where the sidewalk is extended out toward travel lanes to allow for this type of service. Platform lengths for in-line stops are listed in the table below by vehicle type.

Table 2.2: Minimum Platform Length for In-Lane Stops by Vehicle Type

Stop Position	40’ Bus	60’ Bus	2 x 40’ Bus	2 x 60’ Bus
Near-Side	35’	55’	80’	115’
Far-Side	45’	65’	90’	130’
Mid-Block	35’	55’	80’	115’

For these types of stops, NACTO identifies four critical items:

1. Locate platform with at least 10 feet of clear distance from crosswalk or curb return. Measure to transit stop pole at near-side, or rear of transit vehicle at far-side.
2. While five feet is the minimum curb length for a receiving facility at each boarding door (ADA Std. §810.2.2), design platforms to be continuous through all doors, and consider additional elements to improve passenger comfort.
3. Provide 5 to 10 feet of distance between each additional transit vehicle expected to be dwelling at the platform consistently throughout the day.
4. Design boarding bulbs and islands to accommodate proper drainage and sweeping; tight radii may require maintenance agreements to ensure bulbs are properly cleaned and maintained.

NACTO also identifies recommendations for different types of platforms ranging from sidewalk/curb level to “mini high” platforms that are retrofits for older streetcar systems and buses with high floor boardings. For the type of near-level boarding that the Flash BRT uses, NACTO emphasizes buses being able to pull very close to the curb to eliminate the gap between it and the vehicle and following the best practice of installing detectable warning strips at the platform edge. Rub rails along the platform edge can help the driver to more effectively dock the bus at the station and protect buses from striking it. They are discussed later in this chapter.

1.4. Maryland Department of Transportation (MDOT) State Highway Administration (SHA) Guidelines

The SHA’s Accessibility Policy & Guidelines for Pedestrian Facilities along State Highways (2010) provides guidance to planners and engineers working on facilities within the agency’s jurisdiction and recognizes that SHA has a responsibility to provide safe and accessible infrastructure for pedestrians (in additions to motorists). It designates three levels of projects (based on Access Board standards) based on their level of complexity, which informs general expectations for when and where deficiencies in accessibility need to be addressed. Where accommodations cannot be made (such as in highly constrained rights-of-way where additional property acquisition is infeasible), the document also outlines guidelines for design waivers.

The guidelines are generally consistent with ADA Accessibility Guidelines standards but exceed them in some cases (such as sidewalk width) due to the higher travel speeds of vehicles on highways. SHA has been converting all pedestrian-activated (push-button) signals to Accessible Pedestrian Signals (APS), which provide additional tones and messages to people with limited vision.

Where new Flash BRT service is being planned adjacent to SHA facilities, MCDOT and SHA should work together to identify opportunities to coordinate APS deployment with other planning, engineering, and construction efforts to help provide the maximum benefit of infrastructure investments.

1.5. Washington Metropolitan Area Transit Authority (WMATA or Metro) Station Design Criteria

WMATA's Guidelines for the Design and Placement of Transit Stops (2009) provides guidance to Metro and its jurisdictional partners for the design of transit stops in the National Capital Region. It includes sections on bus stop placement and type (such as near-side, far-side, and mid-block), bus stop elements and passenger amenities, and bus stop spacing. The agency also completed a Bus Stop Amenity Reference Guide in 2019 to provide some updates to the 2009 document.

The design criteria specify amenities by bus stop type as illustrated in Table . Enhanced Service Bus Stops are designated limited-stop/skip-stop service and/or BRT. Accessibility standards are considered minimums and are consistent with the ADA Accessibility Guidelines.

Table 2.3: Amenities by Station Type – WMATA Guidelines

Amenity	Basic Stop	Enhanced Service Bus Stop	Transit Center
Bus Stop Sign	Yes	Yes	Yes
ADA 5'x8' Landing Pad	Yes	Yes	Yes
Sidewalk	Yes	Yes	Yes
Lighting	Evening Service	Yes	Yes
Seating	Trip Generator Bound	Yes	Yes
Expanded Board & Alighting Area (Rear-door Access)	No	Site Specific	Yes
Bus Bay (Pull Off)	No	Site Specific	Yes
Shelter(s)	1 (50+ boardings/day)	1	Yes
Trash Receptacle	Site Specific	Yes	Yes
Information Case	Yes	Yes	Yes
System Map	Contingent on Shelter	Yes	Yes
Real-time Display (LED + Audio)	Optional	Yes	Yes
Interactive Phone System	No	No	Yes

Other amenities to consider from an accessibility standpoint include information cases, lighting, landing pads/passenger waiting areas, benches, and shelters. Metro's standards for these items are generally minimums for bus service that are exceeded by Flash BRT standards. A prototype design for an Enhanced Bus Service Stop that would be recommended for BRT service is illustrated in the figure below.

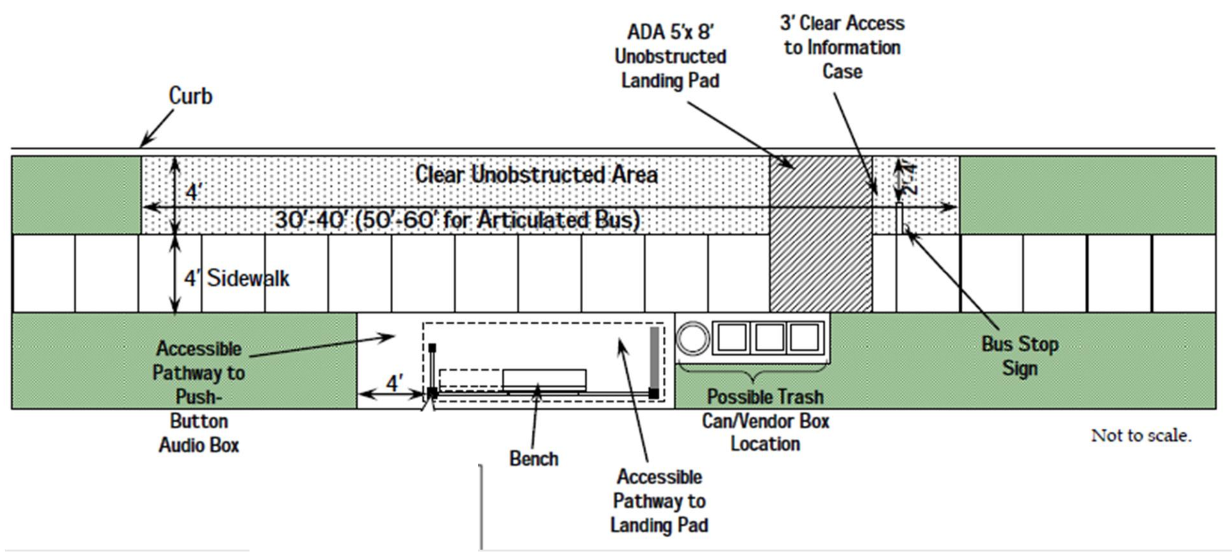


Figure 2.3: Enhanced Bus Service Stop Prototype Diagram (WMATA)

2. Flash BRT Station Component Dimensions and Guidelines

The table below provides an overview of the major station component dimensions and guidelines for Flash BRT. For the purposes of these guidelines, "Preferred Standard" is defined as the standard that should be met by all new Flash BRT stations. The "Constrained Site Minimum" is an exception that may only be allowed in a highly constrained context where installation of a station is necessary and allowing an exception is essential for making the station operationally feasible. "Single" refers to stations with less-frequent service where only a single bus needs to dwell at a time, and "double" refers to stations served more frequently or by multiple lines of service where greater dwell capacity is needed to accommodate more than one vehicles.

Table 2.4: Overview of Flash BRT Station Component Requirements

Station Component	Preferred Standard	Constrained Site Minimums[2]
Platform Length*	Single: 65 feet Double: 150 feet	Single: 65 feet Double: 128 feet
Bus Berthing Length	Single: 65 feet Double: 150 feet	Same as preferred

[2] Constrained Site Minimums reply to acceptable standards where station conditions do not allow the Preferred Standards. If one Station Component is constrained, other Station Components should still adhere to the Preferred Standards where possible.

Platform Depth*	In-line: 15 feet Median: 13 feet	In-line: 12 feet Median: 13 feet
Travel Path Clearance	4 feet	Same as preferred
Tactile Strips	Length of platform; not included	Same as preferred
Slope	2% max in any direction in the station, 5.0–8.3% for ramps	Same as preferred
Benches	2	1
Leaning Rails	Single: 1 rail Double: 2 rails Length needs to align with windscreen structural module; benches are preferred over lean rails	Can be omitted at highly constrained sites
Canopies	2 canopies combine to form a single covering Single: 2 Double: 4	Can be omitted at highly constrained sites
Weather Panes/Windscreen	Work in conjunction with canopies to form station shelter Height should be 8 feet for large canopies and 7 feet for small canopies or at uncovered areas across entire length Provide a 6-inch minimum gap at the bottom for maintenance and cleaning Continuous transparency except when there is rear access	Can be omitted/modified at highly constrained sites
CCTV Cameras	Single: 3 Double: 4	2
Real-Time Information Displays	Single: 2 Double: 3	2
Ticket Vending Machines (TVMs)	1 provided at all stations; additional TVMs may be considered at high-ridership stations	None
Public Wi-Fi	Single: 0 Double: 1 access point for stations with high transfers/boardings	None
Emergency Phones/Help Points	None; can be provided by adjacent property owners (e.g., schools, hospitals) if desired	None
Landscaping and Planting	Developed in coordination with local jurisdictions/property owners.	Station to be designed around any existing street trees; assume no landscaping/ planting added
No Parking Zone and Signage	All stations	All stations

**Platform Dimensions defined from back of curb to rear platform edge*

3. Station Siting

In general, the locating, or “siting,” of stations across the length of a Flash BRT corridor should be oriented toward enhancing the usability and accessibility of the BRT network as a whole. The siting of stations in relation to BRT network interfaces, the corridor’s consistency and conditional factors, and infrastructure characteristics should facilitate key network transfers, optimize transit access, enhance transit travel times and efficiency, and support connected mobility in general. Specifically, guidelines for station siting should focus on considerations related to mobility network integration, connections with key activity centers, and runningway conditions. For additional considerations on station access, refer to Chapter 6.

Concepts surrounding a site-specific design response should highlight the flexibility and modularity of Flash BRT station design. Site specificity should include design elements that can respond to unique site conditions such as microclimate, shading conditions, slope, existing utilities, driveways, local stakeholder concerns, available right-of-way, and surrounding land uses. These factors would also need to be considered integration of Flash BRT into transit centers where the design guidelines of another transit agency may take precedence, and other design specifics such as angled bays would need to be considered.

3.1. Mobility Network Integration

A primary manner by which a station’s location can enhance BRT’s usability, access, and overall ride experience is integrating stations with transportation/mobility hubs throughout the BRT network. BRT stations should be sited wherever major transportation hubs or network transfer points exist and should be situated to facilitate transit and/or intermodal connections as seamlessly as possible. Examples of transportation/mobility hubs warranting BRT station integration include, but are not limited to, the following:

- Rail stations, including WMATA, MARC, and Amtrak facilities, which often serve as key mobility network connection points that are essential for the facilitation of both regional and intercity transit trips
- BRT network transfer points, where connections can be made between multiple BRT lines and where use of the full BRT network is enabled
- Transit centers and key local transit network connection points, which allow riders to transfer between BRT and all other bus network route types/tiers
- Park-and-ride facilities and mobility hubs, which serve as primary BRT access points for riders using personal vehicles or other first-/last-mile solutions to complete their trips

Overall, siting stations at locations where BRT can link with these facilities will optimize BRT access from other BRT lines, other modes, and other connecting transit and mobility services. This supports the usability of BRT as an integrated part of the regional mobility network, better enabling effective local and longer-distance trip-making.

3.2. Connections with Key Activity Centers

The usability of BRT and its overall effectiveness as a transportation mode can be further enhanced by siting stations in coordination with key centers of activity, or destinations, along BRT corridors. While BRT should not, as a faster and more limited-stop-oriented service, stop at every residential or commercial location along a corridor, it should serve key destinations that feature high population density or transit propensity, feature high employment density, or are in high demand in general. Examples of key activity centers warranting direct BRT station connections include, but are not limited to, the following:

- Higher-density residential facilities or districts, especially those with demographic and socioeconomic factors indicating greater-than-average transit propensity
- Major shopping centers or retail/service destinations
- Major employment centers
- Colleges and universities
- Hospitals and/or other facilities that serve as destinations for medical appointments

By siting stations that provide access to key activity centers, BRT will be ensured to provide effective and efficient transit service directly at the locations where riders want to go. BRT stations should be sited at specific locations that facilitate direct, convenient access to key activity centers, enabling riders to access important destinations seamlessly.

3.3. Runningway Conditions

Wherever possible, the environmental and infrastructure conditions of the BRT runningway should be considered as part of the BRT station siting process to enhance both the BRT's efficiency and the overall quality of its ride experience. Stations should be sited strategically to help the BRT operate more quickly and reliably through busy intersections and congested areas. Specifically, in the vicinity of signalized intersections, stations should be located at the "far side," or just beyond the intersection and the traffic signal, as opposed to the "near side," or just before the intersection and the traffic signal.

By siting stations at the far side of intersections, BRT vehicles can take advantage of green signals, as well as any transit signal priority (TSP) infrastructure that may exist and proceed through intersections before having to stop. This helps the BRT to only stop once at a location (when serving the station), as opposed to a near side siting, which would often require BRT to stop twice (when serving the station before the intersection and then at a red signal at the intersection itself). When applied at numerous intersections corridorwide, the travel time savings and reliability enhancement of far-side stop siting can have a considerable effect on the overall usability and ride experience of the BRT network as a whole.

Wherever possible, BRT station siting should coordinate with a corridor's existing pedestrian infrastructure. For example, stations should be sited at locations that directly connect with existing pedestrian access paths, or where convenient and safe connections with these paths can be established. To physically reach BRT stations, many riders rely on access paths such as sidewalks, crosswalks, and walkways to and from destinations. The siting of BRT stations should ensure that these essential infrastructural elements are directly accessible.

The placement of BRT stations needs to balance two important but sometimes competing factors: accessibility to nearby key activity centers along the route and operational efficiency that can be gained or lost due to route selection. Routing BRT service along a particularly busy corridor may be more convenient in some instances because it reduces the distance between the station and a rider's destination but may negatively impact the quality of service along that corridor due to congestion that causes travel delays. Travel speeds and reliability may increase by placing the station on a parallel or adjacent street to a given corridor, and first-/last-mile treatments such as wayfinding and lighting can improve the comfort and convenience for the non-transit portion of a person's trip.

Where relevant, BRT station siting should consider environmental factors, such as slope or other unique topographic conditions. Locating stations on or adjacent to steep grades may violate ADA standards and inhibit access to the BRT by all rider groups. To maximize accessibility, stations should be sited at locations where connections between the BRT and the surrounding environment can be made feasibly, conveniently, and safely by as many riders as possible. Additionally, to enhance the BRT ride quality by improving the wait experience at stops, station siting should avoid locations subject to particularly severe exposure to environmental elements that negatively impact comfort and health, such as wind or noise.

3.4. Hierarchy of Stations

Deployment of different BRT station types will be dependent on factors such as ridership, existing and future land uses, available right-of-way, and connecting transit or active transportation infrastructure. The table below provides an overview of the types of stations that are covered in greater detail in the section that follows.

Table 2.5: Characteristics of Station Types

Station Type	Characteristics / Applications
Side/Curb-Running	▪ Includes single, double, and double-extended lengths ▪ Double and double-extended to be used mainly at terminal/transfer locations ▪ May include "floating" configuration with a bicycle lane running between station and adjacent infrastructure or land uses
Center-Running	▪ Could require use of offset station platforms accessed by crosswalks
Constrained Configuration	▪ Reserve option to be used only in exceptional circumstances where side/curb-running cannot be accommodated ▪ Typically integrated into existing sidewalk

Some transit agencies that have implemented BRT include shared platform stops—stations that are served both by BRT and local bus service provided either by the same agency or another jurisdiction. MCDOT does not anticipate the development of any of these types of stops due to the use of near-level boarding with BRT. Where service may overlap, the best practice is to place local bus stop behind the BRT station platform to prevent the slower service from delaying the faster service.

Double stations (those that can accommodate more than one transit vehicle and additional amenities) may be considered at key locations based on the following factors:

- Existing and future passenger demand
- Transit service plans and proximity to connecting and complementary routes
- Capital cost
- Operating and maintenance cost
- Available right-of-way
- Compatibility of surrounding development plans and land use policies
- Layover needs

MCDOT also is developing a runningway configuration using a single BRT lane that is reversible and used only by buses traveling in the peak direction. Station platform pairs are placed in an offset side configuration that is similar to the configuration of center-running BRT. Buses traveling in the off-peak direction exit general-purpose travel lanes to serve their station platform in the dedicated runningway, then rejoin the general-purpose flow of traffic to continue their route. The center-running lane is widened at station locations to accommodate two-way travel. This operating scenario is used only where available right-of-way is highly constrained and no alternative is feasible. No unique station design elements are anticipated for this scenario.

4. Station Footprint, Configuration, and Modularity

The station footprint and configuration are determined by roadway constraints as well as expected ridership at each station. The station footprint should cover the length of the vehicle being used to service the station plus corresponding pedestrian access paths of travel and clearances; however, some flexibility in dimensions may be needed when operational and accessibility needs dictate deployment of a station in a highly constrained location.

Station platforms should be a consistent height along the corridor to allow for consistent ingress/egress and to simplify servicing the platform for transit operators. The platform also should include a rub rail—a rubber bumper that is affixed to the face of the platform that allows operators to pull buses as close as possible to the platform edge while avoiding damage to the vehicle cause by impacts.

For Flash BRT, the single side/curb-running station platform will be the default configuration, with alternatives selected based on the context of a station location. Visual representations of the station configuration types are illustrated in the pages that follow.

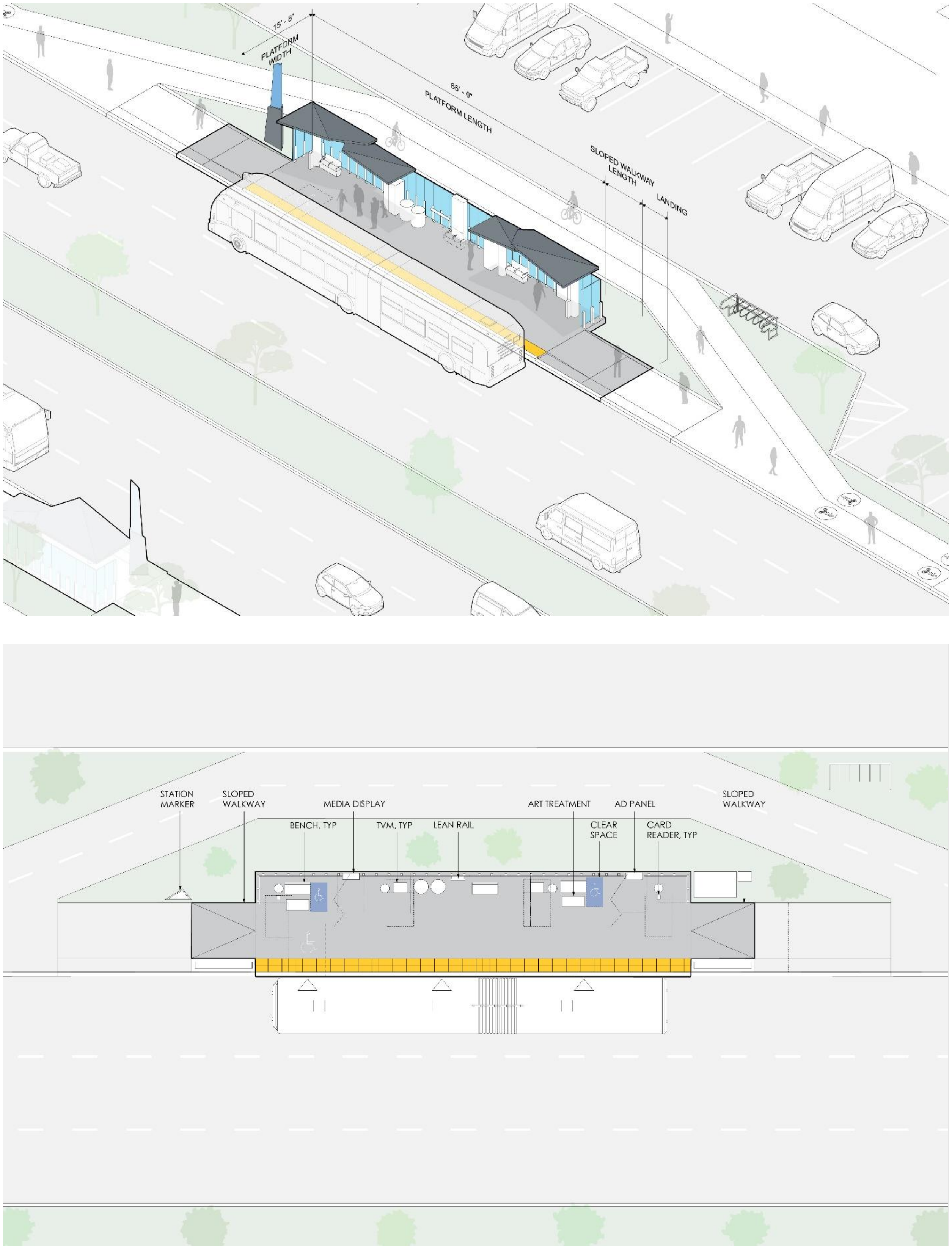


Figure 2.4A: Side-Running – Single-Platform Station

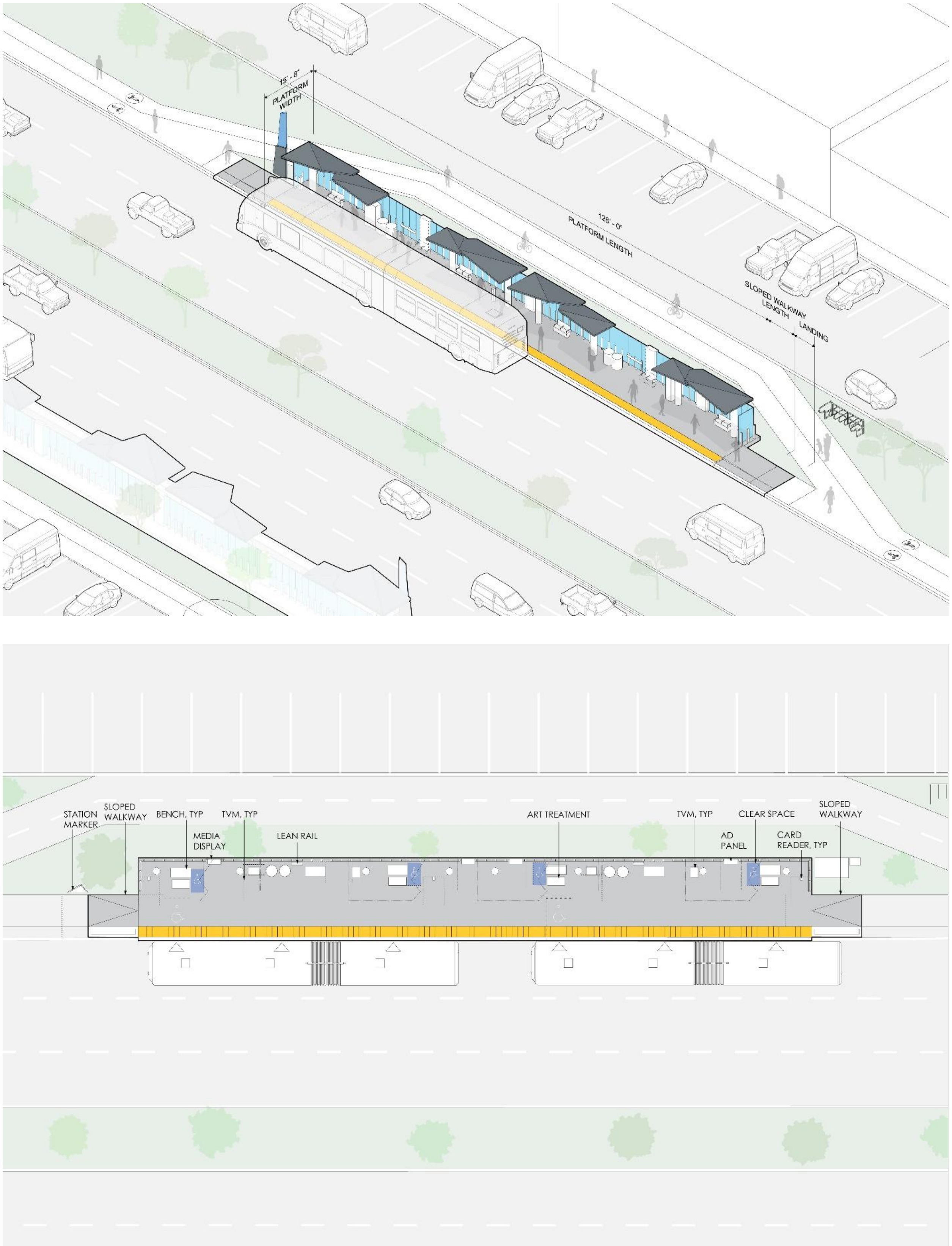


Figure 2.4B: Side-Running – Double-Platform Station

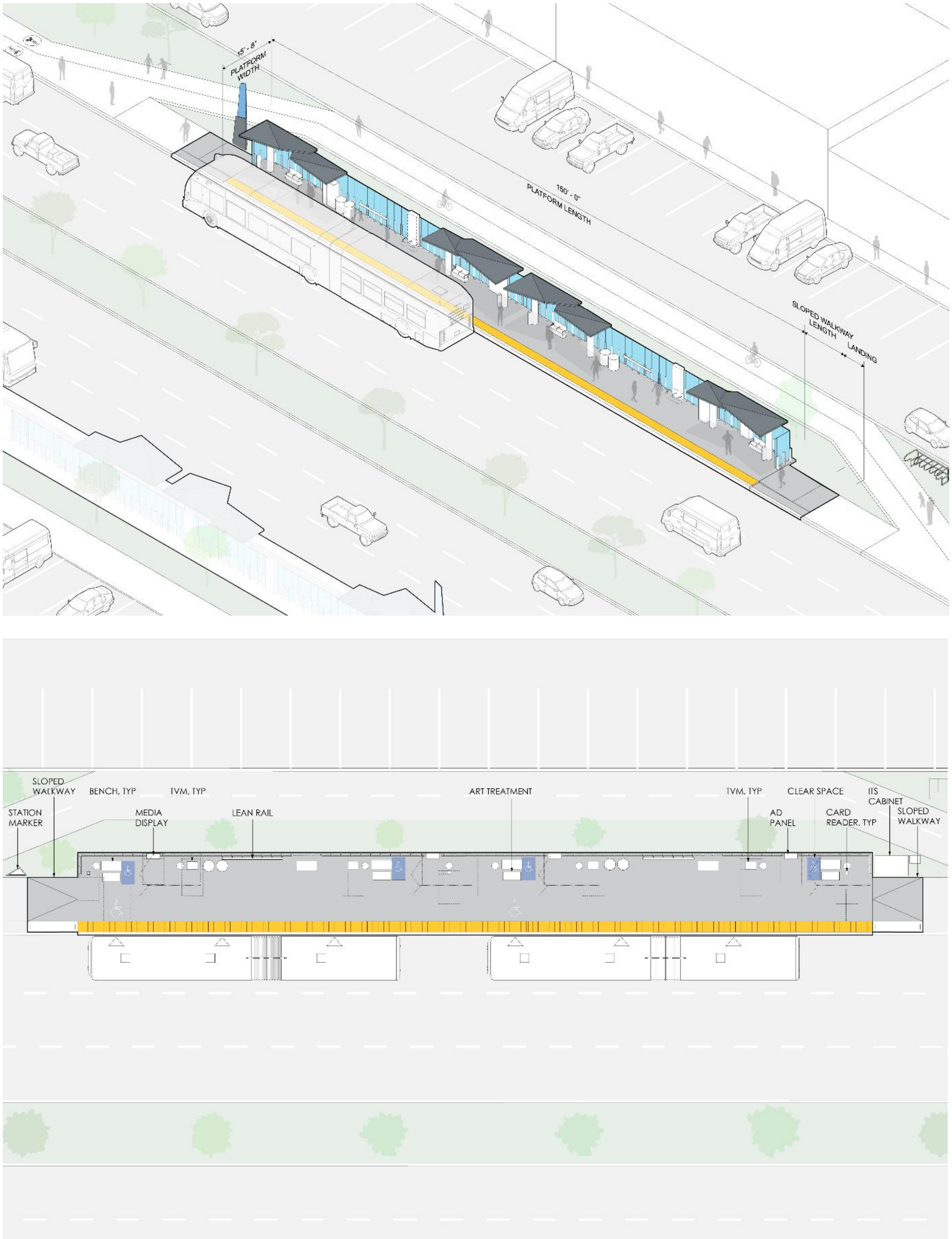


Figure 2.4C: Side-Running – Double-Platform – Extended-Length Station

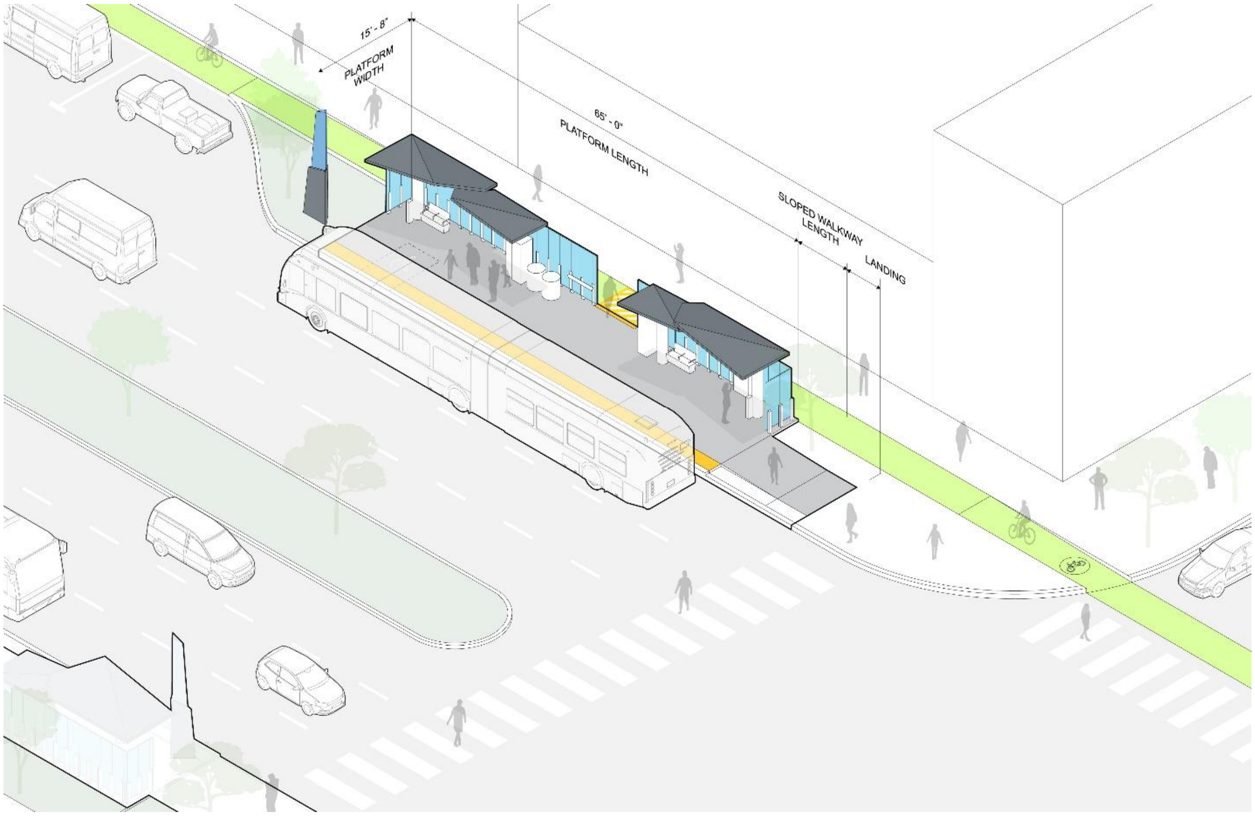


Figure 2.4D: Side-Running Station with On-Street Bike Lane

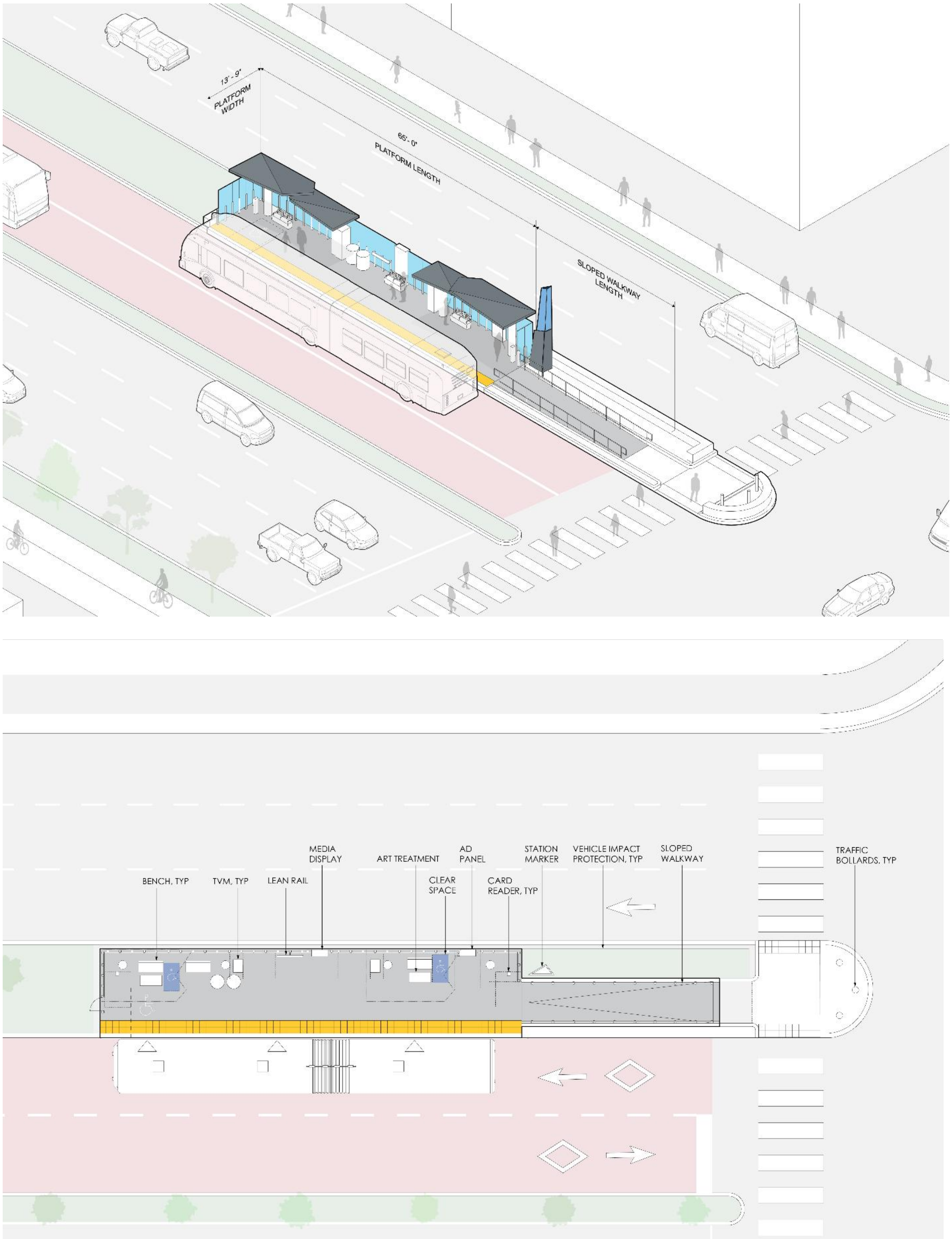


Figure 2.4E: Center-Running Station

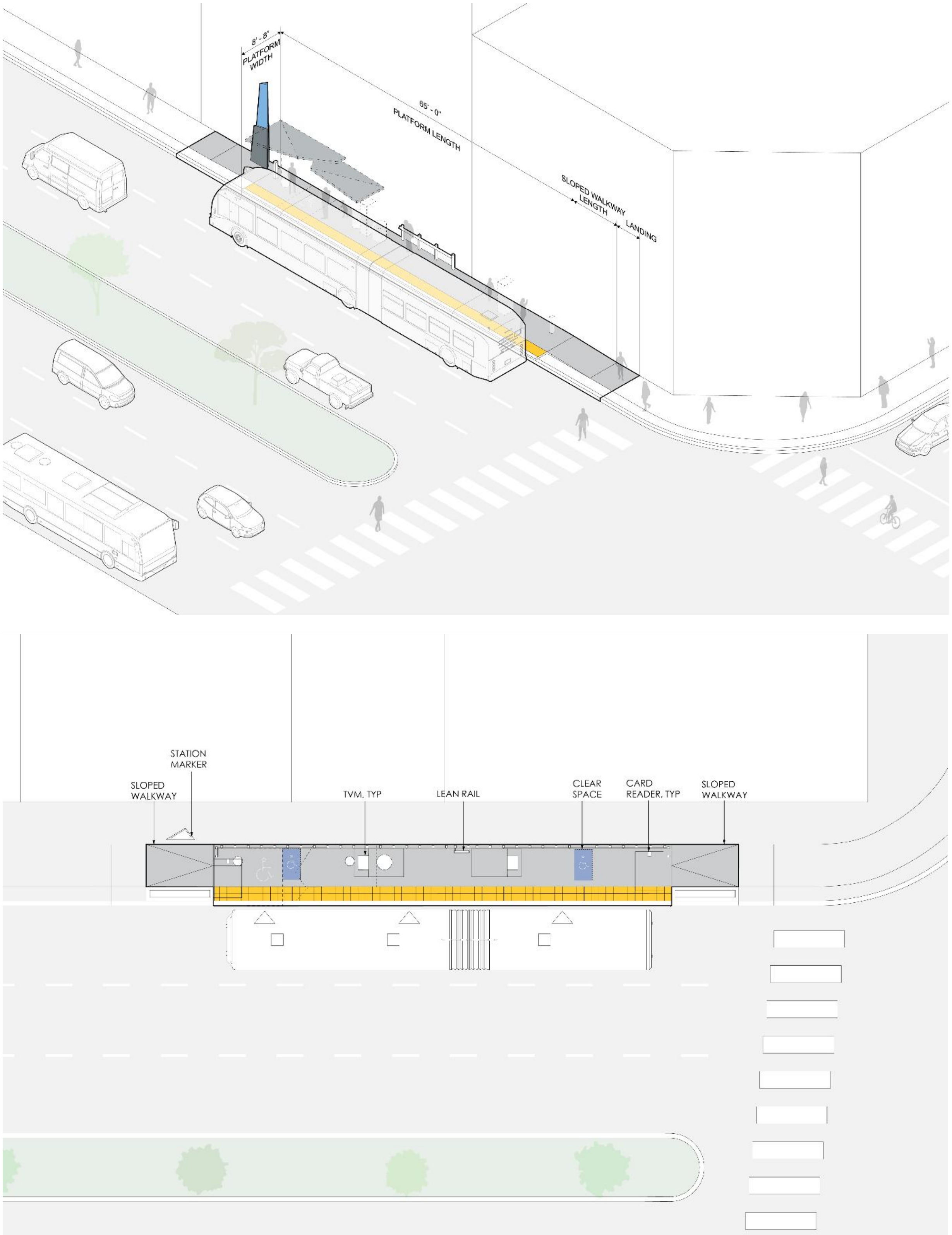


Figure 2.4F: Constrained-Environment Station

5. Accessibility

Accessibility in the context of stations and platform design is primarily focused on the needs of people with disabilities, such as those who have limited vision or use a wheelchair or other mobility device to travel. Accessibility standards benefit all riders, providing clear pathways for people with strollers or luggage, and easier-to-read signage regardless of one's visual capacity. Stations must be designed to meet ADA and PROWAG standards for accessibility.

5.1. Horizontal Clearance to Obstructions

Horizontal clearance to obstructions provides a minimum clear dimension to establish an area where no fixed objects or pedestrians should be located. The primary intention is to accommodate the dynamic vehicle envelope of vehicles traveling in the roadway parallel to the station platform. Maintaining this clear area will reduce the likelihood of collisions between fixtures/structures/pedestrians with objects associated or affixed to vehicles moving in the roadway adjacent to the platforms. BRT station platforms should provide a two-foot horizontal clearance between the face of the curb and any potential obstruction such as an overhead canopy or signage.

5.2. Pedestrian-Accessible Route

The unobstructed pedestrian-accessible route provides a clear path of travel for pedestrians. A minimum clear width of four feet should be maintained along the platform. The accessible route connects areas where movement can occur along the platform without the unreasonable hardship of maneuvering around obstacles located within the path of travel. Additional clearance also is required to accommodate station amenities such as TVMs, seating, media displays, card readers, and other relevant amenities. Minimum widths follow PROWAG standards and are four feet for side platforms and five feet for median platforms.

Sloped walkways should be preferred over ramps. When designing a sloped walkway, the slope should be less than 4.8 percent to consider construction tolerances in design. This will provide a sloped walkway of less than the maximum of five percent

The sloped walkway shall meet the requirements of all applicable codes, and the running slope of sloped walking surfaces shall not be steeper than 1:20. Exterior sloped walkways subject to wet conditions shall be designed to prevent the accumulation of water. Maximum patron flow capacity shall be considered in the configuration of the layout of sloped walkways.

5.3. Bus Boarding and Alighting Area

The boarding and alighting space shall be free of obstacles such as trash receptacles, seating, railings, and walls to allow for continuous movement of patrons with disabilities. The bus boarding and alighting area should provide a clear length of 102 inches minimum, measured perpendicular to the curb or vehicle roadway edge, and a clear width of 64 inches, measured parallel to the vehicle roadway. In addition, the bus boarding and alighting areas should have a firm and stable surface with the slope parallel to the roadway and a cross slope not steeper than 1.8% slope. The maximum longitudinal slope is 4.8% or should follow the roadway slope; however, as noted previously, station siting efforts should seek to minimize the selection of sites where slopes are problematic.

5.4. Accessible Clear Floor Area within Shelter

The station shelter should provide a minimum clear floor or ground space within the shelter. The clear floor or ground space should be 32 inches minimum by 56 inches minimum and be connected by an accessible route to a boarding and alighting area.

5.5. Turning Space

If there is an amenity on the platform that needs to be accessed, a 67-inch-diameter turning space should be provided between it and the platform edge detectable warning strip. Additional details on accessible turning spaces and pathways are available in the American National Standards Institute (ANSI) 117.1 standard.[3]

5.6. Rear Access

Where stations are located in areas with sufficient right-of-way, access to the station can be provided through rear access, where a pathway connects to the station platform through a travel path between sections of the windscreen. Additional signage and protections may be needed where a bike lane travels behind the station platform to reduce the risk of collisions between cyclists and pedestrians.

5.7. Marker Design and Location

The station marker design should be based on the standards set by the most recent previous corridor design and verified with the BRT Senior Advisor and BRT Program Implementation Manager for any modifications, if necessary. The station marker should be placed adjacent to the station platform in the direction of travel—i.e., toward the front of a bus when it stops at a station. The marker should be placed in a location that maximizes visibility from multiple angles, including from adjacent walkways, connecting transit or parking lots, and key activity centers. Placement will be dependent on the unique context of each station location.

5.8. Maintenance Considerations

As some of these features may be critical to riders with mobility limitations, it is paramount that they be maintained in working order. A maintenance plan should be developed, clearly detailing the type of maintenance required, the frequency of monitoring as well as the teams, departments, and agencies responsible for monitoring, maintenance, and repair. Monitoring frequency can be adjusted based on each feature’s importance, from daily to quarterly.

6. Materials and Finishes

The materials and finishes selected for the various components making up a station can play a pivotal role in providing comfort to passengers waiting for their bus. They also play a significant role

[3] https://blog.ansi.org/2017/08/icc-ansi-a117-1-2017-accessible-buildings/

in the creation of a sense of identity and quality of BRT services. There are key elements that need to be considered to guide the selection of materials and finishes.

6.1. Weather Considerations

The weather in Montgomery County is a continental climate with daily average highs above 85°F during the summer and daily average lows below freezing during the winter. The county also receives significant precipitations year-round. Materials and finishes selected for station platforms and amenities must be adapted to the local weather and coated with water-resistant products to limit corrosion and the degradation of the infrastructure over time.

6.2. Style

The materials and finishes selected should provide a consistent feel across all BRT stations and platforms throughout the county. Materials should be representative of the high quality of the service. As such, materials and finishes are an intrinsic part of the branding for the Flash BRT. Updates to the branding should include a thorough review of the materials. The various features and amenities should be built using the same set of materials and finishes to provide a unified look.

6.3. Construction and Maintenance Considerations

To ensure consistency in their selection, a list of pre-approved materials and finishes should be provided to construction and design teams working on station and platform implementation. In addition to the list, memoranda of understanding should be drafted for the replacement and maintenance of the various components and structures installed for a given amount of time.

A table of frequently used materials and their applications on BRT systems currently operating or in design is included below. Materials should be consistent with the most recent previous corridor design, then verified with the BRT Senior Advisor and the BRT Program Implementation Manager for any modifications, if necessary. Future stages of the MCDOT BRT program also may develop new materials/finishes standards and other detailed specifications.

Table 2.6: Frequently Used Station Materials

Material	Application
Steel	Station canopy columns, lean rails, intelligent transportation systems (ITS) cabinets
Galvanized Steel	Canopy beams
Stainless Steel	Lean rail, handrail, bench seat back and supports, trash receptacle, 316 LC used for canopy shrouds
Painted Stainless Steel	Column wrap
Powder Coated Steel	Station marker
Granite	Station marker pylon base, bench base
Glass	Wind screens
Concrete	Platform surface
Cross Laminated Timber	Canopy, ceiling

7. Weather Shelters

When consulted about future BRT routes and station designs, Montgomery County residents and riders identified protection from the elements as a paramount feature for station and platform design. Flash BRT weather shelters are composed of two canopies in a single structure, and designers should therefore be specific about the difference between them when planning new stations.

Canopies should be wide enough to provide shelter for waiting riders. They also should be oriented in a way that optimizes the amount of shade on the platform throughout the day. Shade analysis should be included in the planning process to determine the level of protection using prototypical canopy placement and to prevent riders from needing to stand in unsafe or uncomfortable areas to enjoy weather protection. Additional shelters may be warranted under unique circumstances.

8. Systems Components

Some key technology features must be integrated into all Flash BRT stations, with the intent to support the customer experience, safety and security, and reliable operations of the service. From a station design and architecture standpoint, proper placement of systems components is the primary concern. Additional technical details on system components are available in Chapter 4.

8.1. Customer Experience and Real-Time Displays

A critical component of the customer experience is the ability to know in real time when the next BRT vehicle is arriving as well as to be informed of trip delays or deviations. Other digital resources supporting trip planning and booking also can support ease and convenience when riding transit services.

For single-platform stations, one real-time rider information display should be mounted under each canopy (for a total of two per station) so that it is visible to people approaching the platform or waiting under each canopy. At minimum, one sign should be visible to people waiting under the canopies. For double-platform stations, three real-time rider information displays should be mounted under the canopies, with at least one mounted to be visible to people approaching the platform or waiting under each canopy.

Depending on station configuration and approaches, electronic signage could be single- or double-sided. Digital kiosks offering trip-planning information and route-network information should be installed under the sheltered area of double stations where space allows. Although the frequency of BRT service should keep wait times low and Wi-Fi placed onboard vehicles is preferred, Wi-Fi access points may be placed at double stations with high numbers of boardings or transfers and at transit centers and multiplatform stations.

8.2. Safety and Security

Closed-circuit television (CCTV) cameras are a critical systems component to be installed at all stations, with the number of cameras used proportional to the size and complexity of the station configuration. In addition to supporting investigation and claims when crimes occur, the presence of cameras can act as a deterrent. Video recordings from CCTV cameras should be retained for a defined period of time based on input from the agency's security policies and relationships with law enforcement agencies.

For single-platform stations, two pan-tilt-zoom (PTZ) cameras should be provided for entire-station monitoring (typically outside each end of canopies, covering the areas under canopies and approaches). For double-platform stations, three PTZ cameras should be provided for entire-station monitoring along with an emergency phone/help access point.

In cases where stations have unique configurations, additional camera(s) should cover any special approaches such as toward crosswalks for median stations, toward walkways for pedestrian structures, or other paths to/from parking or other multimodal areas.

8.3. Systems Cabinet

The systems cabinets house all the cabling and technology infrastructure needed to support operations and monitoring at stations. They include servers, fiber, and electrical cables needed to connect and feed CCTV cameras, lighting, and real-time information. They also should include expansion space to account for future needs. To reduce clutter and maximize space for transit riders, ITS/systems cabinets should be placed near (but not on) the transit platform to facilitate maintenance.

9. Lighting and Safety

"Natural Surveillance" is one of the core strategies for crime prevention as detailed in the Crime Prevention Through Environmental Design Principles (CPTED).[4] It means that by improving visibility and "eyes on the street" as well as reducing the number of hidden areas within a space, there is a reduction in opportunities for crime. Station lighting plays an important role in maximizing visibility at transit stations and procuring a sense of safety by patrons waiting for their bus. Some stations may already be located within urban areas that are well lit and highly visible. In this case, specific field study should be conducted to assess whether the surrounding lights provide adequate light levels, and that no area is left dark.

Minimum standards for lighting are set for the following locations:

- Curbside
- Back of platform
- TVM (if used)

Lighting mounted underneath the station canopies is the preferred method of illumination, with a recommended intensity of five-foot candles. Lighting should be uniform and cover all areas of the platform, including ramps and approaches, and be designed so that it is waterproof, vandal-resistant, and easily serviced by maintenance personnel. Lighting should not be custom-designed, so that it can be serviced locally, which minimizes downtime. Linear LED lighting is generally used under canopies.

Lighting in stations can be categorized as ambient or task lighting. Ambient lighting is provided by integrated lighting fixtures in column shrouds and canopy structural beams. Task lighting is provided by the map kiosk in the form of backlighting.

In the context of BRT stations located along high-traffic corridors, there are specific considerations for light levels and fixture locations so the lights from the station do not cause glaring and blind drivers. Lamps should be appropriately pedestrian-scaled (ideally less than 25 feet in height) and designed to minimize light pollution, particularly to reduce effects on residential areas.

10. Landscaping

Landscaping and the inclusion of plants within the design of a station can play a large role in create an inviting space for patrons as well as supporting resiliency and sustainability through water drainage features.

[4] American Public Transportation Association. June 2010. "Crime Prevention Through Environmental Design (CPTED) for Transit Facilities. https://www.apta.com/wp-content/uploads/Standards_Documents/APTA-SS-SIS-RP-007-10.pdf

10.1. Types of Plants and Location

Plants selected should be climate-appropriate, weather-resistant, and low-maintenance to ensure durability and aesthetics. They should be slow-growth plants that would not overgrow and cover up other station amenities. Finally, plants should be strategically placed so that patrons are not inclined to walk over them, and that they would not conflict with other amenities.

10.2. Maintenance Considerations

A list of preapproved plants as well as conceptual landscaping graphics should be prepared to support the consistent and appropriate integration of plants into the overall station design. The maintenance needs of each type of plants also should be clearly detailed into a maintenance plan for the BRT program. Memoranda of understanding with local jurisdictions and any potential partner agencies should be established to ensure that roles and responsibilities for maintenance are well-defined.

11. Wayfinding, Signage, and Passenger Information

In addition to real-time information and digital kiosks that support trip-planning and trip-disruption information, wayfinding is a key element to an enhanced customer experience. Signs should be placed throughout the station platform and around to clearly indicate where patrons are expected to wait and board the bus. Directions to key destinations as well as bicycle paths, pedestrian pathways, connecting transit routes, and other amenities also should be provided through wayfinding.

Signs used at stations should be consistent with the BRT branding to quickly inform riders that they are within a Flash BRT station area. They also should account for users with varying levels of English literacy and rely heavily on icons and graphics.

12. Passenger Amenities

Passenger amenities refer to the various components of a station provided for users’ comfort and convenience.

12.1. Seating

Benches should be provided at every station. The materials and design of the benches should be consistent with Flash BRT branding and based on the most recent corridor design, then verified with the BRT Senior Advisor and the BRT Program Implementation Manager for any modifications, if necessary. A minimum of two benches should be located on the platform and placed under a canopy to provide shade and shelter. For stations with higher ridership and passenger traffic, additional benches should be considered depending on available space. In addition to benches, lean rails should be incorporated into the station, aligned with the length of the windscreen panel module. Some modifications to these minimums may be necessary at highly constrained station locations.

12.2. Windscreen

A windscreen should be provided at all stations except for the constrained configuration. The windscreen helps provide additional rider comfort and shelter from the elements, particularly on rainy, windy, and/or cold days. The height of windscreens needs to be designed so that they tuck under the weather shelters/canopies, and to accommodate the varying heights of the taller and shorter canopies. Designs also should step up or down in line with any grade/elevation at the station location. For double stations with rear access, the length of the windscreen also needs to accommodate the access path.

12.3. Fare Payment and Validation

Fare payment will be accomplished using the SmarTrip system, where riders refill their smartcards or purchase passes loaded onto them online, at select retail locations, or at TVMs. At least one TVM should be located at every Flash BRT station, and one additional TVM may be considered at certain high-volume stations (such as transit centers or where Flash BRT services a Metrorail station). Cash payment will be accomplished at boarding through the front doors of the bus. Riders who have prepaid may board and validate their fare at all doors.

12.4. Other Amenities

Garbage cans should be present at all stations but not be located under the canopies to preserve as much cover as possible for passengers.

13. Branding

BRT stations and platforms do not typically contain branding to the degree that major retailers or fashion labels use branding, but the look and feel of stations can contribute to positive public perceptions of transit that encourages ridership and supports overall satisfaction with the service. Branding at the station and platform can be considered in the following station components.

- Platform – By using high-quality, durable materials and components that are consistent across the network, the platform can support the overall attractiveness of the neighborhood in which it is located.
- Shelter/Canopy – The current shelter/canopy also is designed to fit the aesthetics common in the Mid-Atlantic region with a combination of wood and steel. Modifications to the existing design should be made with long-term deployment across multiple lines of service in mind.
- Station Marker – The existing station marker also contributes to a sense of place and helps guide riders to the station. Modification to its placement in relation to the platform is expected to suit local contexts and space considerations.
- Lighting – Lighting can influence the sense of safety and comfort for riders and should balance brightness with helping the station blend into the surrounding area. Lighting should follow existing agency standards, but coloring or other slight modifications to features could

support branding at stations that are placed in unique locations, such as next to a school or sports venue.

14. Public Art

Public art provides an opportunity to engage local organizations and the community in the planning and placemaking process. It also is a way to create some variation between stations that use a standard kit-of-parts design.

Many agencies have chosen to designate a standard-sized area within their station design guidelines for public art, such as an area on the platform floor or existing vertical structures for a tile mosaic or other design. Local organizations or artists can then work within the dimensions and materials through guidelines set by the agency. Public art guidelines should designate the dimensions and types of materials allowed by the artist. The agency also should designate a person or team responsible for administering the program as well as roles and responsibilities for maintenance and repair of the artwork. Long-term maintenance costs need to be considered in the agency's budget when creating a public art program, selecting acceptable materials, and designating space and dimensions for the art.

15. Marketing and Sponsorships

Marketing and sponsorship of a transit system or of BRT service can generate revenue that supports operating expenses, maintenance of station areas, or other promotion of transit service through additional advertising venues. Examples of marketing or sponsorship opportunities include signage at or near station areas, multimedia displays at stations, or cross-promotional agreements with other local businesses. MCDOT does not allow advertising on the exterior of vehicles, but advertising inside vehicles could potentially be used to support partnership or generate revenue.

Selected US 29 Flash BRT stations were constructed with podiums that would support the CityPost digital advertising and information kiosk. Digital marketing/advertising agencies and the agreements that they administer can change much faster than the hard infrastructure that supports them, so care should be exercised when considering how to incorporate these opportunities into the transit system. Potential income must be weighed against the administrative and operational overhead required to generate it. In addition, some agencies have decided against selling advertising on their vehicles to project a cleaner, more upscale brand image that is intended to attract discretionary riders.

16. Maintenance, Replaceability, and Expansion

16.1. Kit-of-Parts Approach

The station elements described in this chapter are determined as the minimum requirements for Flash BRT station design. Components of the kit-of-parts are designed to be modular in nature to allow for items to be used in different configurations based on the type of platform, surrounding land uses, etc.

16.2. Planning for Long-Term Maintenance

Maintenance is another key strategy listed in the CPTED guidelines.[5] A well-cared-for environment demonstrates ownership of the space and a lack of tolerance for disorder and misgivings. As highlighted throughout this chapter, a comprehensive maintenance plan that includes a clear description of amenities that need to be monitored and cleaned as well as the frequency of each activity should be prepared and implemented. The maintenance plan also should include a detailed definition of roles from the various agencies and teams involved.

17. Long-Term Planning

This section identified several items that are not immediately resolved by these guidelines and that will require ongoing and long-term planning and coordination by and between MCDOT and local jurisdictions. They include:

- Maintenance plans and memoranda of understanding for stations so that they remain in a state of good repair
- Development of a set of materials, finishes, and landscaping/plant selection standards to inform design of station components
- Development of an agencywide wayfinding and signage program and guidelines

[5] American Public Transportation Association. June 2010. “Crime Prevention Through Environmental Design (CPTED) for Transit Facilities. https://www.apta.com/wp-content/uploads/Standards_Documents/APTA-SS-SIS-RP-007-10.pdf

Chapter 3: BRT Runningways

Chapter 3 – BRT Runningways

Introduction

A runningway is the type of corridor in which a bus rapid transit (BRT) system runs with varying differences that will be laid out in this chapter. Runningways are the most critical element in determining the speed and reliability of BRT services. Runningways are one of the most visible components of the BRT system to existing and potential passengers, thus significantly impacting the image and identity of the overall system. This chapter provides guidance and criteria for the design of future BRT corridors in Montgomery County, MD. The purpose of these guidelines is to improve the BRT system within the county, provide consistent customer experience, create a common design approach, and promote ridership on future corridors.

1. General Guidelines

1.1. Description

This chapter provides guidance on the design of and describes the minimum general criteria for the implementation of the various types of BRT runningways in Montgomery County. The characteristics of runningways vary by type, as do the street environments commonly found and planned within the county. Other roadway or roadside elements outside of the BRT guideway will need additional guidance from outside bike and pedestrian guidelines (see list of references below). The minimum general criteria provided are critical to the design of consistent and reliable bus service. Where constrained conditions may require the use of absolute minimum values, or values less than those listed as minimums herein, approval must be given in writing by the Montgomery County Department of Transportation (MCDOT).

1.2. Goals and Issues Addressed

The goal of this chapter is to provide guidance on typical BRT design methods and treatments that provide a level of standard for BRT features and service within Montgomery County to improve transit user access, safety, bus operations, performance, and connections with local service as well as reduce vehicular conflict. These guidelines will distinguish the BRT runningways from local bus service. The runningway configuration should maximize efficiency, buildability, ridership, and ease while minimizing cost. These guidelines will provide consistency in the development of the BRT system while allowing the designs to accommodate specific corridor conditions within the county, encouraging the community to use the transit system.

1.3. Montgomery County Standard Guidance

This chapter is not a standalone document; the following documents should be referenced in the design of a BRT corridor:

- Montgomery County Planning Department Complete Streets Design Guide

- Montgomery County Planning Department Transit Facilities Functional Master Plan
- Montgomery County Planning Department Bicycle Master Plan
- Montgomery County Planning Department Bicycle Facility Design Toolkit
- MCDOT Division of Transportation Design Policies and Standards
- Montgomery County Commercial/Residential and Employment Zones Incentive Density Implementation Guidelines
- MCDOT Division of Transportation Engineering Design Standards

1.4. Guidelines for Implementation

The following guidelines are laid out as a catalog of runningway options for designers to consider within the context of each corridor. These guidelines are intended to be used to meet Montgomery County's goals to provide high-capacity transit, improved multimodal access, and pedestrian safety along congested corridors. To best meet the goals and requirements of each individual project within Montgomery County's overall goals, a combination of runningway types or components may be necessary to best serve the riders of the specific corridor. Each proposed BRT project should consider the potential impacts of lane repurposing in development of the runningway and adjacent infrastructure. The minimum design criteria listed herein and contained within other Montgomery County-adopted design guidelines are requirements, and an individual project must receive written approval from MCDOT for the use of any absolute minimum criteria, the process for which is to be determined at the project level.

1.5. Additional Reference Documentation

- Maryland Department of Transportation State Highway Administration (MDOT SHA) Book of Standards for Highway & Incidental Structures
- American Association of State Highway and Transportation Officials (AASHTO): Policy on Geometric Design of Highways and Streets
- AASHTO: Roadside Design Guide
- AASHTO: Guide for the Development of Bicycle Facilities
- Manual on Uniform Traffic Control Devices (MUTCD)
- Transportation Research Board (TRB) Access Management Manual
- National Association of City Transportation Officials (NACTO): Transit Street Design Guide
- Maryland Department of Transportation Maryland Transit Administration (MDOT MTA) Bus Stop Design Guide

2. Runningway Types and Use Considerations

BRT runningways are where BRT vehicles operate and have varying needs for right-of-way (ROW), lane widths, striping, signage, curb, gutter, medians, intersection geometry, driveway access, physical separation from adjacent facilities and interactions with bicycle and pedestrian facilities. These characteristics vary to optimize the safety, reliability, and efficiency of the BRT system in the specified runningway configuration. The desired ROW configuration for each runningway type listed in this chapter is determined by the Boulevard and Downtown Boulevard street types as defined in the Montgomery County Planning Department Complete Streets Guide Chapter 2: Street Types. For other street type dimensions and configurations, please see the Montgomery County Planning Department Complete Streets Design Guide. Improvements using the following guidelines will allow for the best runningway configurations for the future of the Montgomery County BRT system. A runningway may change type within a corridor; operational impacts, traffic service, and signal timing should be considered at the project level when deciding to change type within a corridor—see **Section 3.8** for more details.

Development planned within Montgomery County should, prior to beginning design and permitting, research the County's approved transportation plans. Planned BRT routes and their respective runningway types should be considered when determining the limitations on use of roadside spaces, ROW constraints, station locations, and bicycle and pedestrian accommodations. These guidelines, along with the County's published standards and specifications, should be used in the planning and design of developments along an existing or planned BRT corridor.

2.1. Center-Running

2.1.1. Description

This section discusses the BRT center-running runningway, which is defined as having the BRT lanes running in both directions in the center of the roadway. The BRT lanes are separated from vehicular traffic either by medians or pavement markings. With this configuration, left-turn movements are only allowable at signalized intersections due to the conflicting movements of left-turning general traffic and through moving BRT traffic. Unique configurations could be considered in specific situations with MCDOT approval. The center-running configuration also allows for stations to be centrally located with typical right-side boarding to decrease the crossing distances for pedestrians. See Figure 3.1 and Figure 3.2 for a graphical representation of this type. See Table 3.1 for desired width dimensions.

Figure 3.1: Center-Running Intersection Configuration with and without Stations (far side)

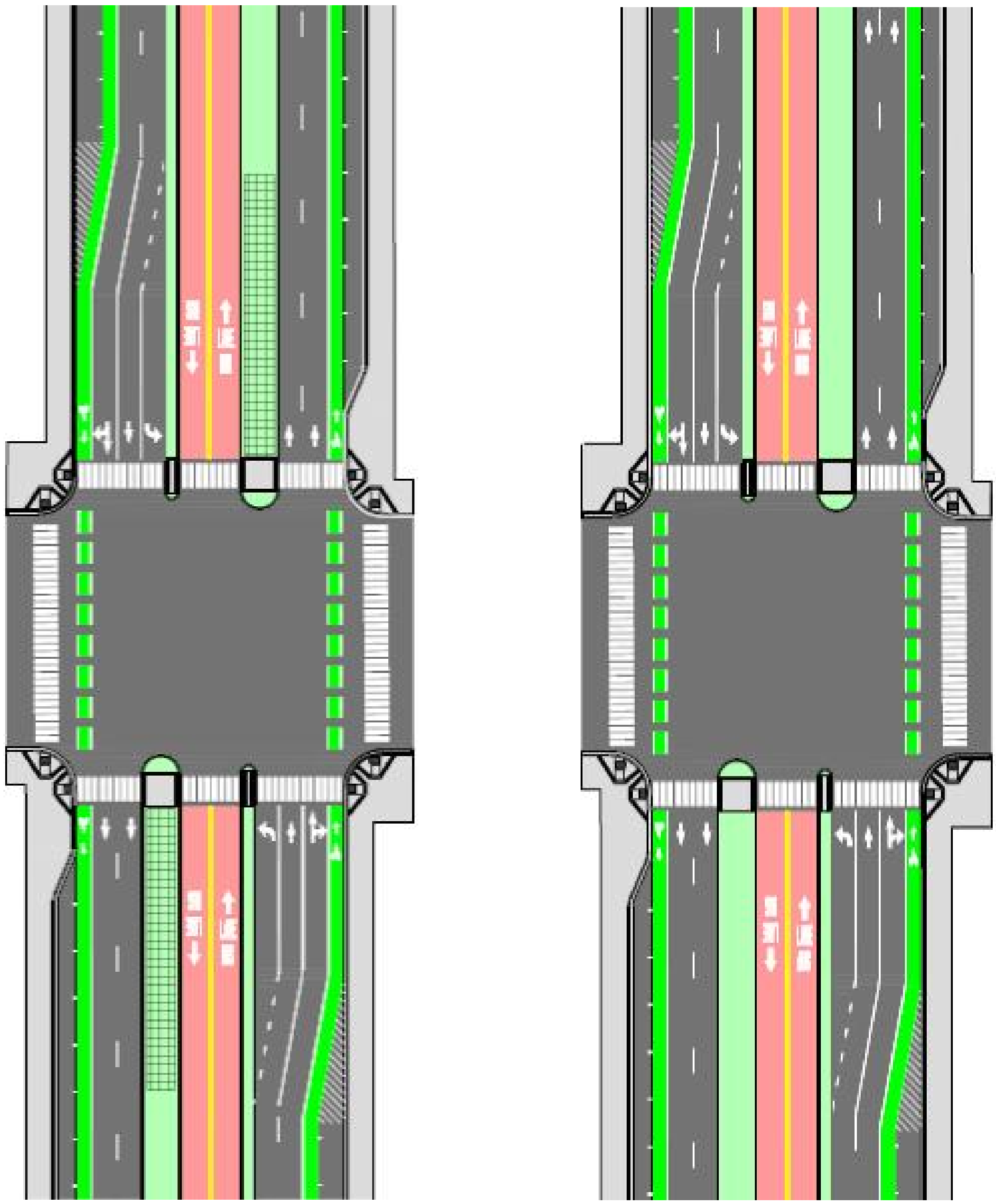


Figure 3.2: Center-Running Intersection Typical Section

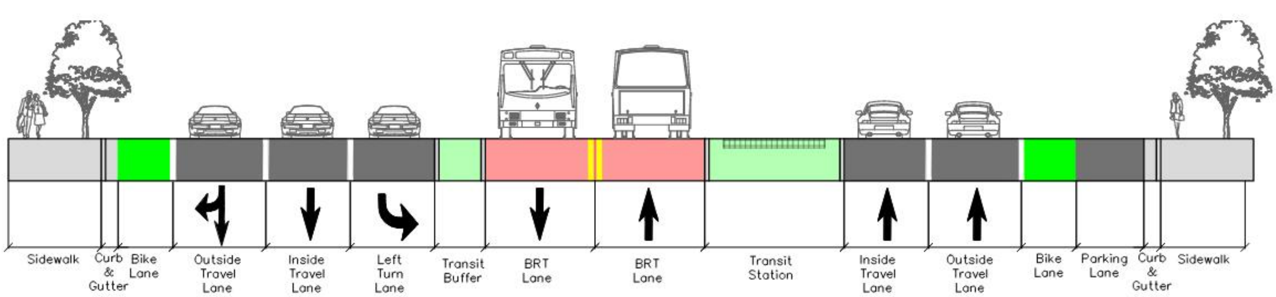


Table 3.1: Center-Running Cross Section Dimensions

Center-Running Cross Section		
	Minimum (ft)	Desired (ft)
Transit Buffer/Median	2	6
BRT Lane	12	13
Station Median	12	14

2.1.2. Guidelines and Implementation

- Center-running runningways are preferred where:
    - ROW is available for a median station cross section to exist
    - Bus speed and efficiency is a priority
    - There are numerous private driveways along the corridor
    - Side/curbside stations are not feasible due to the number of driveway impacts within the corridor
    - There is a large volume of right-turn movements
- Center-running runningways may not be best if:
    - There is insufficient ROW to construct a station in the median
    - Diverting left-turn movements to their own signal is disruptive to the corridor

2.1.3. Opportunities and Challenges

- Opportunities:
    - Eliminates bus/vehicle right-turning movements conflicts
    - Exclusive operation removes the risk of other transit services impacting BRT travel time
    - Median stations that provide more visibility and branding
    - The crossing distance—regardless of which direction the rider is traveling—is shorter due to the use of a median refuge
    - Potential to implement transit signal priority (TSP)

- Challenges:
  - Greater ROW needs, particularly if there is not enough corridor capacity to convert general traffic lanes into BRT lanes
  - Removes the opportunity for transit services to share platforms
  - Greater construction impacts to existing corridor
  - Impacts to signalized and unsignalized mid-block intersections
  - Special signal phasing may need to be introduced to maintain the efficiency of the system
  - Left-turn movement coordination
  - Higher relative cost
  - Users must cross the roadway to access the stations, which presents an opportunity for jaywalking
  - Longer cycle length leads to longer waiting times for pedestrians
  - Motorist education on BRT lane striping and signals
  - Safety considerations at the stations to protect pedestrians from adjacent general-purpose traffic (e.g., barrier, railings, etc.)

2.2. Median-Running

2.2.1. Description

This section discusses the BRT median-running runningway—a runningway with the BRT lanes running opposite directions on either side of a center median. Many existing roadways have center medians, these are shown graphically in the Boulevard or Downtown Boulevard street types as defined in Chapter 2 of the Montgomery County Planning Department Complete Streets Design Guide. This configuration presents an opportunity to easily convert existing roadway lanes of this type to exclusive BRT lanes with a lesser construction impact to the corridor. This runningway allows for stations to be centrally located with typical right-side boarding to maintain consistency in the roadway cross section through the intersection. Other conditions could be considered in unique situations with MCDOT approval. See Figure 3.3 and Figure 3.4 for a graphical representation of this type. See Table 3.2 for desired width dimensions.

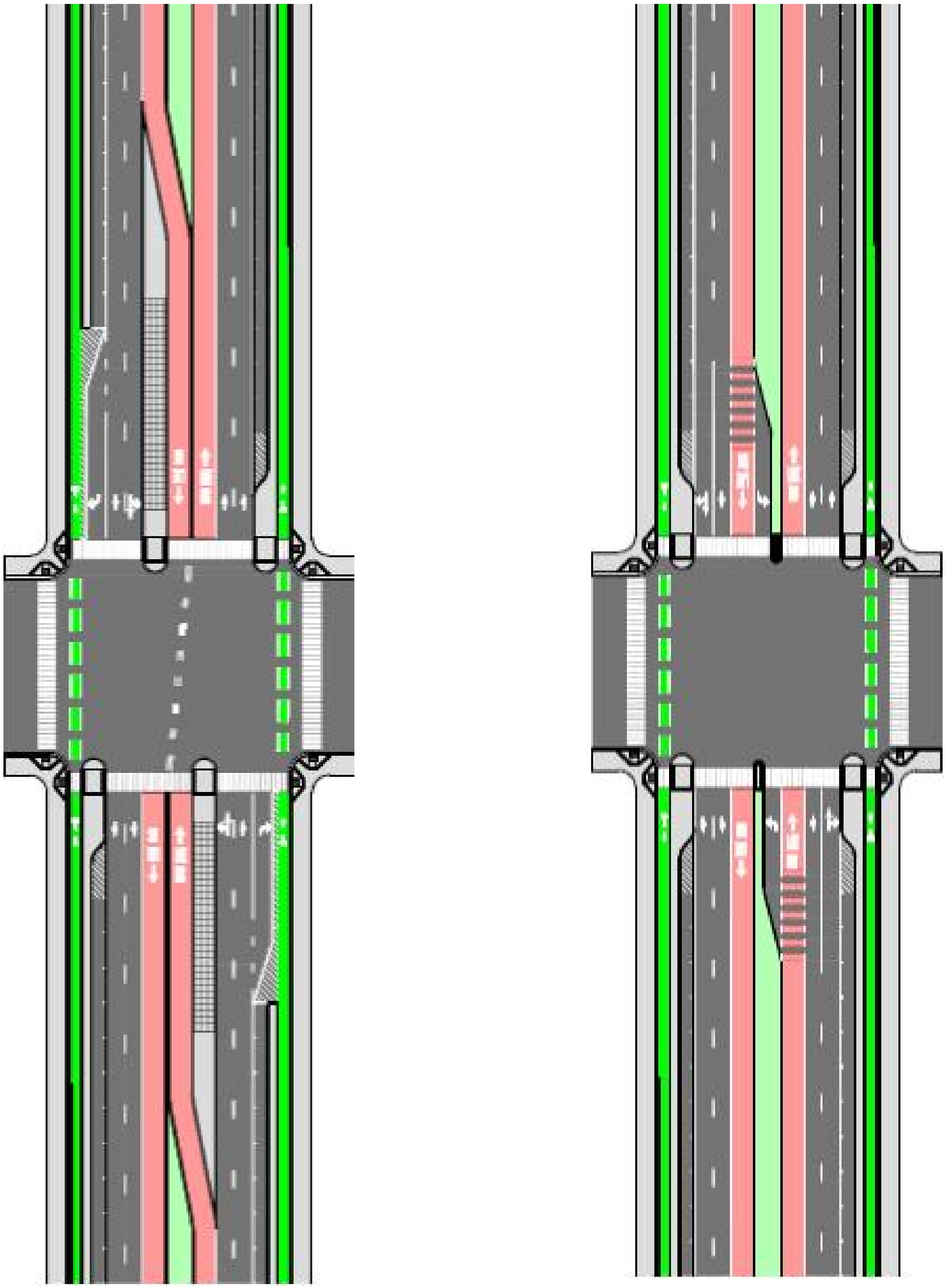


Figure 3.3: Median-Running Intersection Configuration with and without Stations (near side)

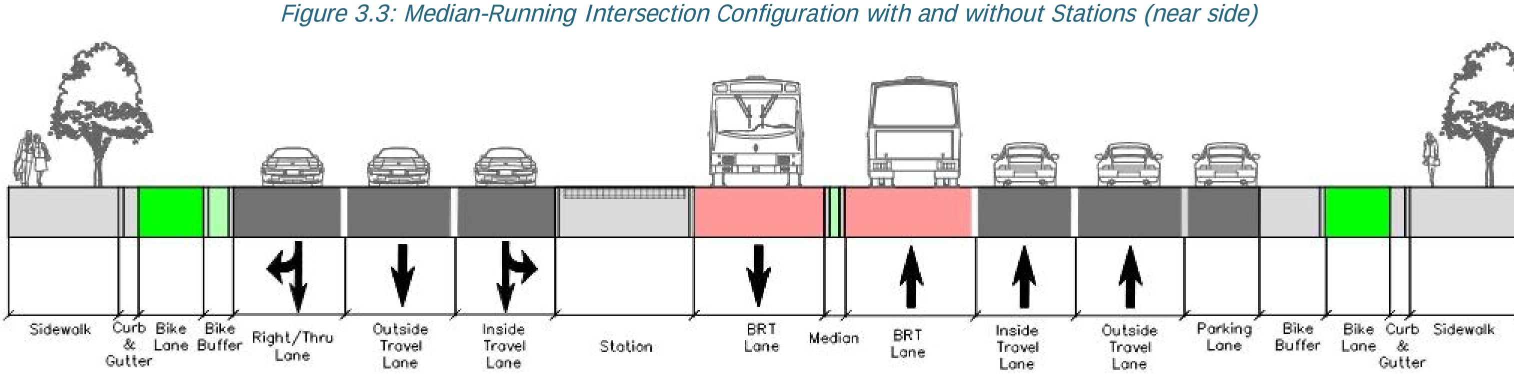


Figure 3.4: Median-Running Intersection Typical Section

Table 3.2: Median-Running Cross Section Dimensions

Median-Running Cross Section		
	Minimum (ft)	Desired (ft)
Transit Buffer/Median	2	6
BRT Lane	12	13
Station Median	12	14

2.2.2. Guidelines for Implementation

- Median-running runningways are preferred where:
  - ROW space is available for a median station
  - Bus speed and efficiency is a priority
  - There are numerous private driveways along the corridor
  - Side/curbside stations are not feasible due to the number of driveway impacts within the corridor
  - There is a large volume of right-turn movements in the corridor
  - A large median is already present within the corridor
- Median-running runningways may not be best if:
  - There is insufficient ROW available to construct a center station
  - Diverting left-turn movements to their own signal or signal phase is disruptive to the corridor
  - There is not already a median present within the corridor

2.2.3. Opportunities and Challenges

- Opportunities:
  - Eliminates right-turning movements conflicts
  - Median stations can allow both directions of BRT travel to utilize the same station, thus reducing the amount of ROW needed within the corridor
  - Construction costs may be lower if an adequate median already exists in the corridor

    - It may be cost effective to introduce a median-running system with lane repurposing if the corridor is adequate

- Challenges:
    - BRT lane transitions through intersections at station locations
    - Deliberate control is needed to advise users of the weave to access the left-turn lane through a crossing of the BRT lane where there is no station at an intersection approach
    - TSP/signal priority for BRT vehicles is needed at intersections where stations are present and the left-turning movement could conflict with the through-moving BRT vehicles
    - Pedestrian accessibility to station
    - Safety considerations for pedestrians accessing or occupying stations (e.g., barrier, railings, etc.)
    - Coordinate with MCDOT on project specifics
    - Operator training for station service, arrival, and departure

2.3. Side-Running

2.3.1. Description

This section discusses the BRT side-running runningway. The side-running runningway has an exclusive BRT lane located to the right or outside of general-purpose lanes and may have either a bike or parking lane between the BRT lane and the curb. This configuration allows existing parking, delivery zones, and right-turn lanes to generally remain in the same configuration as they would without a BRT lane. Side-running runningways allow general traffic to pass through the BRT lane to access parking lanes along the corridor and turn lanes at intersections typically designated with a wide-dashed red pavement marking treatment. Often, this runningway takes an existing travel lane and assigns it to BRT, thus affecting existing traffic capacity and general-purpose travel times. The location of this type of runningway allows for stations to exist on curb extensions or bulb-outs and allows for direct access to the stations by pedestrians from the sidewalk or side path. The side-running configuration also allows for joint use of the BRT lane by local bus service, commuter bus service, or microtransit applications, should the corridor be designated and approved for such uses by the County. BRT lanes also may enhance emergency access to the BRT stations or vehicles given there are typically no physical barriers separating the BRT lanes from general-purpose lanes in a side-running configuration. See Figure 3.5 and Figure 3.6 for a graphical representation of this type. See Table 3.3 for desired width dimensions.

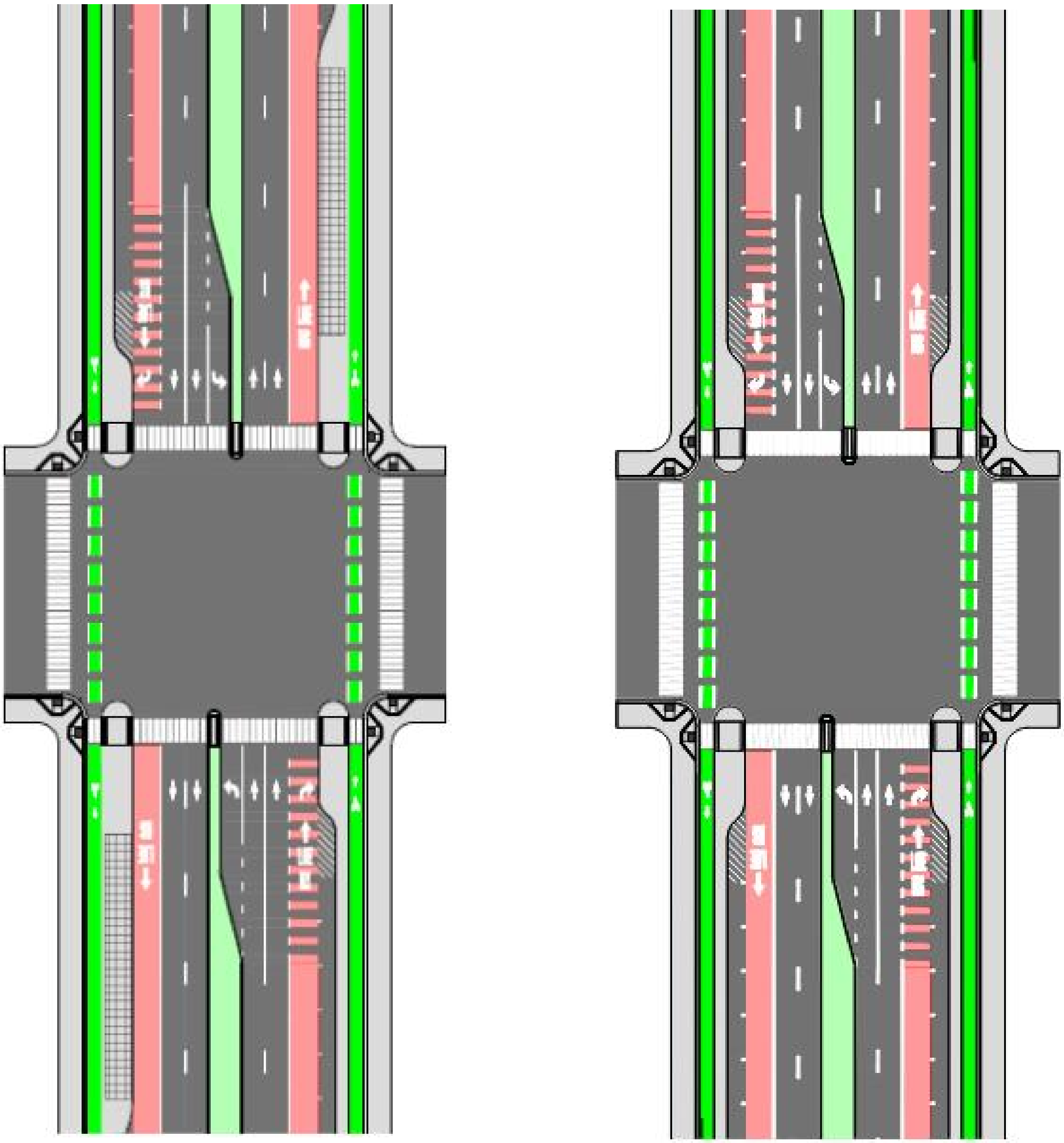


Figure 3.5: Side-Running Intersection Configuration with and without Station (far side)

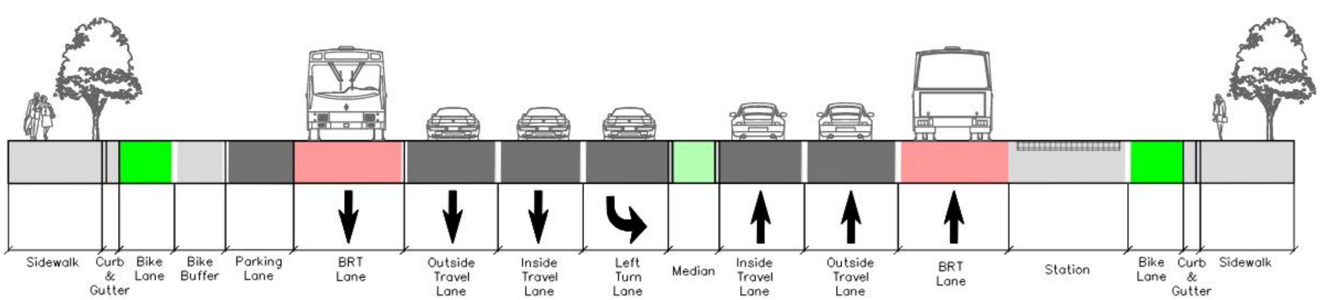


Figure 3.6: Side-Running Intersection Typical Section

Table 3.3: Side-Running Cross Section Dimensions

Side-Running Cross Section		
	Minimum (ft)	Desired (ft)
Transit Buffer/Median	0	*
BRT Lane	12	13
Station Width	12	14

**Buffer between BRT lane and general traffic for side-running determined by project environment and operating characteristics.*

2.3.2. Guidelines for Implementation

- Side-running runningways are preferred where:
    - There is insufficient ROW to build a center- or median-running BRT guideway
    - There may be potential to combine the BRT lane with bicycle accommodations in lower-speed environments
    - Maintaining full movement access of driveways where the corridor doesn't have a median or including median breaks is required; it is advantageous to have curbside station platforms to accommodate adjacent land uses such as schools, hospitals, or specific developments
    - The ability to share the BRT lanes with local bus service, commuter bus service, or microtransit is desirable for the corridor
    - There is desire to maintain existing parking/bike lanes with the conversion of a general traffic lane to a BRT lane
    - A project budget doesn’t allow for a complete reconstruction of the roadway to implement a center-running or median-running runningway
- Side-running runningway may not be preferred if:
    - Available ROW exists to implement a center-running or median-running configuration, which generally see improved travel times and reliability compared to side-running configurations
    - There are numerous driveways along the corridor that would cause high volumes of right-turn movements to impact the BRT lanes
    - There is a high volume or high-frequency use of driveways and properties along the corridor that would impact the operations of side-running BRT

    - Driveways and curbside deliveries to commercial properties conflict with the desired station locations and runningway

2.3.3. Opportunities and Challenges

- Opportunities:
    - Potential to implement TSP
    - ROW available or opportunity to repurpose an existing lane into a BRT lane
    - In low-speed urban environments, BRT lanes may be shared between buses and bicycles but only implemented as a multimodal solution where ROW is constrained and buses/bicycles are priority modes
    - No side-swipe conflict with automobile left-turn movements in the same direction of travel
    - Allows left-turn movements at unsignalized intersections
    - Able to accommodate parking and bike lanes
    - Stations are typically located on bump outs or curb extensions, which in turn reduces crosswalk distances
    - Can offer direct pedestrian access to stations
- Challenges:
    - Conflicts with vehicle parking/loading zones
    - Shared right-turn lanes/exclusive right-turn lanes with pockets introduce potential conflict and should be evaluated on a case-by-case basis
    - Planning of pedestrian access to stations through use of existing sidewalks and/or coordination with planned developments
    - Maintenance of bike lane when located between station and sidewalk—can create the need for “floating” station configurations (see Chapter 6 – Station Access Guidelines)
    - Motorist education and signing guidance

2.4. Curbside-Running

2.4.1. Description

This section discusses the BRT curbside-running runningway. The curbside-running runningway has BRT lanes running directly adjacent to the outside curb. In this configuration, bike lanes may be introduced between the BRT lane and general-purpose lanes, or a cycle track may be located off the road surface adjacent to the sidewalk/side path. Curbside-running runningways are best for roadways where parking is either not provided due to limited ROW availability or high traffic demands or can be provided in the BRT lane during off-peak periods when ridership demands are lower. Therefore, curbside-running configurations can provide the opportunity for peak-hour BRT-only lane use, depending on the balance of needs within a specific corridor. Assuming BRT does not already exist within the corridor, this configuration can maintain existing behaviors within the ROW that would be familiar to drivers.

Stations are placed along the curb of the roadway, allowing direct access to the station for pedestrians. At intersections, right-turning vehicles are placed in the BRT lane for a short distance to make that turn, typically designated with a dashed full-width red pavement marking treatment. In cases where space allows, a right-turn lane may be placed outside the BRT lane at intersections, accessed by general traffic temporarily crossing the BRT lane to make right turns without queuing in the BRT lane. Curbside-running BRT lanes can be exclusive to buses or can allow mixed traffic during certain time periods. These BRT lanes must provide appropriate signage and striping for safe use. See Figure 3.7 and Figure 3.8 for a graphical representation of this type. See Table 3.4 for desired width dimensions.

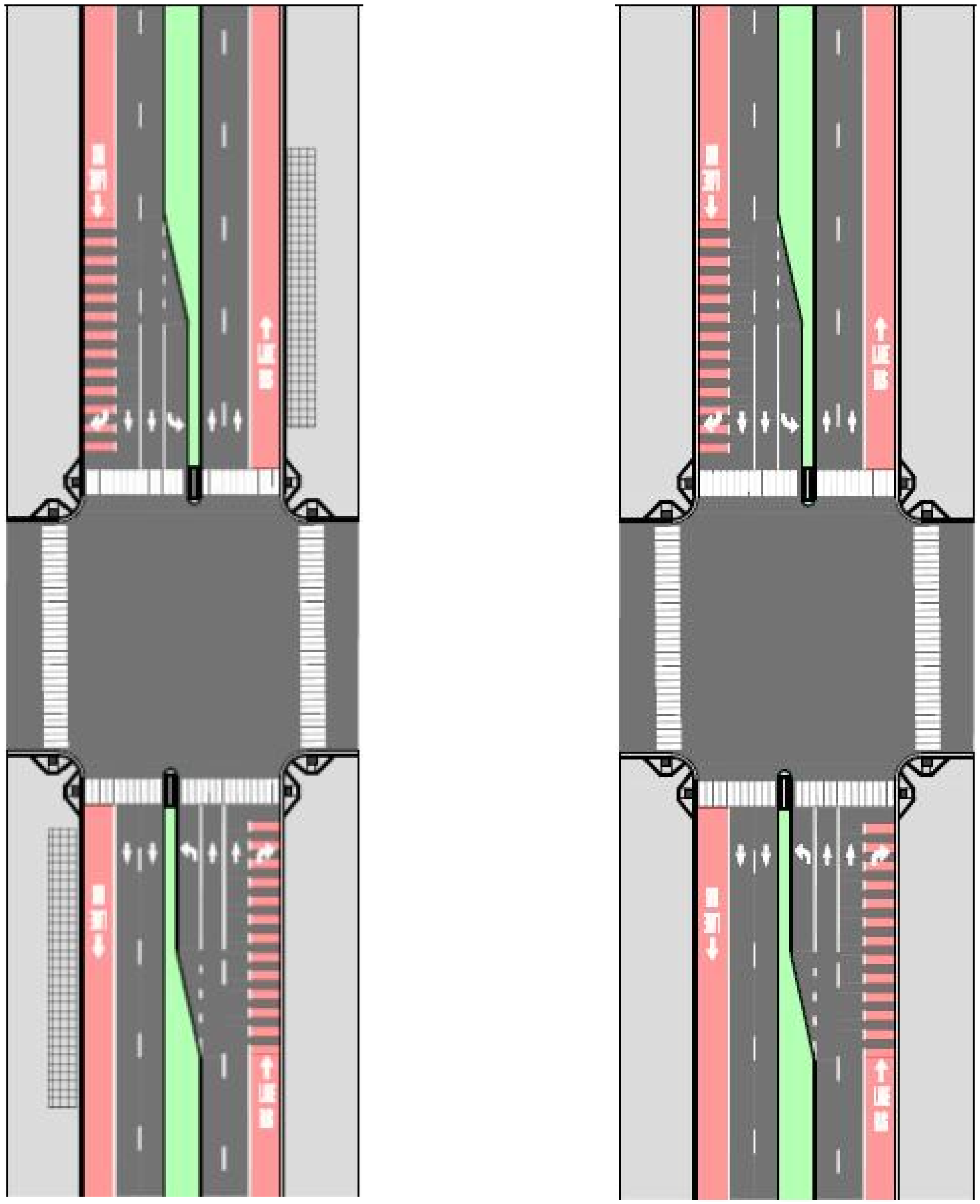


Figure 3.7: Curbside-Running Intersection Configuration with and without Station (far side)

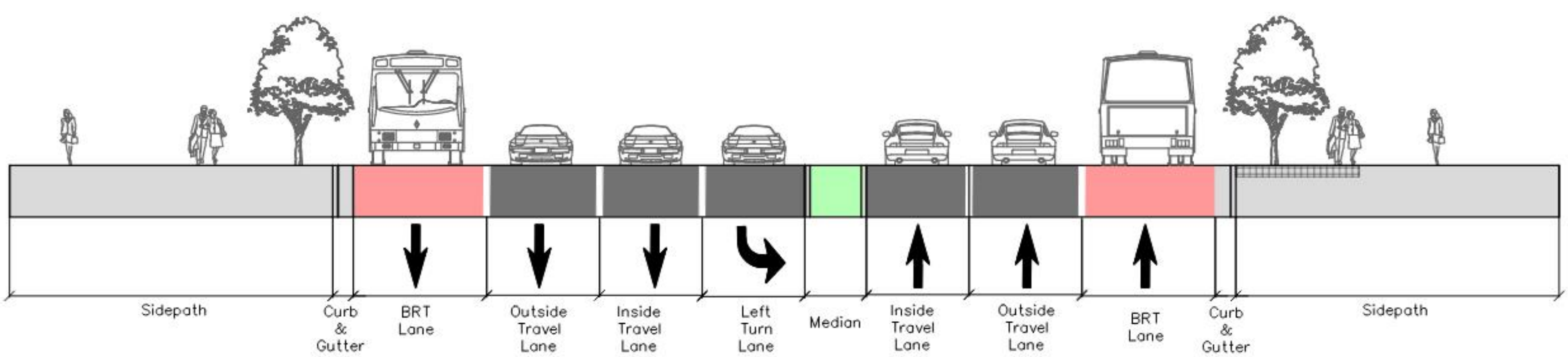


Figure 3.8: Curbside-Running Intersection Typical Section

Table 3.4: Reversible-Running Cross Section Dimensions

Curbside-Running Cross Section		
	Minimum (ft)	Desired (ft)
Transit Buffer/Median	0	*
BRT Lane	12	13
Station Width	12	14

**Buffer between BRT lane and general traffic for curbside-running determined by project environment and operating characteristics.*

2.4.2. Guidelines for Implementation

- Curbside-running runningways are preferred where:
  - There is insufficient ROW to build a center- or median-running guideway
  - Maintaining exclusive left-turn lanes without an additional conflict point with same-direction BRT vehicles (as with a center- or median-running configuration) is required for traffic capacity and space in the corridor is limited
  - A corridor must maintain specific full access to driveways and either new median cannot be introduced, or an existing median cut must be maintained
  - Loading on to buses directly from the sidewalk is a high priority
  - Exclusive use of the BRT lane is limited to peak periods and used for parking, transportation network companies (TNCs), courier delivery pickup, bicycles, or general traffic in the off-peak periods
  - The ability to share the BRT lanes with local bus service, commuter buses, microtransit, or bicycles is desirable for the corridor
  - The budget doesn’t allow for a complete reconstruction of the median and roadway
- Curbside-running runningways may not be best if:
  - The corridor experiences a high volume of right-turn movements and the ROW available does not allow for an addition of a right-turn pocket
  - There are numerous driveways along the corridor, use of which has the potential to block the BRT lane often

- There is limited space or land use, such as in dense commercial areas, as it may be difficult to place stations along the curb line. Unlike a median station, for example. that could potentially be placed on an already existing wide median that wouldn't impact the existing ROW

2.4.3. Opportunities and Challenges

- Opportunities:
  - Stations may not infringe on roadway ROW
  - Median not required, allowing access management flexibility
  - In low-speed urban environments, BRT lanes may be shared between buses and bicycles but only implemented as a multimodal solution where ROW is constrained and buses/bicycles are priority modes
  - Limited infrastructure impact
  - Potential lane repurposing
  - Limited unsignalized intersection access impacts
  - No left-turn lane conflict with BRT lanes
  - Familiar roadway configuration for automobile drivers
  - Provides users with direct access to stations from surrounding land uses
  - Reduced construction costs and impacts
- Challenges:
  - Increased local traffic impacts due to lane repurposing
  - May conflict with local bus operations
  - On-time performance impacts due to lane sharing with vehicular traffic
  - Potential removal of parking lanes
  - Potential changes to bike network configuration
  - Station may conflict with existing sidewalk
  - Right-turning vehicles are likely to share the BRT lane at intersections; right-turn lanes and/or exclusive right-turn pockets should be evaluated on a case-by-case basis given the road configuration and traffic data
  - Lesser "premium service brand"
  - Visibility and wayfinding

- Enforcement of BRT lane operation
- Public education on use of BRT lanes

2.5. Reversible Peak-Direction Single-Lane Runningway

2.5.1. Definition

This section discusses the BRT reversible runningway. Reversible lanes carry BRT vehicles in a single direction at any given time, often to accommodate peak direction travel only, reversed for AM and PM peak periods. Median located stations are placed offset and to the right of the centerline of the roadway. This configuration allows for BRT service to operate in specific directions to accommodate peak-hour transit capacity needs in a corridor with constrained ROW or other physical constraints that may limit the ability to implement a traditional two-lane BRT runningway. This scenario is most useful in areas where ROW is constrained but should be applied for peak direction operation only. On a project specific basis, schedules of operation are to be established and confirmed with MCDOT and bus operators using the corridor. A goal of implementing this runningway type is to be able to maintain general traffic capacity while also accommodating a dedicated BRT lane in peak directions. At stations, the non-peak-direction BRT vehicle enters a second exclusive BRT lane from mixed flow to access the station platform. When leaving the station, the non-peak vehicle merges back into mixed flow via an exclusive slip lane. All left-turn movements at intersections are signalized with this configuration and must be given protected signal phases to avoid conflict with BRT through movements. See Figure 3.9 and Figure 3.10 for a graphical representation of this type. Figure 9 shows a unique scenario, as seen on Maryland Route 355, in which a reversible runningway is central in a bidirectional traffic corridor. See Table 3.5 for desired width dimensions.

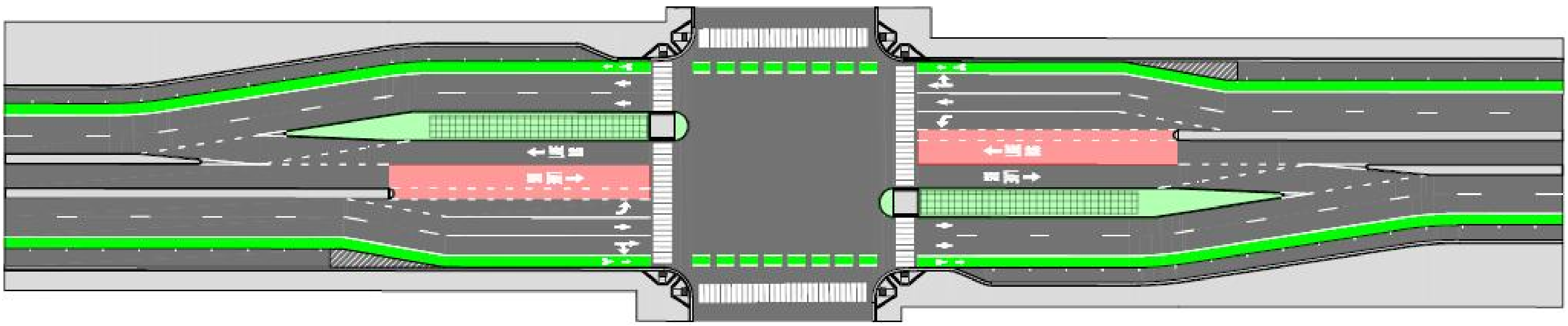


Figure 3.9: Reversible Peak-Direction Single-Lane Runningway Configuration (at an intersection with station)

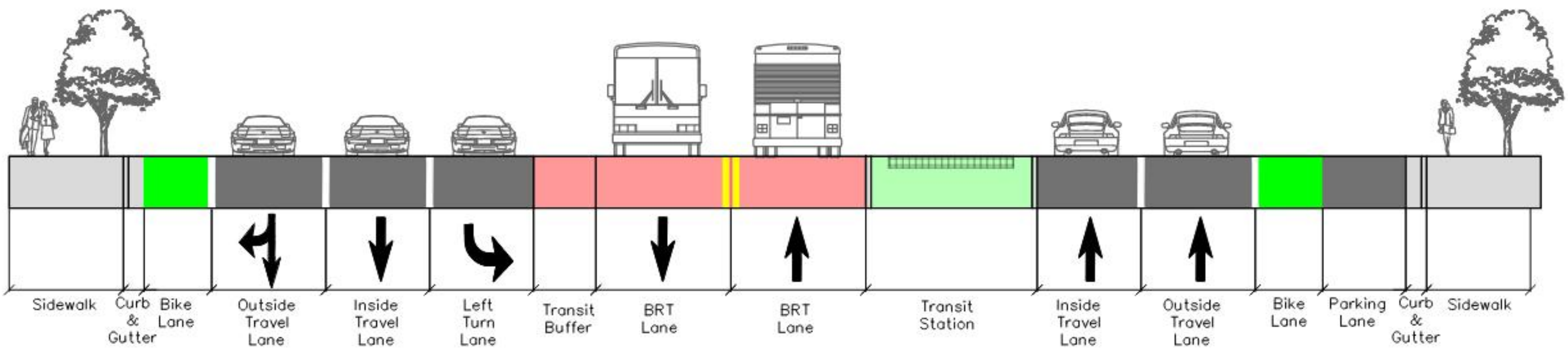


Figure 3.10: Reversible Peak-Direction Single-Lane Runningway Typical Section at Station

Table 3.5: Reversible-Running Cross Section Dimensions

Bi-Directional/Reversible-Running Cross Section		
	Minimum (ft)	Desired (ft)
Transit Buffer/Median	2	6
BRT Lane	12	13
Station Median	12	14

2.5.2. Guidelines for Implementation

- Reversible runningways are preferred where:
    - Exclusive BRT lanes are needed to improve travel times and reliability in a corridor (particularly in peak directions during peak hours) that is physically constrained or has limited available ROW
    - There is no opportunity to convert an additional general traffic lane to an exclusive BRT lane due to roadway capacity needs, excessive queuing, or other constraints on the traveling public
    - Cost of constructing a two-lane exclusive BRT runningway is prohibitive
- Reversible runningways may not be best if:
    - Transit capacity needs are required in both directions during peak hours, and/or during off-peak hours

- ROW and sufficient cross-sectional space are not available to accommodate the dedicated reversible lane and median separation of the runningway from general purpose lanes; considering safety of the traveling public and any potential for a motorist to travel against the prevailing direction of the BRT system, median separation on both sides of the runningway is required.

2.5.3. Opportunities and Challenges

- Opportunities:
  - Provides the ability to implement an exclusive BRT facility serving peak-direction travel in constrained areas
  - Allows for premium, median-located stations at intersections
  - Can be more cost effective than two-lane, exclusive BRT facilities if travel demands can be met with the reversible, single-lane runningway

- Challenges:
    - Signalization at intersections and merge/diverge areas
    - Clear delineation, use of, and treatment of medians, gore areas, and other means of physically defining the runningway and providing guidance to motorists
    - Future conversion from this single-lane runningway to a typical two-lane runningway

3. Roadway Geometrics

This section summarizes the general roadway geometry considerations that should be utilized when implementing a BRT runningway. It includes considerations of the following:

- Exclusive lanes
- Exclusive roadways
- Queue jump lanes
- Mixed flow conditions
- Peak-hour BRT operations
- Vertical profiles and cross sections specific to BRT
- Contraflow lanes
- Transitions in runningway types
- Station considerations
- Sidewalks
- Pedestrian crossings
- Bicycles
- Driveways
- Bus pullouts

3.1. Exclusive Lanes

3.1.1. Description

Exclusive lanes provide BRT vehicles with a runningway generally clear of other vehicle types, particularly in a center- or median-running configuration. In side- or curb-running configurations, general traffic will be directed to stay out of the exclusive BRT lanes through guide signage, overhead signalization, and in some cases physical delineation such as bollards, raised button markers, or barriers. The operating speed of the exclusive BRT lane is limited to the physical design of the roadway (i.e., horizontal curvature, vertical curvature, superelevation, and sight distance). Exclusive lanes are used in center-running and median-running configurations.

3.1.2. Guidelines for Implementation

- Exclusive guideway is defined for BRT use only, while exclusive lanes may be shared in certain scenarios such as for right turns or for use by other non-BRT buses; exclusive lanes not adjacent to another exclusive lane must be a minimum of 12 feet wide
- If two exclusive lanes are adjacent and separated only by pavement markings, they must be 13 feet wide
- The exclusive lane may be separated from parallel general traffic with varying forms of delineation and physical separators, such as barrier, bollards or flex posts, non-mountable barrier curbs, mountable curbs, striping, and/or lane designation
- Signalization must be used to avoid left-turning traffic conflict with the BRT

3.1.3. Opportunities and Challenges

- Opportunities:
    - Exclusive lanes allow for decreased overall travel time, increased safety, and improved reliability for the BRT
    - Exclusive lanes present the opportunity for improved headways and the ability to stay on a set schedule, thus maximizing efficiency and reliability
    - Conflicts between BRT vehicles and general traffic are greatly reduced with exclusive lanes
    - Exclusive lanes can provide dual use for local/non-BRT buses as well as BRT vehicles; this would be determined on a project- or corridor-specific basis
- Challenges:
    - Enough ROW must be available to allow for exclusive lanes when lane repurposing is not utilized
    - Grade separation may be desirable to remove conflict points with general traffic and BRT at existing at-grade intersections
    - Impact to travel times for other modes of traffic if the exclusive lane is repurposed from an existing travel lane

3.2. Exclusive Roadways

3.2.1. Description

This section describes the geometric guidelines for exclusive roadway configurations for bus traffic only. Exclusive roadways can either be grade separated from general traffic and pedestrian crossings or be placed alongside parallel public roadway facilities at the same grade with physical separation. Exclusive roadways also can be on a unique alignment not adjacent to or parallel with public roadways.

3.2.2. Guidelines for Implementation

- Exclusive BRT shall have two lanes within the corridor, each 14 feet in width from the face of curb to the centerline
- Exclusive BRT roadways on bridge structures should have minimum lane widths of 15 feet for each lane measured from centerline to face of barrier or parapet wall. The distance from the right lane stripe to the barrier face shall be 2 feet minimum. The 4-inch-wide white thermoplastic right edge line shall have raised and inverted profile
- Operating speed is determined by the roadway classification, design parameters, and operating environment of the facility. For exclusive roadways on new alignment, design speed should be coordinated with the adjacent roadway such that signal timing can be coordinated and should be set to promote safe operation of the BRT runningway within the surrounding environment. Pedestrian, bicycle, and vehicular crossings should be evaluated along with intersection spacing, curve geometry, vertical profile characteristics, and other factors when setting operating and design speed for exclusive roadways.
- Montgomery County preference for control of exclusive roadway access is through the use of signing and marking. Physical control of access via gates or similar equipment may be considered on a project-specific basis.
- Special signal timing must be implemented for at-grade crossings of exclusive BRT roadways and adjusted if gates or similar equipment are introduced

3.2.3. Opportunities and Challenges

- Opportunities:
    - Exclusive roadways create an opportunity to convert the guideway to a light rail system in the future, if desired
    - Exclusive roadways can create an uninterrupted BRT trip, creating the highest level of travel efficiency, safety, and reliability
    - Exclusive roadways can accommodate the highest level of peak passenger flows

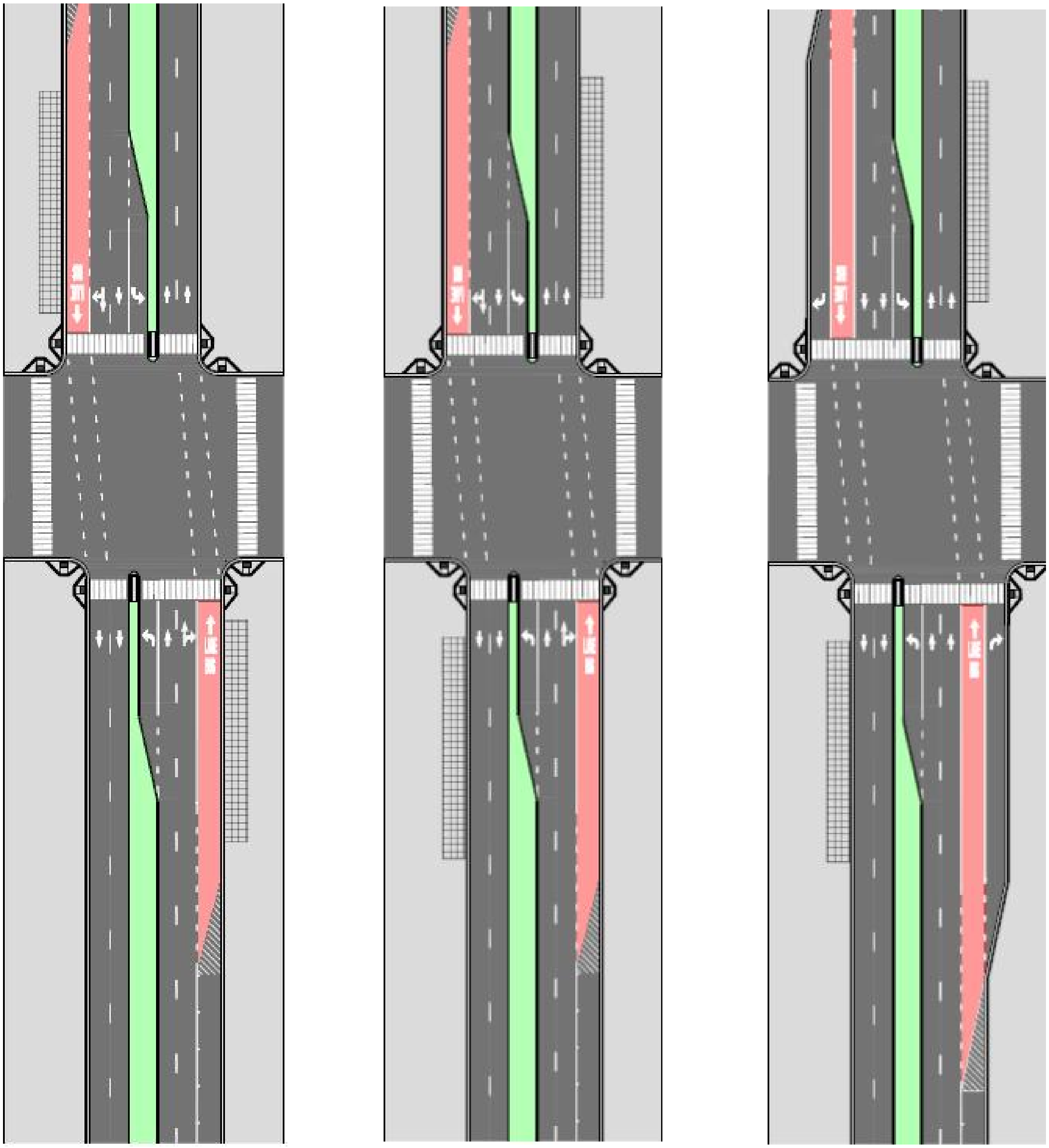
- When designed in conjunction with site developments and prominently emphasized, exclusive roadways can enhance transit-oriented development (TOD) characteristics

- Challenges:
  - Exclusive roadways can be the most expensive BRT guideway type; these corridors can require significant ROW and infrastructure to construct the system, particularly on new alignment/not parallel to existing roadway facilities
  - The amount of ROW necessary for the system may not be available
  - Construction impacts can be similar to light rail transit
  - Gated crossings are typically required at all at-grade intersections

3.3. Queue Jump Lanes

3.3.1. Description

Queue jump lanes combine short, dedicated transit facilities with either a leading bus interval or active signal priority to allow buses to easily enter traffic flow in a priority position. This gives the BRT priority over other vehicular queued traffic to pass through the intersection uninterrupted. This movement is achieved through signal priority at the intersection. These are typically used at high-congestion intersections with significant and consistent queuing. The minimum width for a queue jump lane is 12 feet and typically only serves BRT vehicles. If the queue jump lane is servicing all buses, the TSP employed will need to account for all services to maintain travel times. Right-turning vehicles would either use a combined right/through lane to the inside of a queue jump lane, or an exclusive right-turn lane located to the outside of the queue jump lane and would operate separately from the queue jump signal phase. The queue jump lane minimum length is determined by queue length trends and traffic patterns. Traffic and queue length analysis/observation should be completed to inform the design of these lanes. See Figure 3.12 for a graphical representation of this condition.



A B C

Figure 3.12A, 3.12B, 3.12C: Full Queue Jump at Intersection (with TSP)

A. Full Queue Jump with Near-Side Station

B. Full Queue Jump with Far-Side Station

C. Full Queue Jump with Right-Only Turn Lane

3.3.2. Guidelines for Implementation

- Queue jump lanes are preferred where:
  - A right-turning lane may be replaced to allow only buses to move through ahead of queued traffic, or act as a dedicated lane between the turn lane and parallel traffic lanes; in either case, the BRT vehicle would receive a signal phase to allow it to advance ahead of the queued traffic—this improves the travel time along the BRT corridor and removes the weave conflict of right-turning vehicles via signal phasing
  - When operating in mixed traffic and a queue jump lane is used to advance a left-turn movement for the BRT vehicle, the queue jump lane will generally be located inside (or to the left) of the general-purpose left-turn lane and should have an advance signal phase to allow the BRT vehicle to complete that turn and access the receiving lane without conflict with other turning traffic
  - Maintaining consistent service is essential and the BRT benefits from advancing ahead of a queue at a traffic signal via an exclusive advance phase, particularly where traffic queuing is historically long, causing consistent delay in transit travel times
  - The BRT is operating in mixed-traffic conditions. The standard placement for a queue jump lane is directly to the right of the outside through traffic lane. If there is a right-turn lane, the queue jump lane will be located between the through lane and the right-turn lane. See Chapter 5 of the Montgomery County Planning Department Complete Streets Guidelines for bikeway information and Chapter 6, Section 13 for pedestrian details and requirements.
- Queue jump lanes may not be best if:
  - Additional ROW is required to add the queue jump lane and ROW is not available
  - Traffic volumes and typical queuing trends do not warrant use of a queue jump lane
  - Queuing is regularly observed to extend beyond the point where a queue jump is not able to be accessed by a bus
  - The additional signal timing/phase has significant adverse effects on intersection level of service

3.3.3. Opportunities and Challenges

- Opportunities:
  - Improves the runningway in otherwise mixed-flow areas and/or where ROW is constrained and existing lanes may be converted to queue jump lanes to enhance BRT performance without adding significant additional infrastructure
  - Can improve overall timing of the BRT route
  - This operation works in direct coordination with the TSP and can reduce overall BRT travel time by avoiding delays at intersections due to traffic queuing
  - Allows BRT vehicles to "jump" congested intersections through targeted implementation of queue jump lanes to improve overall efficiency of the BRT system with relatively low-cost implications
- Challenges:
  - A corridor without existing right-turn lanes may limit the ROW available
  - Traffic operations may be impacted if the queue jump lane causes any other lanes to shift, or displaces an existing turn lane
  - Pedestrian volumes and crossing patterns may impact the effectiveness of a queue jump, and therefore should be considered when designing a queue jump lane (see NACTO Transit Street Design Guide for further guidance)
  - A transition must be considered from the mixed-flow lane to the queue jump lane. This is normally done with a taper if the lane is being added to the roadway section, or with dashed red paint across the full lane width where a general-purpose lane transitions into a BRT queue jump lane. Existing conditions may dictate the location of this transition or prohibit the implementation of a queue jump lane with sufficient length to recognize an operational benefit to the system

3.4 Mixed-Flow

3.4.1. Description

This section discusses the roadway geometric guidelines for the operation of mixed-flow BRT corridors. "Mixed-flow" describes the type of traffic within the runningway. In this case, it may involve multiple modes including, but not limited to, BRT, local bus, vehicles, and cyclists sharing the roadway lanes. These types of corridors have a greater operational impact in urban areas, resulting in a higher opportunity for operating conflicts and slower travel times. BRT corridors should consider parallel and intersecting local bus routes in the design of guideway for right-of-way and amenities, and the placement of the stations for transfer locations, but local bus service will generally be permitted in mixed-flow conditions only, unless specifically approved by MCDOT. For further details regarding stations with local buses see Chapter 1 Section 9. Mixed-flow lanes are often unmarked for any specific use and are not painted lanes like exclusive BRT lanes. Figure 3.11 shows a transition from a curbside-running BRT lane to a mixed-flow runningway through an intersection; however, this is not the only configuration. The BRT could also have its own receiving lane on the far side of the intersection and merge into mixed-flow traffic on the far side. This movement is often completed using a queue jump lane. For more information on queue jump lanes, see Section 3.2. A transition from an exclusive or peak-hour BRT lane to mixed-flow also may require an exclusive signal phase for the BRT vehicle to be able to complete that movement without conflict. This transition is similar to the operation of a queue jump lane but may occur at the end of a longer section of exclusive BRT runningway. This transition also may occur from center-running or median-running BRT configurations. In these configurations, the transition may occur via an exclusive signal phase at an intersection similar to the side-running configuration described above or may occur via a merge from the center- or median-running BRT lane into mixed-flow lanes through a yield condition. See Figure 3.11 for a graphical representation of this condition.

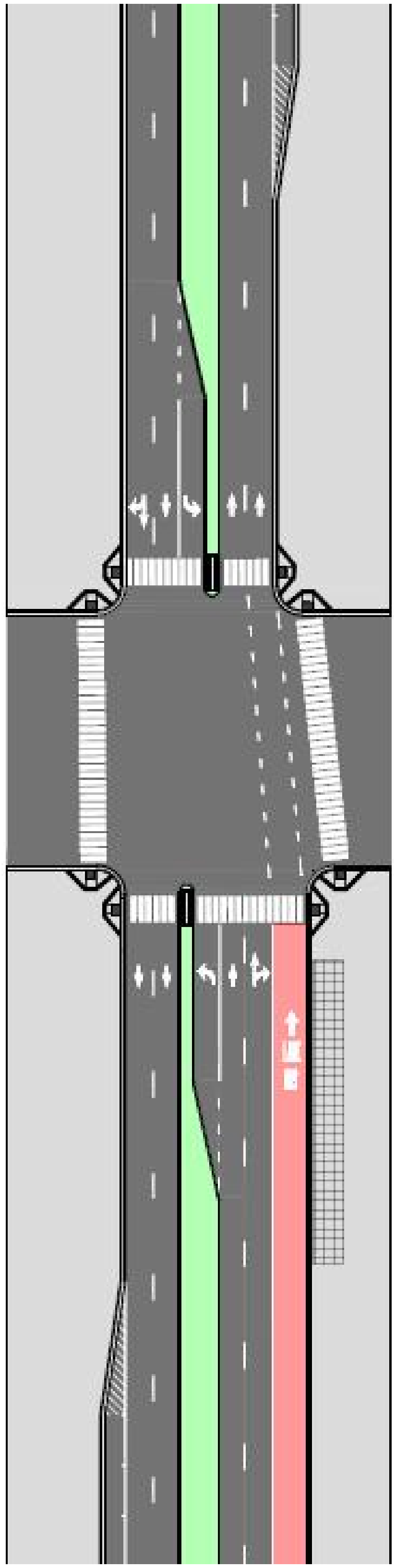


Figure 3.11: Transition from Exclusive to Mixed-Flow at Intersection (requires signal preemption)

Table 3.6: Mixed-Flow Runningway Cross Section Dimensions

Mixed Flow-Running Cross Section		
	Minimum (ft)	Desired (ft)
BRT Lane	12	13
Median	12	14
Inside Shared Travel Lane	11	12
Outside Shared Travel Lane	12	13
Shared Left-Turn Lane	11	12

3.4.2. Guidelines for Implementation

- Mixed-flow lanes are preferred where:
  - There is limited ROW available to add exclusive BRT lanes
  - The addition of BRT service would avoid impacting existing traffic
  - Corridors have lower congestion, and a dedicated BRT lane would not create significant improvement in travel times or reliability, lowering the benefit vs. cost ratio
  - Gaps in travel demand, typical congestion, or queuing lengths exist within a larger BRT corridor and exclusive lanes do not provide significant benefit compared to their cost for a certain length in said corridor
  - The corridor project has a lower budget, and priority may be given to station, access, or other roadside amenities
- Mixed-flow lanes may not be best if:
  - Delays in the system would be detrimental to ridership or performance
  - Exclusive BRT lanes are necessary to provide improved headways, consistent travel times and reliability (see Section 3.4)
  - Bike, vehicular, and bus traffic are to have exclusive facilities
  - The corridor cannot accommodate a minimum lane width of 12 feet for the BRT to operate in at least one mixed-flow lane

3.4.3. Opportunities and Challenges

- Opportunities:
    - Require little to no additional ROW
    - Maintain existing traffic patterns
    - Intersection delay can be reduced with queue jump lanes (see Section 3.2)
    - Allow for the gradual implementation of a BRT system in a new corridor
    - Potential for reduced construction impacts to the corridor as compared with an exclusive BRT lane
    - Infrastructure improvements are typically limited to station and station access improvements
    - The cross section of the existing roadway can be maintained
    - Lowest relative capital costs compared to other runningway configurations
    - Signal improvements to benefit both bus and automobile traffic
- Challenges:
    - Bus travel times are generally least improved in mixed-flow lanes, resulting in the lowest travel time savings, increased headways, and decreased reliability of the system depending on the operating characteristics of a specific corridor. Additionally, turning, stopping, or parking vehicles have the greatest opportunity to impact bus operations in mixed-flow environments, and buses making stops at stations can cause direct delays and queuing for the traveling public
    - More points of conflict with other modes of traffic exist in mixed-flow due to the potential for rear-ends and sideswipe crashes
    - Mixed-flow lanes can appear less permanent, which in turn can have a less significant economic impact on a corridor regarding redevelopment opportunity and attractiveness for investment

3.5. Peak-Hour BRT Operations

3.5.1. Description

A peak-hour BRT lane subjects the BRT to all intersection signal controls but allows the BRT to run on its own dedicated lane under certain circumstances or subject to an operating schedule. A peak-hour lane within the ROW is subject to crossing traffic and pedestrians. In a case where physical separation measures are introduced (e.g., median, bollard, or other means), this lane would no longer be considered peak hour only but exclusive. Peak-hour BRT-only lanes are typically employed in side-running and curbside-running configurations, although others can be considered at the project level depending on specific corridor needs and characteristics.

3.5.2. Guidelines for Implementation

- The desired lane width of a peak-hour lane is 13 feet; the minimum lane width is 12 feet
- The delineation between the BRT lane and parallel traffic lanes in a peak-hour operating environment is generally limited to striping and/or lane designation but may extend to mountable curb or flex posts in certain circumstances; these means should be considered on a project-by-project or location-specific basis
- Peak-hour lanes can be located within the roadway
- In a side-running configuration, the right-turn lane, bike lanes, and parking lanes will all be located to the right of the BRT lane; the peak-hour BRT lane could be used by general traffic according to an operating schedule (i.e., during off-peak hours)
- Right-turn lanes may be combined with peak-hour BRT lanes at intersections where traffic volumes or other constraints dictate
- General traffic is not permitted in the BRT travel lane during restricted times (i.e., during peak hour/peak direction operation); traffic may enter the BRT lane to access right- and left-turn lanes at intersections or cross through to access driveways and on-street parking
- For a median-running configuration, the left-turn lane should be located left of the BRT lane when the BRT continues through the intersection and may be combined with the general traffic left-turn lane when the BRT is turning left; dashed bus lane striping, mini-skips, or other means of identifying this joint-use lane should be implemented

3.5.3. Opportunities and Challenges

- Opportunities:
    - Allows for other uses of lanes when the BRT is not in operation (i.e., parking lanes)
    - Peak-hour lanes allow BRT travel times to be more competitive with automobiles, especially in congested areas through which the BRT can pass unimpeded, while allowing alternative uses in the same space in off-peak hours
    - More consistent travel times as compared to a mixed-flow operation
    - Peak-hour lanes can be an opportunity for increased cost savings on the project when the lanes use existing infrastructure

- Challenges:
    - To accommodate the peak-hour BRT lane where constrained, the ROW from the existing lanes may need to be redistributed. This redistribution may result in a reduction or removal of parking, bicycle, or general travel lanes. The restructuring of ROW within an existing corridor may impact existing travel times
    - Additional lanes can be added to the roadway section if needed, which may require additional ROW
    - General traffic movements across the BRT guideway presents opportunities for conflict
- Public education and appropriate signing are key to ensuring safe operation and use of these lanes, particularly at or shortly following implementation

3.6. Vertical Profiles and Cross Section

3.6.1. Description

This section discusses the vertical geometric guidelines for runningways. The low-boarding floors and overall length of typical BRT vehicles must be considered when designing a BRT corridor. Vertical profiles or running grades contribute to characteristics such as rider comfort, running speeds, and reliability in inclement weather. Corridor grade should be considered when siting stations. Where station placement is required in areas where running grade is not favorable, considerations should be made in design to reduce the running grade at stations. If a new BRT alignment is being designed or an existing alignment redesigned, the following guidelines should be followed.

3.6.2. Guidelines for Implementation

- If roadway reconstruction is already part of the BRT corridor project, then the opportunity to optimize the profile geometry of the roadway for the BRT system should be taken to the extent possible
- Consider the regrading of cross streets at intersections with the BRT runningway in the design and budget of the project, particularly where the BRT route turns onto the cross street
- Longitudinal grades should be a minimum of 1.0% to promote best practices for stormwater management; the absolute maximum and minimum grades should be determined using the AASHTO Policy on Geometric Design of Highways and Streets Guide
- The cross slope of the roadway and BRT facility should be a maximum of 2.0%; exceptions can only be made for a facility type and operating speed requiring superelevation. County approval is required for use of cross slopes exceeding 2.0% in BRT facilities

- Refer to Chapter 3.4 in the AASHTO Policy on Geometric Design of Highways and Streets Guide for vertical curve minimums and maximum grade differentials
    - Refer to AASHTO A Policy on Geometric Design of Highways and Streets, latest edition, for required roadway geometry design criteria

3.7. Contraflow Lanes

3.7.1. Description

This section discusses the geometric guidelines for contraflow lanes. Contraflow BRT lanes operate adjacent to and in the opposing direction of general traffic within the same roadway facility. This design method is helpful in corridors with one-way streets where BRT service is needed in both directions or only in the opposing direction. Contraflow lanes are generally reserved for application in lower-speed urban areas where safety can be addressed using bollards, raised button markers, or barriers to separate the opposing BRT lane from general traffic. Contraflow lanes can only operate in side-running and curbside-running configurations.

3.7.2. Guidelines for Implementation

- Contraflow lanes must be 13 feet wide, at a 12-foot minimum
- These lanes are typically designed similarly to a side-running runningway, except the travel in the BRT-exclusive lane is in the opposite direction of the general-purpose lanes
- Contraflow lanes must be clearly marked, distinguishing them from the normal travel lanes. These should be marked with pavement markings and appropriate signage including a bus lane arrow pavement marking and directional arrows. Bollards or flex posts are preferred, as they provide a visual and physical separator with a minimal width requirement—generally 2 feet
- In a bidirectional runningway configuration, lanes should be clearly marked and posted with appropriate signage indicating peak time direction restrictions to maintain efficiency and safety within the corridor
- Double yellow pavement markings must be used to separate the contraflow lanes from the opposing travel lanes—see the latest version of the MUTCD for specifics
- Transit-only signals will need to be installed for the contraflow lane direction
- To ensure safety through intersections, calculations must be performed with BRT-specific standards to design for appropriate clearance intervals
- Intersection turning movements shall be evaluated with consideration of contraflow operation movements

3.7.3. Opportunities and Challenges

- Opportunities:
    - Contraflow lanes often required a redesign of the corridor, and thus create an opportunity to consider additional bikes lanes or other first-/last-mile transportation
    - Contraflow lanes can provide direct access and reduced travel times for BRT service
    - BRT service operating in both directions on the same corridor allows for ease of transfers and can result in a quicker overall trip
- Challenges:
    - Limited ROW makes corridors with contraflow lanes challenging
    - Specific safety considerations are required when introducing a contraflow BRT lane
    - Contraflow lanes are counterintuitive for pedestrians and increases the risk for potential hazard. Appropriate signage and warning will be needed to alert pedestrians sufficiently
    - There is an inherent learning curve for operators and the traveling public once implemented

3.8. Transitions in Runningway Placement

3.8.1. Description

This section discusses the roadway geometric guidelines when transitions in runningway type are applied within a BRT corridor. In some cases, the runningways must transition from center-running with stations in the center of the roadway to side- or median-running with stations located on the outside curb line to accommodate ROW constraints, driveways, etc. In other cases, runningways may transition in and out of using mixed-flow, peak-hour, and exclusive lanes.

3.8.2. Guidelines for Implementation

- A runningway type must span a minimum of one mile before transitioning to another type
- Mixed-flow segments within a corridor can be used to give buses ample time to transition between runningway types
    - This mixed-flow segment should be placed between two signalized intersections to provide enough time to make the necessary movement across lanes
- In some cases, the transition from one runningway type to another can occur at the intersection with a signal phase if the geometry of the roadway supports this movement

3.8.3. Opportunities and Challenges

- Opportunities:
  - Transitions are especially helpful in urban settings with changing land uses and ROW
  - Well-executed transitions allow for the optimal runningway type to occur on each block
  - Transitioning during an exclusive signal phase eliminates points of conflict within the block
- Challenges:
  - ROW may not be available to allow for buses to transition in an exclusive signal phase depending on the turning radius and geometry of the roadway onto which the bus is turning
  - Mixed-lane transitions require the bus to cross multiple lanes; in congested areas, this may create delays and increase the number of conflict points
  - Additional operator safety training is needed
  - Additional public education and signage is needed

3.9. Station Considerations

3.9.1. Description

This section discusses runningway design considerations at BRT station areas. Stations are an integral part of both the BRT runningway and the overall multimodal and intersection environment. Their placement varies depending on the runningway type and can influence details of the runningway design. Lane types, curb height, offset of station equipment from the face of the curb, and interaction of the station to adjacent elements of the runningway (e.g., sidewalks, bike lanes, etc.) can have an impact on the runningway design and how it is approached.

3.9.2. Guidelines for Implementation

- See Chapter 2 – Stations for details specific to station design and the layout of stations themselves
- Level or near-level boarding is preferred at station platforms. Station platform curb height, while determined at the project-specific level, should aim to provide level boarding, where feasible. Refer to Chapter 2 – Station Design for further details
- Rub rails should be considered at station platforms depending on platform curb height, and in advance of station platforms depending on the approach geometry of the runningway itself

- Reinforced concrete bus pads should be considered in the BRT lane adjacent to all station platform curb and shall extend the entire width of the lane up to, but not including, the lane line pavement marking. The reinforced concrete pad is to extend the full length of the station platform in the roadway. See Section 4.3 – Concrete Bus Pads for details about bus pad placement at intersections
- Both stopping sight distance and intersection sight distance shall be considered when designing BRT runningway at or adjacent to BRT stations
- For a station accessed by a bus needing to pull off the roadway or out of the runningway through lanes, re-entry to the BRT lane shall be considered; these scenarios should be avoided where steep grades exist within the corridor and are otherwise unavoidable
- Stations should, if possible, be located along generally level segments of the runningway to avoid bus stopping and starting movements becoming a challenge during inclement weather, and to maintain Americans with Disabilities Act (ADA) accessibility; avoid placing stations on running grades greater than 5.0%

3.10. Sidewalks

3.10.1. Description

This section discusses the roadway geometric guidelines for sidewalks serving the BRT stations. While not part of the BRT runningway itself, roadside elements such as sidewalks are likely to be impacted by the implementation of a BRT runningway in an existing roadway corridor. Therefore, considerations are to be made for sidewalks and sidewalk connections along a BRT corridor whether to maintain or enhance access to developments and stations alike. It is important to maintain ADA-compliant cross slopes and grades with the implementation of a BRT runningway, which may drive the need for regrading of an existing roadway or roadside facility, the intentional use of buffer or planting strips, retaining walls, ramps, and other creative means of providing or maintaining access to adjacent properties and BRT facilities. This guidance applies only to sidewalks that are not part of the roadway typical section.

3.10.2. Guidelines for Implementation

- Where existing sidewalk infrastructure is impacted by the BRT configuration or implementation, the sidewalk is to be designed by prevailing MCDOT, SHA, and/or AASHTO standards
- All ADA requirements must be met along sidewalks, driveways, alleys, and ramps
- See Chapter 6 – Station Access Guidelines as well as the Montgomery County Planning Department Complete Streets Design Guidelines for more information about sidewalk design

3.11. Pedestrian Crossings

3.11.1. Description

This section describes BRT system guidelines for pedestrian crossings. When establishing a new runningway, crosswalks are essential to provide a safe path for pedestrians to be able to access or cross the BRT runningway.

3.11.2. Guidelines for Implementation

- Crosswalks must accommodate the at-grade crossing of the runningway as well as general-purpose lanes and other roadway facilities for pedestrians
- Pedestrian crossings should be perpendicular to the runningway to ensure adequate sight lines are maintained
- When introducing a new runningway configuration to a corridor or improving an existing runningway, design considerations that reduce the crossing length for pedestrians are preferred; shorter walkways increase pedestrian visibility, reduce pedestrian crossing time, and increase overall safety
- Standard pedestrian signals should be present at all intersections
- Include push buttons at curb ramps and median pedestrian refuges
- Medians should be extended to accommodate a pedestrian refuge where feasible to improve pedestrian safety and shorten crossing distances
- Mid-block crossing signals should be analyzed for costs and benefits to both BRT vehicles and general traffic
- At all intersections, sight lines must be analyzed to ensure the safe visibility of pedestrians
- Bulb-outs should be considered to reduce crossing lengths and improve signal timing where feasible
- All crosswalks across public streets must meet minimum criteria of the controlling agency
- See Chapter 6 – Station Access Guidelines for more crossing information and detail

3.12. Bicycle Facilities

3.12.1. Description

This section describes BRT system guidelines related to bicycle facilities. Any bicycle facility modifications beyond the roadway ROW are not considered to be a part of the runningway. For further bicycle design see Chapter 5 – Bikeways of the Montgomery County Planning Department Complete Streets Design Guide.

3.12.2. Guidelines for Implementation

- On-street, one-way bikeway facilities should have a minimum width of 6.5 feet (inclusive of the gutter pan, where present) per the Montgomery County Planning Department Complete Streets Design Guidelines. Other bikeway facility types requiring different lane widths and considerations should be confirmed for the specific project location/roadway type. Existing bike lanes and planned future bike routes are to be considered in the roadway cross section and design of BRT runningways to ensure the facility has the appropriate available ROW width (whether existing or obtained with the project). When constructing a BRT runningway, for all potential bike considerations, the design consultant must work with Montgomery County planning to coordinate for all non-BRT-funded projects
- The latest edition of the Montgomery County Bicycle Master Plan should be considered when planning and designing BRT corridors within the county, and planned facilities should be accounted for in the design to the extent feasible
- Reference Chapter 6 – Station Access Guidelines as well as the Montgomery County Planning Department Complete Streets Design Guidelines, Bicycle Facility Design Toolkit, and AASHTO Guide for the Development of Bicycle Facilities for detailed design information

3.13. Driveways

3.13.1. Description

This section discusses the relationship between BRT lanes and driveways along a BRT corridor.

3.13.2. Guidelines for Implementation

- Driveways within 100 feet of a signalized intersection could impact the location of stations for side-running or curbside-running configurations, which are generally preferred to be placed directly far or near-side of an intersecting street. See Chapter 6 – Station Access Guidelines for additional details on station placement. Depending on the purpose of a driveway in close proximity to an intersection, the station may be moved to the opposite side of the intersection if space is available, or the driveway may be closed/relocated if possible, to accommodate a new station
- Driveways in proximity to stations may experience limited sight distance when the station is occupied. Driveway locations should be considered and reviewed when implementing any BRT runningway type for physical conflicts, sight distance limitations, access patterns, and pedestrian safety. Where possible, driveways should not be placed near either end of the platform. A driveway apron should be a minimum of 25 feet from either end of a BRT station platform to allow bus approach and departure movements and accommodate any curb transitions to elevated station platforms
- Limit the number of driveways impacting the BRT system and combine driveways in locations where possible as an access management measure—this will help limit interruption to BRT operations caused by driveway use

- As part of the BRT planning and design process, access management best practices should be implemented. The Montgomery County Planning Department should be consulted to determine appropriate access management measures for the specific corridor being designed. Refer also to the latest edition of the TRB Access Management Manual for further guidance

3.14. Bus Pullouts

3.14.1. Description

Bus pullouts are most commonly used in local bus service and not recommended for BRT corridors. The exceptions may be for mixed-flow conditions at a high-volume/high ridership station or when developing express service to allow another bus to pass within an exclusive facility. In a typical BRT corridor, the use of a pullout by a BRT bus should be limited to express service as described above or in emergency situations only. The benefit of bus pullouts is that they allow continuous vehicular traffic movement while buses stop to load and unload passengers. Bus pullouts are insets within the curb past the normal curb line that give the bus enough space to get out of the travel lane. The bus re-entering traffic from the pullout can cause some delay within the guideway. If many pullouts are used within a corridor, these delays can accumulate and be harmful to the efficiency of the system.

3.14.2. Guidelines for Implementation

- Bus pullouts are not recommended for BRT systems due to delays caused by re-entering traffic from the pullout
- Wherever possible, pullouts are not to be combined with station platforms.
- If a bus pullout is necessary for a corridor-specific application, the pullout must be a minimum of 12 feet in width and 90 feet in length

3.14.3. Opportunities and Challenges

- Opportunities:
    - Bus pullouts could be considered at terminus points where buses will be idle for longer periods of time
    - A pullout also may be a good solution where BRT lanes are shared by BRT and local buses, which may require passing to maintain headways for the BRT corridor

- Challenges:
    - Bus pullouts can have a significant negative impact on overall system travel time due to the time required for the bus to merge back into regular traffic
    - Bus pullouts reduce the amount of ROW behind the back of curb to add additional passenger amenities such as shelters, benches, etc.

4. Intersection Geometrics

4.1. Left/Right Turns

4.1.1. Description

This section describes the intersection geometric guidelines as they relate to the BRT left and right turning movements. Median and center runningways require left-turn crossings. Side and curbside runningways require right-turn crossings.

4.1.2. Guidelines for Implementation

- At unsignalized intersections, left turns across BRT lanes are to be prohibited
- Generally, left turns for center runningways at signalized intersections have the left-turn lane to the right of the BRT lanes
- Permissible left-turn crossings should only be considered in center-running configurations when the left-turn lane is left of (or “inside”) the BRT lane; if the general-purpose left-turn lane is right of (or “outside”) the center-running BRT lane, then it requires a protected signal phase
- A parking lane may be replaced with a right-turn pocket to reduce ROW needs
- In the case that the ROW does not allow the space for a right-turn pocket, vehicles may enter the BRT lane prior to the intersection to make a right-turn movement
- Proper pavement markings and signage are required
- The length of a dedicated left- or right-turn lane is determined based on the anticipated queue length; exclusive turn lanes should be no less than 60 feet in length not including the taper, enough for a typical articulated bus to wait in the turn lane without blocking adjacent travel lanes
- In a mixing zone or weave area, vehicles turning left or right may cross through the BRT lanes to access the appropriate turn lane; to determine the mixing zone length prior to a left- or right-turn lane, use the MUTCD Taper Length Formulas

- If the posted speed limit is less than or equal to 45mph, the taper length (L) is $WS^2/60$, where W=width of the bus lane in feet, S=posted speed limit or anticipated operating speed in mph
- When the posted speed is greater than 45mph, L=WS

- Example: If the BRT lane is 12 feet wide, and the speed is 30mph, the mixing zone should be 180 feet in length. The minimum mixing zone length is 100 feet

4.2. Intersection Lane Offsets

4.2.1. Description

This section discusses the intersection geometric guidelines for lane offsets through an intersection. Lane offsets are particularly useful in center-running configurations, when the bus does not have both right- and left-side boarding, to maintain consistency in the runningway alignment within the overall roadway section.

4.2.2. Guidelines for Implementation

- Lane offsets through intersections should be minimized. The desired maximum lane offset is less than or equal to ½ the width of the travel lane being offset. The absolute maximum offset may be calculated using the MUTCD taper length formula. Signal head position over the approach lanes must be considered when a lane offset through an intersection is introduced
- Extra caution should be taken with lane offsets when designing a center-running way to avoid significant BRT lane alignment shifts through intersections. Refer to Montgomery County Planning Department Complete Streets Design Guide Chapter 6 – Intersections

4.3. Concrete Bus Pads

4.3.1. Description

This section discusses the design and incorporation of concrete bus pads into the runningway. Concrete bus pads are installed at stopping points to prevent wear and tear on the roadway (e.g., gaps, cracks, and rutting) due to the weight of and force applied by the stopping and starting motion of buses. As mentioned in Section 3.9 Station Considerations, reinforced concrete bus pads should be placed in the BRT lane adjacent to platform curb for the entire length of the platform and extending the entire width of the adjacent lane. See the MDOT SHA Book of Standards for Highway & Incidental Structures manual for more details on the concrete bus pads

4.3.2. Guidelines for Implementation

- If the BRT project requires a bus stop relocation, a new bus pad should be installed in the new bus stop location

- If the construction of a BRT system encroaches on an existing bus stop, a new concrete pad should be installed to meet BRT system needs
- For existing or newly installed bus pads, the design of the concrete must meet the geotechnical requirements as laid out in a project-specific geotechnical report; the concrete pad design also must meet MCDOT Division of Transportation Design Policies and Standards and MTA Bus Stop Design Guide, Chapter 4
- Bus pads should span the full BRT lane width, and equal the BRT station platform in length or clear curb zone, whichever is greater (see MTA Bus Stop Design Guide, Chapter 4)
- Adjacent lane pavement markings should be placed off the concrete bus pad to maintain optimal visibility of the lane marking for roadway users
- In corridors with articulated buses or multiple bus lines, longer bus pads may be required
- For retrofit applications, the adjacent roadway pavement structure should be tested and known prior to finalizing design of the concrete bus pad; appropriate sawcutting and pavement restoration should be considered when retrofitting a concrete bus pad

4.4. Ramps

4.4.1. Description

This section discusses the geometric guidelines for BRT-focused pedestrian access ramps. Ramps are essential for access to the BRT system.

4.4.2. Guidelines for Implementation

- If the BRT project impacts existing curb ramps, they will need to be replaced according to Montgomery County's standards and shall meet or exceed current prevailing ADA guidelines or requirements
- Dual curb ramps should be considered at intersections where the curb returns are redesigned for the BRT project and should provide direct access to stations, aligning with the crosswalks they serve to aid in ADA access and clarity for users
- Detectable/tactile warning strips are required at all pedestrian crossing ramps
- The proximity to and need for replacement of or additional traffic and pedestrian signal equipment should be considered when designing crossings of BRT runningways; this equipment should be added to pedestrian refuges located within transit buffers/medians along the runningway

4.5. Bulb-outs

4.5.1. Description

This section describes the geometric guidelines for bulb-outs. Unlike a bus pullout, the BRT does not leave the travel way with a bulb-out, thus avoiding any delay caused by merging into traffic. A bulb-out is a curb extension that can be located at an intersection or midblock. Bulb-outs improve pedestrian access by reducing crossing distance, creating additional sidewalk space, and increased visibility of traffic. In some situations, the bulb-out may be suitable for a BRT station location.

4.5.2. Guidelines for Implementation

- Bulb-outs can be applied where existing parallel parking already exists
- Bulb-out placement should be considered near BRT stations
- The edge of pavement at a bulb-out shall be aligned with the edge of travel lane in advance of the bulb-out; if a bike lane is present, design for the bulb-out should consider the impacts of drainage on the bike lane
- If bulb-outs conflict with bus or vehicle turning movements, attempts should be made to shorten the bulb-out before eliminating it completely
- Consider sight distance and emergency access when adding amenities and landscaping to bulb-outs
- Design bulb-outs to avoid ponding and direct stormwater flow into nearby inlets
- If a bulb-out with a station is placed where a bike lane exists, the bike lane should be relocated to avoid conflicting with the station loading area

4.5.3. Opportunities and Challenges

- Opportunities:
  - Allows most on-street parking and turning lanes to remain
  - Allows for additional station space features
  - Improves pedestrian interaction and safety within the corridor
  - Allows BRT to remain in the lane rather than entering and exiting the travel lane
- Challenges:
  - Bulb-outs must consider the existing drainage conditions of the guideway
  - Increase the total capital cost of a project

4.6. Exclusive Roadway Entry/Exit

4.6.1. Description

This section discusses geometric guidelines for the entry/exit into exclusive roadways by BRT vehicles, and the design of this access. Exclusive roadways are separated from general traffic by barriers, bollards, or pavement markings as described above in Section 3.5.

4.6.2. Guidelines for Implementation

- BRT access to exclusive lanes depends on the placement of entry and exit barriers
- Access to BRT-exclusive roadways should be signalized, where possible, and either combined with intersection signalization such that conflicts are reduced or eliminated or separated enough from signalized intersections such that typical intersection spacing is not interrupted by the access to the exclusive BRT facility
- Sight distance prior to the exclusive roadway entry point should be considered for the safety of the BRT and the traveling public
- Appropriate mitigation shall be designed to prevent non-authorized vehicles from entering the BRT-exclusive roadway
- To give BRT vehicles priority ramp access onto a highway, ramp meter interrupt technology may be used—this can be advantageous where a BRT guideway may end and route onto a highway for a section of the corridor via an interchange ramp

4.6.3. Opportunities and Challenges

- Opportunities:
  - If conflicts between BRT vehicles and general traffic can be mitigated for entry and exit into an exclusive roadway facility, this may be a less disruptive option than constructing an exclusive BRT guideway on an existing roadway
  - Depending on the location of the proposed exclusive roadway, the relative cost may be less than implementing an exclusive guideway within an existing roadway
- Challenges:
  - Entry and exit points provide design and operational challenges for BRT operation and general traffic
  - Depending on the traffic operation of the BRT lane, the bus entering from the perpendicular street may need to speed up or slow down to appropriately enter the guideway

  - Entry/exit points introduce additional pedestrian and bicycle conflict points to the crossing roadway

4.7. Pavement Sections

4.7.1. Description

This section discusses pavement design in corridors in which the roadway is widened or modified to accommodate BRT runningway.

4.7.2. Guidelines for Implementation

- Current pavement conditions as well as additional loading from BRT should be considered in pavement design
- Current pavement conditions will be addressed by MCDOT prior to the design of a BRT system. Signs of pavement distress should be noted in locations planned for future BRT lanes. Distress indicators can include rutting, cracking, or potholes and must be addressed before implementation of the BRT system
- Rigid concrete pavements should be considered for use in the following locations:
  - At and approaching station areas
  - At traffic signals or stop signs where possible
  - At any existing relocated bus stops
- Drainage design should be considered at stations to avoid ponding and excess water along the curb line to avoid splashing when the BRT vehicle enters and exits the facility
- Exclusive and non-grade-separated BRT lanes must be painted red to differentiate between regular traffic lanes. For non-exclusive BRT lane markings, consult the County on a project-by-project basis. For this and all other pavement markings and striping guidance, refer to the latest version of the MUTCD

4.8. Street Signing and Striping

4.8.1. Description

This section discusses street signing and striping for BRT runningways. Providing visual guidance and regulatory signage directing motorists how to navigate within a BRT corridor is essential for both the operation of the BRT system and for public safety. Common examples of delineation of BRT lanes include bollards, flex posts, raised button type markers, barrier, medians, and pavement markings. Each should be considered and applied on a project-by-project basis depending on the operating environment and characteristics to maximize safety with consideration of standardizing the countywide BRT network consistency throughout the corridor with signage and delineation

4.8.2. Guidelines for Implementation

- All appropriate local agencies should be consulted before BRT design for striping, markings, and signage is completed
- Parking restrictions should be properly marked and signed according to the MUTCD guidelines and MCDOT requirements
- Appropriate regulatory signs, flashing beacons, overhead signs, and dynamic signs should be installed according to MUTCD guidelines to communicate the time-of-day restrictions and permitted turns for both BRT and vehicular traffic
- Transit signal heads must be placed at all intersections in which BRT has a specific signal phase
- BRT lanes within all runningways except a mixed-flow environment should consider marking across the entire lane width in red paint on a project-by-project basis with consideration of standardizing the countywide BRT network consistency throughout the corridor; the material is to be approved by MCDOT prior to final design approval and construction.
- Where transition areas are to be marked with a full-lane-width dashed red paint, the marking shall be 4 feet of red paint equal to the lane width edged with a 6-inch-wide white lane line marking, followed by a 4-foot gap in both the white edge line and red lane paint; the paint color specifications are to be specified by the controlling agency
- During construction, temporary traffic control should conform to MUTCD standards and guidelines, and any supplemental requirements of MCDOT and the MDOT SHA Book of Standards for Highways & Incidental Structures

4.8.3. Opportunities and Challenges

- Opportunities:
  - Appropriate signage and pavement markings create a more consistent and safer environment for traffic to move through BRT corridors
  - The right level of guidance minimizes confusion, which in turn can improve the efficiency of the corridor as a whole
  - Certain BRT-specific signage can present the opportunity to introduce, continue, or enhance the branding of a BRT system
- Challenges:
  - Unclear markings or signage can cause confusion and disrupt BRT operations
  - Placement of signs can be challenging and cause unforeseen conflicts with other roadway or utility elements

  - Excessive signage can create confusion, so deliberate guidance to motorists must be considered when designing a BRT corridor

4.9. Green Streets and Landscaping

4.9.1. Description

This section discusses the green streets and landscaping components of implementing a BRT project within a corridor. A green street is one that protects natural resources by filtering stormwater, promotes healthy habitats by incorporating green elements into the design, and is designed for safety/mobility, financial stability, resilience, and performance. Roadways are designed to capture stormwater and guide it to a stormwater management system. Roadway runoff contains many pollutants and materials that must be removed. Green streets and landscaping elements are designed and implemented to help mitigate the pollutants and treat the runoff to promote a healthy environment.

4.9.2. Guidelines for Implementation

- These components are not mandatory to the design of BRT systems; however, these should be implemented wherever feasible to benefit the corridor as a whole
- Coordinate with Montgomery County on a project-by-project basis to determine the best green street components that align with the goals and plans for the corridor
- Potential green streets and landscaping elements include:
  - Street trees
  - Drought-tolerant landscapes
  - Green stormwater infrastructure
  - Biofiltration systems
  - Porous pavement
  - Rain gardens
  - Bioswales
  - Low-impact development (LID) techniques—material and construction strategies used to minimize lifecycle cost, greenhouse gas emissions, and waste
  - See Chapter 7 – Green Streets in the Montgomery County Planning Department Complete Streets Design Guidelines and Montgomery County Transit Facility Functional Master Plan for further guidance

5. Traffic Operation Considerations

5.1. Transit Signal Priority

5.1.1. Description

TSP are components that modify traffic signal timing or phasing when transit vehicles are present to improve service reliability and transit times. This section discusses passive and active TSP for BRT operation. The guidelines below provide general TSP guidance; see Chapter 4 – ITS for detailed guidance.

5.1.2. Guidelines for Implementation

- Passive TSP provides preference to BRT movements through the intersection by implementing signal timing in a corridor with high transit use with timing that favors average bus speeds/rhythms
  - Preference to BRT should be given by timing the green signal just past a station after the typical dwell time at the station
  - Signal timing and network elements of the project corridor should be evaluated to recommend appropriate changes to the TSP; parallel corridors should be timed accordingly
  - Typical station dwell times for time of day and traffic conditions also should be considered
  - In the cases in which BRT in both directions cannot have priority green time at intersections, the higher occupancy direction should have precedence
- Active TSP provides adjustments to the signal timing to provide preference to the BRT by detecting the presence of the BRT as it arrives at the signal
  - By either holding a green light for the BRT or reducing the side street green time to allow for the BRT to receive an early green light should be done using central control systems
  - Queue jump lane operation requires the use of active TSP to give preference to BRT vehicle movement ahead of general traffic
- When feasible, passive and active TSP should be used in conjunction to maximize the efficiency of the BRT—this allows the signals to be timed to give preference to the BRT (passive) and allow for spot improvements in the BRT timing at certain points (active)
- Signal priority can be applied to the signal system to either hold the green signal for the BRT that is incoming or give the next green signal to the BRT that is waiting.

5.1.3. Opportunities and Challenges

- Opportunities:
  - TSP can reduce travel times for the overall BRT system
  - TSP can limit impacts to other vehicular traffic within the corridor
- Challenges:
  - Active TSP may result in situations in which side street green cycles and pedestrian priorities are skipped if there are multiple BRT arriving at intersections back to back, appropriate timing of the TSP cycles must be designed to create the safest corridor for BRT, vehicular traffic, and pedestrians

5.2. Bus Lane Enforcement

5.2.1. Description

This section discusses bus lane enforcement to keep the BRT lanes free from unauthorized traffic. This requires education on the use and conditions of the BRT corridor partnered with support from law enforcement. Enforcement of bus lane access can be challenging in peak-hour lanes or lanes in which access is dependent on time of day.

5.2.2. Guidelines for Implementation

- The design of the BRT system should take enforcement into consideration by choosing a design that is as easy and safe as possible to enforce
- All runningways should be clearly marked with appropriate pavement markings and signage to partner with enforcement
- Municipal code may need updated to enforce certain regulations
- A design feature that can be added to the corridor to help with enforcement is a pull-out area for violators to be cited

5.3. Utility Considerations

5.3.1. Description

This section discusses utility considerations regarding BRT systems.

5.3.2. Guidelines for Implementation

- During preliminary design, locate all utilities and design to avoid as many existing utilities as possible
- For center-running or median-running runningways in which a station or island would need to be added to the corridor, longitudinal utilities should be rerouted

- BRT designs that require numerous utility relocations will significantly increase the cost of the total project
- Minimize the number of service access areas (manholes) within the runningway to avoid the need for maintenance activities to foul the runningway and impact BRT operations
- All maintenance, relocation, support, restoration, and construction should conform to Montgomery County's standards, criteria, specifications, and practices
- All relocations of utilities should conform to Montgomery County's standards, criteria, specifications, and practices as well as those put forth by any private utility providers impacted by the BRT runningway implementation
- The runningway should generally be crowned for stormwater management purposes (see the AASHTO Roadside Design Guide for further guidance); placement of stormwater management infrastructure within the runningway lanes should be avoided where possible to minimize disruption of service due to maintenance or repair activities
- Include measures in the BRT design that would not foul the runningway when maintenance is needed

Chapter 4: BRT Intelligent Transportation Systems (ITS)

Chapter 4 – Bus Rapid Transit (BRT) Intelligent Transportation Systems (ITS)

Introduction

This chapter expands upon the BRT Design Guidelines detailed in Chapters 2 and 3 by exploring ITS solutions that should be considered as part of BRT planning, design, and implementation efforts. The chapter presents a diverse array of ITS solutions and their potential applications, organized into distinct categories based on their primary functions and deployment areas. This categorization offers a structured overview of various ITS components, highlighting their respective roles, interdependencies, and the ways they interact within the broader transportation system.

The chapter is divided into the following sections:

- Roadside Elements: This section discusses ITS components that are deployed along BRT corridors to perform traffic management and safety functions.
- Station Elements: This section focuses on ITS technologies employed within the stations, with a primarily focus on enhancing passenger experiences and streamlining station operations.
- Vehicle-Based Elements: This section explores the ITS technologies that are integrated within BRT vehicles, with a primary focus to perform critical, operations supporting tasks.
- Central System/Operation Control Elements: This section discusses central ITS elements that perform overall coordination and management of BRT system operations.
- Emerging Technologies: The concluding segment explores the realm of emerging technologies in the field of ITS, and their potential application in the context of a BRT system.

What is ITS?

ITS are fundamental components of a modern BRT system. These systems are designed to reduce travel times, improve service reliability, maximize system efficiency, and enhance BRT operations with the help of technology and data.

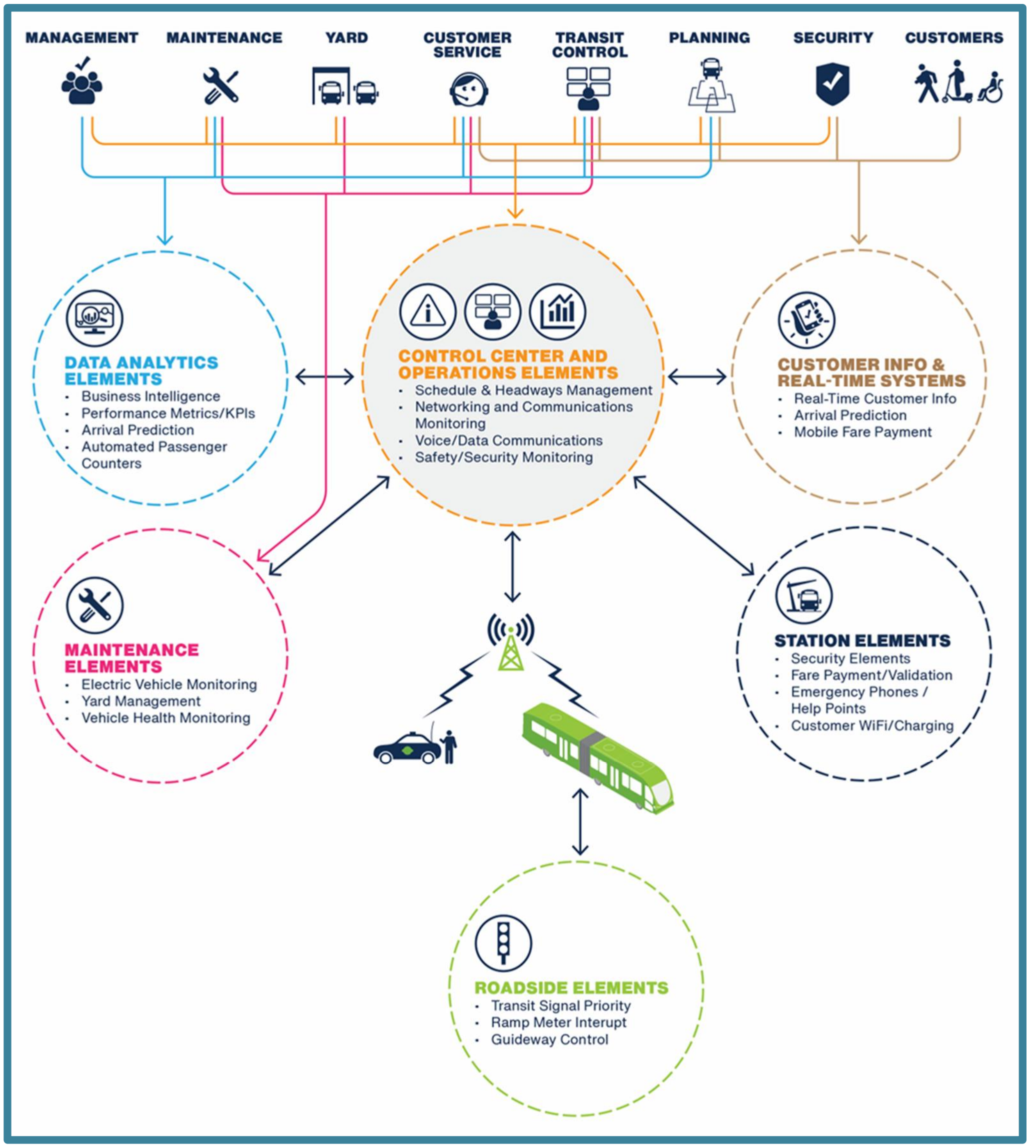


Figure 4.1: Overview of BRT-Related ITS Components

ITS can be effectively integrated into virtually every aspect of the BRT system, offering numerous benefits such as optimized operations, enhanced service frequency and reliability, improved safety measures for personnel and passengers, streamlined fare collection processes, and an overall enriched travel experience. This list is not exhaustive, and as the ever-evolving landscape of ITS solutions continues to expand so do the features and benefits that they provide. Regardless, the primary objectives for ITS deployment in a BRT system are to:

Reduce travel time and elevate traveler experience

Maximize system efficiency and optimize operations

Enhance the safety of passengers and assets

Boost situational awareness, proactive management, and expedite service impact recovery

1.General Guidelines and Standards

ITS is not a one-size-fits-all solution, and to maximize return on ITS-related investments, it is essential that deployments follow a robust architecture and seamless integration framework that enables the various components to work harmoniously. This approach should take into account the agency's goals, objectives, and specific needs of the transportation system to help identify focus areas and establish a path for implementation.

While the selection process for specific ITS solutions may vary, the general focus should be on interoperability, standardization, and connectivity to existing systems.

These core principles should help establish a list of qualified ITS solutions for evaluation. During this process, the focus should be on evaluating potential benefits and risks, compatibility with existing and future systems, as well as estimated costs and implementation timelines. If potential solutions yield similar evaluation scores, adopting a more holistic approach is advisable. This could involve assessing the solutions based on the agency staff's familiarity with the system and the availability of in-house expertise to operate and maintain it. Alternatively, reviewing the solution provider's portfolio can be helpful to gauge the range of integrations available once the solution is implemented as well as the general flexibility of new integrations.

Once a suitable solution has been selected, the implementation process should begin with documenting communication paths, establishing data collection protocols, and devising strategies to mitigate any identified risks. These steps should be defined prior to testing the systems in pilot projects and fine-tuned before ultimately moving forward with full-scale deployment. To ensure success, it is also recommended that clear performance measures and performance monitoring processes are in place prior to implementation.

As information transfer is one of the most prominent aspects of ITS, following common standards is essential for ensuring seamless communication, interoperability, and compatibility across different transportation systems and technologies. By utilizing common standards, ITS components can effectively exchange information and streamline overall system performance.

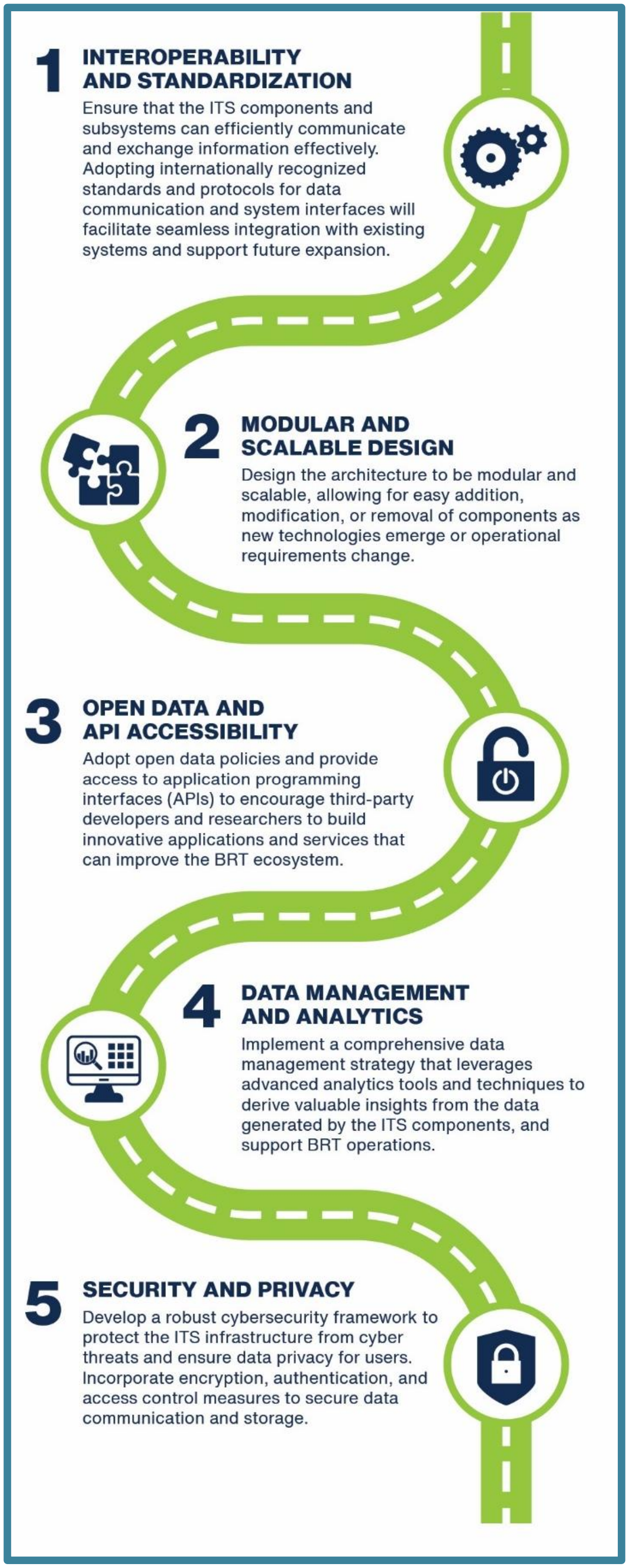


Figure 4.2: Core Principles in Evaluating ITS Solutions

Standards also play a pivotal role in facilitating the integration of emerging technologies and providing a foundation for seamless expansion of the ITS system architecture. While applicable standards vary depending on the technology used, the most common ITS-related standards are:

1.1. Legacy Systems and Current Standards

The Montgomery County Department of Transportation (MCDOT) operates numerous systems and applications that are key elements of supporting BRT implementation and operations. These systems will evolve over time, but consideration of current systems, integration requirements, and timelines for those systems to be updated or replaced should be considered as part of BRT planning, design, and implementation. In many cases, new BRT corridors may seek to pilot, replace, or advance the functionality of current solutions where these functions are viewed as key to operations of the BRT. For example, physical infrastructure considerations and signal operations for a new BRT may place special needs on current systems that requires new or enhanced functionality. It is important that physical design of BRT elements such as bus lanes, constrained lane widths, very high-volume boarding and alighting areas, or areas of special safety concerns consider: (a) what functionality or capabilities are required of systems to achieve operational goals and (b) are current systems and standards adequate to provide these capabilities or are new or improved solutions required. Current areas of key existing BRT support systems include (as examples):

- Computer Aided Dispatch/Automatic Vehicle Location (CAD/AVL) System – MCDOT has deployed a CleverCAD CAD/AVL system for fleetwide operations, communications, and coordination. This is a key tool for monitoring and adjusting service for local and BRT services. This system includes some tools that are important to BRT operations, such as the functionality for headway management. Data from this system can also serve to support specialized BRT functions and capabilities. This system is also a key source of data for customer information solutions.
- Econolite Signal Software/Solutions – MCDOT and state traffic signals currently use Econolite software and systems for operating and monitoring traffic signals. These are generally set up for the ACS/2 software, but there is the potential for upgrades to newer Advanced Traffic Controller software in the future, such as EOS. Signal control software and solutions, in combination with the specific intersection and roadway detection, are crucial to ensuring efficient movement of BRT. This includes both signal priority approaches for BRT, as well as simply ensuring efficient use of BRT priority infrastructure such as queue jumps or bus guideway lanes.
- SmartTrip Card Fare Collection Solution – MCDOT uses the regional smartcard solution which supports multimodal customer access to various MCDOT and partner agency services, including BRT. This is the predominant form of fare payment by customers.

In addition to these key solutions, there are numerous other systems and solutions that support MCDOT operations, including BRT. Current MCDOT solutions and their respective lifecycles (e.g., in development, recently deployed, mid-life, or due for replacement) should be considered as part of ITS evaluation and design for BRT.

1.2. Maryland Statewide ITS Architecture

ITS system deployments are governed by the standards and requirements set forward in USDOT's National ITS Architecture standards and requirements. The Maryland Statewide ITS Architecture is a subset version of the National ITS Architecture tailored to the region. It identifies existing and planned ITS projects across the state and categorizes them into specific Architecture "Elements" that serve as the basic building blocks of the Statewide ITS Architecture. Specifically, "Elements" represent blocks of hardware, software, data, processes, and people that work together by exchanging information (through Interconnects and Information Flows) to achieve a common goal within the overall Maryland transportation system. Compliance with the national and State ITS architectures is a requirement of most federal funding associated with ITS and BRT technologies. The architecture can be a useful resource in identifying gaps in systems and functionality.

1.3. GTFS/GTFS-RT

General Transit Feed Specification (GTFS) is a widely accepted format for exchanging transit schedule data between multiple agencies and providing real-time information to riders. The GTFS is an open-source file format that enables transit agencies to publish their transit data in an interoperable manner and allows developers to use the data to create applications. It includes information such as route and schedule information, fare rules, stop locations and details, interchange points between routes, service days and holidays.

GTFS-Realtime (GTFS-RT) is an extension of the GTFS format that allows transit agencies to provide real-time updates regarding the location and status of buses. This format is used to send updates about delays, detours, vehicle locations and other information that can be shared with riders.

Emerging GTFS data specifications are in development, including GTFS-Service Changes that will allow for easy exchange of service adjustments such as trip or block cancellations, trip additions, detours, etc. As these specifications develop, MCDOT should consider their applicability to BRT and overall operations, as they may serve as the basis for multi-agency exchange of service adjustment information, as well as a common format for customer information solutions.

1.4. NTCIP

The National Transportation Communications for Intelligent Transportation System (ITS) Protocol (NTCIP) is a suite of communication protocols designed to facilitate the exchange of information between transportation devices and systems from different manufacturers and providers. NTCIP encompasses a wide range of standardized protocols, data models, and message sets, allowing for interoperability between various ITS elements such as traffic signals, variable message signs, ramp meters, and other elements.

1.5. IEEE 802.11p

IEEE 802.11p, commonly referred to as the Wireless Access in Vehicular Environments (WAVE) standard, serves as the foundation for dedicated short-range communications (DSRC) within vehicle-based communications networks. Developed by the Institute of Electrical and Electronics Engineers (IEEE), this standard enhances the 802.11 Wi-Fi technology to accommodate ITS applications by specifying communication protocols that enable vehicle-to-infrastructure (V2I) and vehicle-to-vehicle (V2V) interactions. This standard is anticipated to become of increasing importance over time as connected vehicle applications further develop. These standards should be considered where MCDOT might consider driver assistance, safety, or guidance control systems.

1.6. Traffic Management Data Dictionary (TMDD)

TMDD is a set of central system to central system data standards that define the data elements and message sets required for effective communication between traffic management centers and other ITS components. TMDD may apply to the exchange of data between traffic control, signal control, and specialized guideway or reversible lane systems as they might be applied to BRT applications.

1.7. International Organization for Standardization (ISO)

Several ISO standards, such as ISO/TS 19091 for cooperative ITS and ISO/IEC 15118 for vehicle-to-grid communication, provide guidelines and specifications for various aspects of ITS integration and operation.

2.Roadside Elements

Roadside elements are critical components of an effective BRT system. They enable the communication and integration of BRT vehicles with roadway infrastructure—and the central system—to greatly enhance operations and safety. Roadside elements grant BRT vehicles access to a broad range of enhanced functionalities including expedited travel in mixed-flow operations, real-time arrival times, or improved safety. An effective implementation of the roadside elements is essential for providing a reliable BRT service that meets the needs of passengers and agency operations goals.

2.1 Transit Signal Priority (TSP)

TSP is one of the foundational elements in the design of a successful BRT system, particularly if routes operate in mixed traffic or share intersections with general traffic. The TSP system is developed to enhance the efficiency and dependability of transit operations by enabling buses to request priority at intersections, to help reduce the number of stops at signalized intersections along the route. By granting priority requests, TSP not only streamlines bus

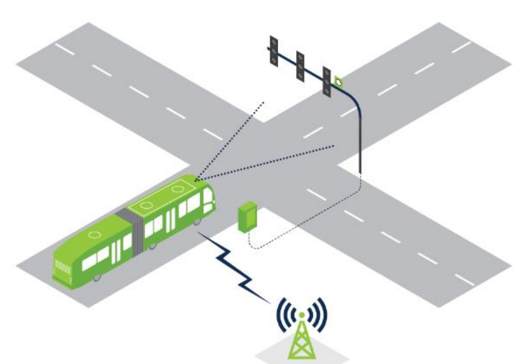


Figure 4.3: Illustration of TSP Components

service times, but also improves safety conditions for drivers and pedestrians. Additionally, TSP contributes to the reduction of carbon emissions and air pollution generated by BRT vehicles.

The TSP system is designed with a dual purpose—to bolster service reliability and minimize signal related travel delays. To effectively achieve these objectives, it is recommended that TSP technology is integrated with other infrastructure elements, such as dedicated lanes or queue jumps, and operational strategies like active headway management. The guiding principles for TSP design should focus on maximizing efficiency, optimizing safety, and ensuring seamless integration with existing transit infrastructure and operations.

2.1.1. General Guiding Principles

There are two main approaches to deploying TSP along a BRT corridor: passive signal priority and active signal priority. Active signal priority can be further divided by the type of TSP solution utilized for processing and granting priority: active signal priority where buses communicate with individual signals to request and process localized priority often based on specific conditions, and next-generation Transit Signal Priority as a Service (TSPaaS) system where signal priority is coordinated across the corridor or area.

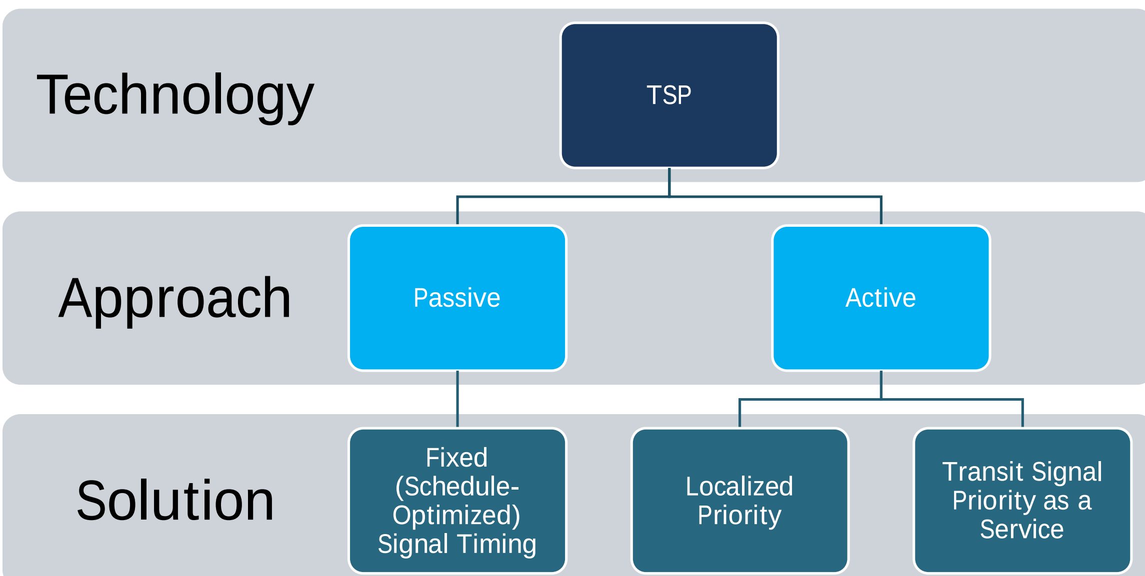


Figure 4.4: Overview of Main TSP System Configurations

Passive TSP is a traffic signal coordination method that optimizes timing to enhance operations between BRT stations, minimizing the number of stops at signals along the route. This is typically achieved by dividing the bus route into segments between bus stops and fine-tuning the signal timing plans based on average dwell times and travel times. In mixed traffic operations, passive TSP is very similar to signal coordination to enhance green bands for autos but adjusted to focus more on progression of BRT vehicles between stations, and it relies on typical signal vehicle detection methods. Where an exclusive guideway or lane exists, additional or specialized detection may be required particularly where stations are near-side and closer to a signal. Passive TSP serves as a fundamental strategy that can be augmented with active and adaptive strategies as needed. In general, it is recommended that passive TSP be implemented for all BRT corridors. Field experience and tests have indicated that passive TSP coordination efforts tend to benefit both BRT and auto traffic along the corridor.

Active TSP uses an active decision-making process based on a set of pre-existing conditions to provide priority to buses. This may include the consideration of schedule adherence, time of day, and ridership amongst other parameters to determine if and how much priority is granted. In most deployments, priority treatments occur at individual intersections or in conjunction with adjacent traffic signals using peer-to-peer communication. However, in next generation TSPaaS deployments, signal timing can be adjusted simultaneously along the corridor with the help of additional information from the Traffic Operations Center, such as traffic flow and demand data.

As MCDOT continues to evaluate future TSP configurations, it is essential to build upon existing successful implementations, which followed a structured methodology for corridor and intersection selection. Decisions should be informed by a comprehensive analysis that include the state of the existing network, traffic density, customization needs, agency goals, cost/benefit considerations, and other operational factors. The analysis should also involve ranking potential TSP corridors based on their impact on existing traffic congestion and benefits to existing service, volume-to-capacity ratio, and available slack time. The following guiding principles are suggested to further aid MCDOT in making well-informed decisions on selecting the most appropriate TSP approach, balancing cost-effectiveness, technology compatibility, flexibility, collaboration, and regulatory compliance:

- Network Complexity and Traffic Density: A structured methodology is recommended for selecting TSP corridors, taking into account existing infrastructure and the anticipated impact on traffic and transit service. Active TSP is generally favored for complex networks with multiple intersections and variable traffic, as it allows for real-time signal adjustments based on set conditionality rules. TSPaaS systems are the most adaptable but come with higher complexity and cost. For smaller, non-priority corridors, employing passive TSP on existing infrastructure can be beneficial, particularly in straightforward linear networks with limited entry and exit points and consistent traffic patterns.
- Customization: Active TSP systems offer a broad range of customizable features that allow for adjusting signal times at specific stop points or intersections based on user defined parameters and conditions. TSPaaS systems provide the greatest control and configuration scenarios.
- Future Positioning: As MCDOT aims for long-term improvements, planning for a future regionwide implementation of TSPaaS is advisable. In the interim, MCDOT may choose to deploy an active TSP system that is compatible with existing and planned infrastructure with a goal to accommodate future changes in system needs or technology advancements. Concurrently, it is recommended that MCDOT begin coordinating with neighboring and statewide agencies to develop uniform standards in operations and equipment.

While the above are the core principles that can help MCDOT select a TSP configuration, it is important that a comprehensive decision-making process is utilized with consideration on operational needs, efficiency gains, resource availability, technology compatibility, cost-effectiveness, and safety and environmental impacts. TSP is not a "silver-bullet" solution and must be designed, implemented, and operated in conjunction with the physical facilities and operational processes of BRT.

2.1.2. Roles and Responsibilities

The seamless transition from system design to implementation is closely tied to a clear definition of roles and responsibilities, which are essential for the successful deployment of the TSP System. In any deployment, the roles and responsibilities of those involved in the TSP System should at a minimum address the following:

- Equipment Ownership: The ownership of traffic signals in the region is distributed among multiple agencies. The Maryland Department of Transportation Maryland State Highway Administration (MDOT SHA) owns the signals located along state routes and serves as the ultimate approver for signal design, including the installation of new signals, modifications, or reconstruction of these signals. MCDOT owns a substantial portion of the remainder signals in the area, while a minor portion is owned and managed by local jurisdictions.
- Operation and Maintenance: As part of a longstanding maintenance agreement, MCDOT operates and maintains MDOT SHA, County, and select city signals in the region. All activities should adhere to existing operation and maintenance guidelines.
- Performance Oversight: MCDOT should consider establishing a joint signal operations group to oversee TSP operations, review operations and suggest improvements.
- Equipment and Operational Standards: MCDOT should strive to establish a standard for compatibility across all intersection equipment within its service area. This may include developing distinctive documentation for localized treatments such as typical sets of drawings, system designs, preemption protocols, and others. It is recommended that Memorandum of Understanding (MOU) agreements are also established between relevant stakeholders (such as the MDOT SHA and MCDOT) to ensure the same type of equipment within the service area, and that priority access protocols and scenarios are defined.

2.1.3. Physical Requirements

The physical requirements of the TSP system must consider the existing technology and infrastructure in place. Currently, MCDOT uses Opticom 764 radio-controlled solutions for both roadside and onboard bus hardware equipment to facilitate active TSP. The system employs GPS devices installed on buses and at each intersection to communicate priority requests based on pre-programmed conditions such as bus frequency, route adherence, and revenue operation status.

For optimal performance, it is recommended that MCDOT considers upgrading the traffic signal software used on Econolite Cobalt controllers from ASC/3 to EOS. The newer software offers significantly enhanced TSP capabilities including peer-to-peer logic and improve performance metrics and can be accommodated by the majority of MCDOT’s existing signal infrastructure. Moreover, the typical bandwidth requirements for even the more advanced TSP components remain relatively modest, with the primary requirement being network reliability. Consequently, current market offerings for roadside communications infrastructure are generally well-equipped to meet necessary data exchange requirements.

Nonetheless, in support of system compatibility and standardization efforts, the TSP system should be designed to work effectively with the County's hybrid fiber and copper signal communications network. Selection of specific infrastructure components for new TSP deployments, should be informed by current market solutions and tailored to each project’s unique requirements, while conforming to agency standards and accommodating both current and projected future infrastructure needs.

2.1.4. Functional Requirements

General functional requirements of any TSP deployment should encompass meeting established performance standards in improving bus travel and reducing intersection dwell times. Additional guiding principles can be used to define the functional requirements of each TSP type:

Table 4.5: Overview of Suggested Functional Requirements for TSP

Guiding Principle	Passive TSP	Active TSP	TSPaaS
Performance Standards	Ensure signal progression timing plans support efficient movement of buses and minimize stops	Meet transit agency's standards for response time and accuracy	Detect and respond quickly to unexpected traffic conditions
System Responsiveness	Ensure signal timing plans account for operational characteristics and traffic patterns	Support real-time adaptation and responsiveness to detected traffic conditions	Incorporate intelligent algorithms for optimal bus speed calculations based on live traffic conditions and ATMS data
Schedule Adherence Control	N/A	Ensure priority is granted based on predefined conditions, such as adherence to schedule or ridership	Ensure priority is granted based on predefined conditions and ATMS data
Traffic Adaptability	N/A	N/A	Enable dynamic adjustments to signal priority based on real-time traffic conditions
Scalability and Interoperability	Align passive TSP strategies with long-term transit planning	Support scalability and flexibility to accommodate future expansions and technological advancements, including support for various signal system designs. Interoperability with WMATA, MTA, and other agencies should be enabled through the regional uniformization of standards in operations and equipment, as defined in interoperability frameworks developed under regional multiagency coordination	
Data Collection and Analysis	N/A	Offer priority analytics for route optimization and vehicle scheduling Provide data on bus travel times and dwelling times for performance analysis	

2.1.5. Performance Requirements

MCDOT can establish performance requirements for TSP in form of various key performance indicators (KPIs). The development of KPIs should follow a comprehensive assessment of operational goals and environments., and performance tracking is dependent on a monitoring system being in place. If such a system is not yet established and is deemed necessary, a performance monitoring system may be developed. The core areas for consideration should include the following:

- Response Time: Delays in priority request response times may result in unnecessary stopping of vehicles and render TSP system benefits. Aim for a target response time wherein 95 percent of priority requests are addressed within two seconds.
- Priority Granting: The effectiveness of the TSP system relies on the accuracy of granting priority to qualified vehicles (i.e., vehicles running more than 5 minutes late). Establish a target of at least 95 percent for valid priority request where a BRT vehicle is recognized, and TSP processes occur. (Note: TSP may not always alert signal operations, as for example when a bus requests priority but was already arriving on a green light.)
- Schedule Adherence: To maintain consistent service, strive for 90% of buses to maintain their headway within a ±5-minute range.
- Travel Time Reduction: To enhance the overall efficiency of the BRT corridor, target a 10% reduction in average travel time for buses along the corridor, compared to pre-TSP implementation.
- Intersection Delay Reduction: To improve overall performance, aim for a 30% reduction in average bus signal related delays at signalized intersections compared to pre-TSP implementation.

The performance requirements should be periodically reviewed and adjusted as necessary to ensure the TSP system continues to meet MCDOT's goals for improved transit efficiency, reliability, and overall service quality.

2.1.6. Future Outlook

The effectiveness of TSP is largely dependent on the local environment, the predictability of transit operations and general travel behaviors. To that effect, the deployment of TSP necessitates a comprehensive understanding of the corridor, affected routes, passenger loads, schedules, and dwell times. Nonetheless, MCDOT should strive to adopt Active TSP along all BRT corridors. Hardware improvements should be implemented as necessary, and it is recommended that the ASC/3 software on Econolite Cobalt controllers be upgraded to EOS for enhanced TSP capabilities.

MCDOT should also consider adopting TSPaaS, to further boost the efficiency and reliability of BRT operations. Concurrently, it is recommended that MCDOT coordinate with neighboring and statewide agencies on developing a framework regional TSPaaS system and utilize uniform standards in operations and equipment.

2.1.6. Challenges and Opportunities

Installing and operating a TSP system requires sufficient resources and expertise. As the system's success depends on the accuracy of traffic data collected before and after deployment, investments in comprehensive evaluations and reliable hardware and software are recommended.

For signals positioned along dedicated runningways, the use of advanced signal management techniques (e.g., advanced signal controller logic, peer-to-peer logic, or signal interval control) may help maximize TSP benefits by allowing timely adjustments of signal timings based on vehicle location and a more predictable vehicle progression.

2.1.7. Related Elements

- Guideway Control
- Ramp Meter Interrupt
- Voice Communications
- Schedule and Headways Management
- Arrival Prediction

2.1.8. Reference Documentation

- Maryland Statewide ITS Architecture
- National Transportation Communications for Intelligent Transportation System (ITS) Protocol (NTCIP)

2.2. Guideway Control

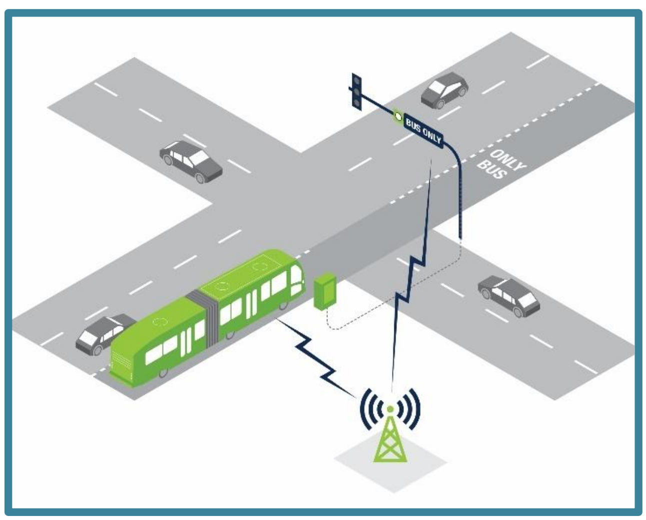


Figure 4.6: Illustration of a Guideway Control System for Dedicated Transit-only Lanes

BRT systems are designed to provide faster and more reliable public transportation service by utilizing dedicated lanes or guideways that separate buses from general traffic. Dedicated BRT lanes or guideways come in various forms, including median running lanes situated in the center of arterial roads, separated runningways that often repurposed from former railroad rights-of-way, and curbside lanes adjacent to sidewalks that can function as exclusive or dynamic transit only lanes. Exclusive transit only lanes may have time restrictions and can be reserved exclusively for BRT vehicles or shared with other local transit services, such as fixed service lines, circulator shuttles, rideshares, or carpools.

Guideway control encompasses a variety of operational strategies, restrictions, and flow management techniques to regulate access to dedicated BRT runningway, ranging from static signage and striping, to signal indicators, gates, and variable message signs, and even software-based controls that utilize GPS and on-board vehicle displays to inform operators.

2.2.1. General Guiding Principles

The selection of guideway control configurations should take into account the guideway type, use-cases, and desired level of control and safety. Various guideway control configurations cater to different objectives, such as traffic regulation, access control for non-BRT transit vehicles, flow management for reversible dedicated lanes, and dynamic curbside guideway management. Bearing these factors in mind, the following general guiding principles should be considered:

- Guideway Configuration: Customize control mechanisms to accommodate the specific guideway type and its unique operational requirements.
    - Bidirectional Lanes: Prioritize the highest level of control to prevent head-on collisions when a single lane is used either interchangeably by direction or by peak direction. In such cases, guideway control mechanisms should at a minimum include lane marking and/or striping, signage (static and/or variable), as well as signal indicators and/or access gates.
    - Single-Direction Lanes: Simple guideway control can be carried out using stationary markings, such as signage and striping. If other transit services access the BRT guideway at specific locations, their access can be managed based on relative bus spacing and headways utilizing static markings and software-based guidance through on-board displays. For increased management, consider using signal indicators, gates, or variable message signs.
    - Dynamic mixed-flow lanes: Employ guideway control strategies that allow mixed-flow lanes (often curbside lanes) to be adjusted to BRT or bus-only lanes during specified periods. Due to the dynamic nature of this scenario, recommended mechanisms include signage and lane markings at a minimum, and consider variable message signs for additional safety benefits.
- Access Control: Install automated guideway controls at all dedicated lane entrances, utilizing signal indicators, gates, variable message signs, barriers, or other suitable solutions.
- Bus Detection: Implement a system that accurately detects and identifies approaching transit vehicles for active guideway access management based on predefined conditionality rules. For exclusive BRT guideways, simpler detection methods may be sufficient.
- Signal Interval Control: Integrate guideway management and control with TSP to establish programmed intervals, enabling BRT vehicles to travel between stations while encountering fewer red lights. Base signal programming on the physical guideway layout and

bus headways, with active TSP measures adjusting vehicle speeds and signal timings as needed.

- Public Awareness and Education: To ensure safe and optimal operations, utilize specialized indications for BRT vehicles and buses that are distinguishable and consider launching public awareness campaigns that inform drivers and the community about guideway control operations. Fostering a good public understanding of the system is especially important when guideway control is used for dynamic mixed-flow management.

2.2.2. Roles and Responsibilities

Guideway control systems share many similarities in roles and responsibilities with TSP systems. Effective operation of guideway control systems relies on developing operational and maintenance guidelines that guide close cooperation and coordination among stakeholders:

- Equipment Ownership: Agency ownership of guideway control equipment and supporting communications systems is recommended. Dependent on the type of guideway control system being deployed, this also would encompass supporting equipment installed on BRT vehicles.
- Operation and Maintenance: MCDOT should provision budget allocations for operations, maintenance, and monitoring efforts. While simple guideway control and access management can be carried out by typical design, construction, and engineering teams, more sophisticated interval control and speed management may require specialized expertise. In such cases, the involvement of specialty software, vehicle system, and/or university research contractors may be necessary to meet the project's specific needs.
- Performance Oversight: Regular performance monitoring of system operations shall be performed by operations staff. In deployments where guideway access may be managed for other agency services, or the public (dynamic guideways), reoccurring performance oversight meetings with stakeholders are recommended.

2.2.3. Physical Requirements

- Signage and Markings: Use appropriate signage and striping to make guideway access points clear and understandable to both bus operators and general traffic.
- Signal Indicators: Deploy distinct signal indicators to differentiate between BRT guideway access and general traffic lanes.

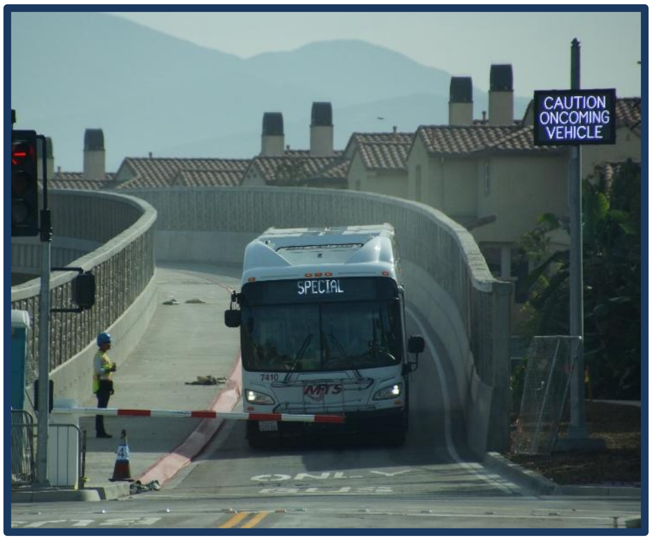


Figure 4.7 Bidirectional BRT Lane Guideway Control System, San Diego MTS (source: Arcadis IBI Group)

- Access Gates: Implement a control system with adaptive controls that can be adjusted in real-time based on changing traffic patterns.
- Bus Detection: Incorporate a reliable bus detection system to accurately detect and/or identify approaching BRT vehicles, allowing the guideway control system to manage access based on predetermined conditionality rules and ensuring seamless integration with other components.

2.2.4. Functional Requirements

- Access Control: Implement an automated system to manage access to dedicated BRT lanes, using a combination of signal indicators, gates, and other appropriate barrier solutions to prevent unauthorized entry.
- Status Display: Ensure that real-time status information is presented clearly and understandably for bus operators, the public, and control center staff. The details of these status notifications will depend on the specific lane configurations but may include actuated LED displays or variable message signs with information on lane status (whether it's limited to BRT vehicles only or open to other transit services, closed due to the opposite directionality of an interchangeable runningway, or whether the dynamic mixed-flow lane is currently designated as a bus lane or a general traffic lane). The status display should be easy to see and comprehend on both roadway equipment and in-vehicle screens and maintain real-time communication with the central guideway control system interface.
- Bus Detection: Ensure that the system can accurately detect and/or identify approaching BRT vehicles.
- Signal Interval Control: Coordinate the guideway control system with TSP and signal coordination/management efforts to establish programmed intervals, allowing BRT vehicles to travel between stations with minimal delays. This can be accomplished through a number of means including peer-to-peer signal controller logic, TSPaaS applications, and/or means of advanced detection. It is important that guideways be supported by advanced traffic signal control and detection equipment and techniques to allow the highest probability of the bus proceeding through signals and control points without stopping. Applying traditional signal design and control techniques to a guideway can make it more of a “trap” for BRT vehicles than a benefit.

2.2.5. Performance Requirements

- Guideway Control Compliance: Monitor the percentage of bus operators and other drivers who comply with guideway control rules, aiming for a compliance rate of at least 99 percent.
- System Reliability: Ensure the guideway control system maintains a high level of operational uptime and availability, with a target of at least 99.9 percent uptime to minimize disruptions and safety incidents.

2.2.6. Future Outlook

As MCDOT continues to expand its dedicated BRT lane network, the harmonization of guideway controls will play a critical role in ensuring smooth operations and effectiveness. Properly implemented controls will be essential to keep BRT services running efficiently and reliably. In particular, runningways featuring interchangeable lanes, complex cross-street intersections, and dynamic mixed-flow runningways should be prioritized for guideway control enhancements.

2.2.7. Challenges and Opportunities

There are several challenges and opportunities associated with the implementation of guideway control systems. One key challenge is the need to carefully consider pedestrian impacts and timing, as these can cause significant delays and pose potential safety hazards. By taking a comprehensive approach to pedestrian safety, MCDOT can minimize risks and ensure that all users of the transportation network are accounted for.

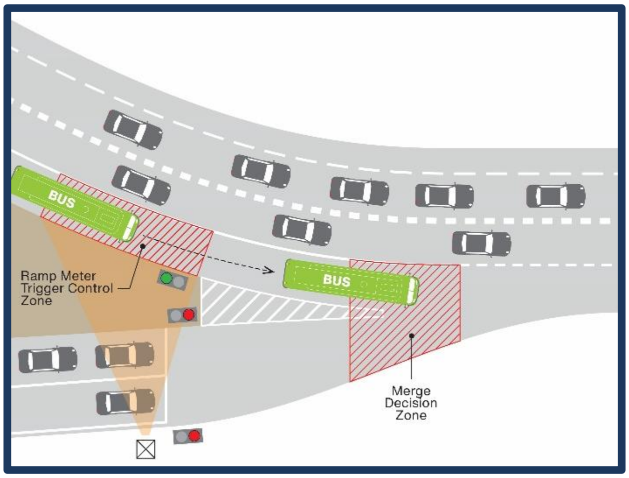


Figure 4.8: Illustration of General Roadside Components of a Ramp Meter Interrupt System

Integrating guideway control system operations with advanced timing controls and TSP presents a significant opportunity to enhance the smooth progression of BRT vehicles and prevent the segmentation of dedicated routes that result in delays for buses as typical traffic signal operations take place.

Additionally, more sophisticated guideway control systems provide the opportunity to implement dedicated transit lanes on space-constrained roadways. As assisted and connected vehicle technologies become more widespread, these systems will continue to improve, opening up new possibilities for enhancing the efficiency and effectiveness of BRT services.

2.2.8. Related Elements

- Transit Signal Priority
- Ramp Meter Interrupt
- Schedule and Headways Management

2.3. Ramp Meter Interrupt

The ramp meter interrupt system is a traffic management solution designed to improve the flow of traffic on highways and interstates during peak hours. The system uses real-time data from sensors and cameras to monitor traffic conditions and can automatically adjust ramp metering rates in response to changing traffic patterns.

The key objective of the system is to reduce congestion and delay for buses, while also improving overall safety on the roadway by minimizing stop-and-go traffic and reducing the likelihood of accidents caused by sudden slowdowns or backups.

Ramp meter interrupt can be used in two different ways: (1) as a method of allowing a bus using a high-occupancy vehicle (HOV) or transit ramp lane to more easily progress up a ramp and merge with other ramp traffic and onto the freeway; (2) as an interrupt to hold ramp traffic for a few seconds to create a "gap" for a shoulder running bus to proceed more easily across the transition/merge zone.

2.3.1. General Guiding Principles

- Automated Controls and Beacons: Implement automated controls with adaptive algorithms that can adjust ramp metering in real-time.
- Bus Detection and Priority: Configure the system to accurately detect approaching buses traveling on the shoulder, allowing them to pass by briefly holding vehicles on the ramp. Depending on local ramp configurations, the system should also provide priority for buses on the ramp.
- Queue Management: Ensure the system can detect when vehicles are queued up on the ramp and activate pre-programmed strategies to clear out the backed-up vehicles.
- Real-Time Traffic Data Collection: Utilize sensors and/or cameras to accurately monitor traffic conditions and support in real-time operations.
- System Integration and Coordination: Integrate the ramp meter interrupt system with existing ramp metering system as well as other traffic management infrastructure and coordinate with relevant stakeholders to achieve maximum efficiency and alignment with broader transportation goals.
- Public Awareness and Education: Develop public awareness campaigns to educate drivers and the community about the ramp meter interrupt system, its benefits, fostering a sense of familiarity and compliance among road users.

2.3.2 Roles and Responsibilities

Ramp meter interrupt implementation and operations requires close coordination with MDOT SHA. The following general responsibilities apply:

- Equipment Ownership: As the jurisdictional agency, MDOT SHA is the ultimate approver for design, deployment, and ownership of the ramp interrupt system. Concurrently, it is expected that MCDOT would retain ownership of ramp meter interrupt equipment and detection technology.

- Operation and Maintenance: The operational and maintenance activities of the ramp meter interrupt system necessitate close coordination with efforts related to the ramp metering system and may result in split responsibilities between MCDOT and MDOT SHA.

2.3.3. Physical Requirements

- Ramp Bypass Lanes or Transit-Only Lanes: To allow the smooth flow of BRT vehicles while minimizing interference with other traffic, establish ramp bypass lanes or improved shoulders designated as transit-only lanes.
- Signage and Beacons: Install a combination of static signage, electronic signage, and signal indications/beacons at ramps to effectively inform drivers of ongoing ramp meter interrupts and the associated traffic conditions.
- Mounting Locations: Identify suitable mounting locations for communications equipment and detection systems to facilitate effective monitoring and control of the ramp meter interrupt system.

2.3.4. Functional Requirements

- System Integration: Design the system with a focus on compatibility with MDOT SHA's ramp metering system to ensure that the two systems can reliably communicate and operate.
- Bus Detection: Configure the system to accurately detect approaching BRT vehicles and provide priority by holding vehicles on the ramp for a brief duration.
- Responsive and Adaptive Controls: Implement a control system with adaptive algorithms that can adjust ramp metering operations in real-time based on changing traffic patterns, enabling efficient prioritization of BRT vehicles without the need for manual intervention.
- Ramp Queue Management: Design the system to detect when vehicles are queued up on the ramp and trigger preprogrammed strategies to clear out backed-up vehicles with considerations to bus locations during this event.
- Performance Monitoring and Reporting: Establish a monitoring and reporting framework with clear performance indicators to assess the system's effectiveness, identify areas for improvement, in support of data-driven decision-making.
- System Reliability and Redundancy: Design the ramp meter interrupt system with built-in redundancy and fail-safe mechanisms to maintain functionality and safety in case of component failures, communication errors, or other unexpected events.

2.3.5. Performance Requirements

- Bus Delay Reduction: The introduction of a ramp meter interrupt system is generally observed to yield substantial benefits in reducing delays for buses merging onto the freeway.

A target value 40 percent reduction in ramp delays for buses using the system is recommended during peak congestion periods.

- Vehicle Queue Length: Measure the average queue length on ramps with the ramp meter interrupt system, ensuring that the queue length does not exceed a predetermined acceptable threshold, such as 100 percent of the ramp storage capacity.
- Vehicle Throughput: Monitor the average number of vehicles passing through the ramp during peak hours to ensure that the ramp meter interrupt system does not negatively impact overall traffic flow. Aim for a target value that maintains or improves pre-implementation throughput levels.
- Ramp Meter Activation: Monitor the average time between the activation of the ramp meter interrupt and the bus passing to ensure that the ramp meter interrupt system does not disrupt ramp metering operations extensively.
- Safety Incident Rate: Track the number of safety incidents (e.g., accidents, near-misses) on the ramps with the ramp meter interrupt system. Aim for a target value resulting in reduced number of safety incidents compared to pre-implementation levels.
- System Reliability: Monitor the uptime and availability of the ramp meter interrupt system, ensuring that it is operational at least 99 percent of the time.

2.3.6. Future Outlook

Due to the unique location and operational characteristics of freeway running ramp meter interrupt systems, it is recommended to start coordination with MDOT SHA during the early stages of system design. Doing so will help ensure that the ramp meter interrupt system is fully operational at launch, and roadway users are introduced to the new service route and the ramp meter interrupt system under one campaign. Beyond freeway applications, the adaptability of the Ramp Meter Interrupt system to other traffic contexts allows for deployment on arterial roads and major corridors where merging onto the mainline is facilitated through ramp-like configurations. Such deployment is particularly beneficial in areas where segments of the mainline exhibit increased congestion near a particular merging location. In these scenarios, a ramp meter interrupt system can be a viable choice, to smooth out traffic flow and reduce merging-related accidents by enabling controlled merging onto the mainline and decreasing the necessity for vehicles on the mainline to reduce speed.

2.3.7. Challenges and Opportunities

The implementation of ramp meter interrupt systems presents both challenges and opportunities for improving transit operations. Recent deployments of similar systems across the US faced complications in effective configuration of ramp meter interrupt systems, especially related to assigning freeway transit-only lanes on shoulders. As a result, it may be necessary to treat the effort as a pilot program, allowing for adjustments and refinements based on real-world experiences and feedback from stakeholders.

Institutional challenges can also arise in the implementation of ramp meter interrupt systems. These challenges may include coordination among different agencies, jurisdictions, and stakeholders, as well as addressing concerns from the public and other users. Fostering open communication and collaboration, can help MCDOT overcome these challenges and create a successful ramp meter interrupt system that benefits all users of the transportation network.

The advancement of connected vehicle technology presents a significant opportunity for streamlining and substantially improving the ramp meter interrupt system. As connected vehicle technology becomes more widespread, ramp meter interrupt systems can leverage this technology to enhance communication between vehicles and infrastructure, optimize signal timings, and improve overall system performance.

2.3.8. Related Elements

- Transit Signal Priority
- Schedule and Headways Management
- Guideway Control

2.3.9. Reference Documentation

- FHWA Ramp Management and Control Handbook, and Ramp Metering Primer

3.Station Elements

Stations often serve as the first point of contact between passengers and the BRT network, acting as gateways to the system. Accordingly, station elements center around technologies designed to enhance the passenger experience and streamline operations. Station elements can encompass a variety of key functionalities, including providing real-time passenger information, facilitating seamless fare transactions, enabling platform-level boarding, and ensuring optimal accessibility.

Figure 4.9: Symbolic Representation of BRT Station Elements for Double Platform

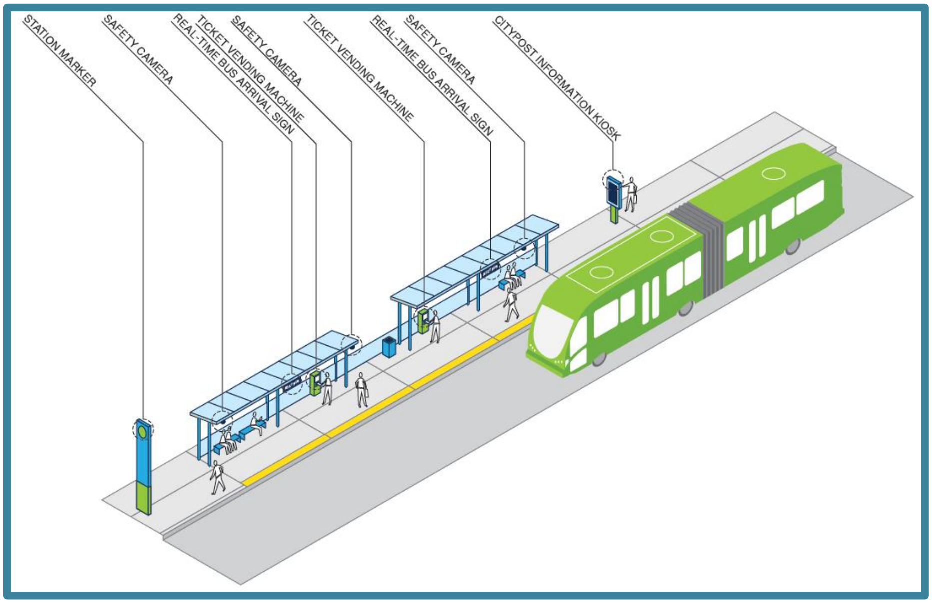


Table 4.10: Suggested Minimum Quantities of Station Elements

Station Element	Preferred Standard	Constrained Site Minimums[1]
Real-Time Traveler Information Signs	Single Station: 2 Double Station: 3	2 per station
Multimedia Displays/Information Kiosks	1 per station	Low-volume Stations: 0 High-volume Stations: 1
Ticket Vending Machines (TVM)	Low-volume Station: 1 High-volume Station: 2	1 per station
Safety Cameras	Single Station: 3 Double Station: 4	2 per station

[1] Constrained Site Minimums refer to acceptable standards where station conditions do not allow the Preferred Standards. If one Station Component is constrained, other Station Components should still adhere to the Preferred Standards where possible.

3.1 Station Displays

Station displays are foundational in supporting good rider experience by providing up-to-date information to riders regarding service, schedules, arrival predictions, and service alerts. Station displays also can provide wayfinding information to customers, supporting multimodal trips and first-/last-mile connections.

Figure 4.11: MCDOT Station Marker on US29 Flash service

In this document, station displays are categorized by their main function:

- Real-Time Information Displays: Located under station canopies (facing perpendicular to platform approaches for greatest visibility) or integrated into the station marker, these displays deliver essential, easily accessible service information to passengers.
- Customer Infotainment Displays: Larger and more interactive displays located near the center of the station (generally facing parallel to platform approaches) or inside informational kiosks. These displays provide detailed information and enable the presentation of local content, advertisement, and wayfinding.

3.1.1. General Guiding Principles

Real-time information displays are mandatory at all BRT stations, while customer infotainment displays are recommended at major and multimodal stops. The technology used for station displays can vary, but the implementation should typically account for the following:

- Content and Information: Determine the most relevant and valuable information to be displayed for passengers, such as arrival/departure times, route details, service alerts, and wayfinding information. Prioritize displaying real-time data whenever possible to enhance the passenger experience.
- Types of Displays: Based on the desired content, evaluate the advantages and disadvantages of various display technologies, such as basic LED/LCD, multimedia LED/LCD, or low-power electronic displays (e.g., e-paper). Each type of display offers different levels of visual appeal, energy efficiency, and maintenance requirements.
  - Basic LED/LCD displays are primarily used for the most critical information such as routes, arrival predictions for the next few buses, and significant service alerts using large font sizes.
  - Multimedia LED/LCD displays capable of providing more detailed service information, arrival predictions, service alerts, and upcoming changes or

announcements. These displays are usually larger than those used for real-time information and are positioned parallel to stations at a lower height.

  - Low-Power Electronic (e-ink) displays are most commonly used as an alternative to traditional static posted schedules. These types of displays can present static schedule information, details about other available travel services, digital ID, and service announcements, using minimal power consumption.

- Display Design: Consider principles of visibility, readability, and accessibility. Ensure that text size, colors, and contrast are optimized for easy reading under various lighting conditions. Incorporate clear, concise messaging, and use universally recognized symbols and icons where appropriate.

- Location and Placement: Strategically place displays at key points within the station, such as entrances, or waiting areas. Consider the visibility and accessibility of displays for all passengers, including those with disabilities or limited mobility—ensuring unobstructed visibility from key areas of the platform and main station approaches.

- Data Accuracy and Reliability: Ensure that the information displayed is accurate, up-to-date, and reliable by integrating the displays with the BRT system's data sources, such as CAD/AVL, or other vehicle tracking and scheduling systems utilized.

3.1.2. Roles and Responsibilities

In the implementation and operation of station displays, various stakeholders play key roles and have specific responsibilities:

- Equipment Ownership: Station displays should be owned by MCDOT to ensure sufficient oversight over display design, installation, and maintenance.

- Operation and Maintenance: Operation and maintenance may vary depending on the specifics of the contract agreement. Generally, transit agencies assume responsibility over operations and general maintenance following the initial deployment of systems to ensure that the malfunctioning displays can be brought up to date using agency technicians in a timely manner. If operation and/or maintenance responsibilities fall on the vendor or a contractor, MCDOT should establish and manage contracts and detailed standard operating procedures (SOP) documents that specify procedures and corresponding response timeframes.

3.1.3. Physical Requirements

The physical requirements that should be considered during the implementation of station displays include:

- Sizing and Mounting: Determine the appropriate size and mounting options for displays based on factors such as station layout, passenger flow, and visibility. Displays should be installed at an optimal height and angle in compliance with ADA for easy readability. For interactive displays, the recommended height range is between 48 inches and 60 inches to facilitate access by wheelchair users. Display mounting should also provide protection against vandalism ("bat-test").

- Power and Connectivity: Ensure that displays have access to a reliable power source and proper connectivity for real-time data updates. Bandwidth requirements of stations displays are generally modest, given that content can be stored on the device and real-time updates consist of small data packets. However, even for products that rely on entirely on online content, the bandwidth requirements do not exceed standard broadband or Ethernet connections, due to a comparatively low resolution of displayed content.
- Refresh Frequency and Latency: Establish appropriate update frequencies for real-time data, considering factors such as network capacity and passenger expectations. Minimize latency to ensure that displayed information is as current as possible, with a recommended refresh rate under 30 seconds.
- Protective Enclosure: Station displays shall be encased in protective housing suitable to withstand adverse weather conditions and potential vandalism. This should include weatherproof (IP55/65) protective enclosures, anti-graffiti glare-free coatings, and impact-resistant materials. As a recommendation, displays must be operationally rated in temperatures ranging from -4°F to 125°F.

3.1.4. Functional Requirements

The functional requirements for station displays should include:

- Consistent Branding: Ensure that the presented content and information is consistent across the agency. Particular focus should be placed on data accuracy between station and vehicle on-board displays, as well as the web. Using a consistent look across the various outputs helps improve traveler experience, awareness, and brand recognition.
- Accessibility: Station displays should incorporate a streamlined layout of presented information, to minimize language barriers and support effective communication of information across diverse passenger demographics. Where required, the displays shall be speech-output enabled for full and independent use by individuals with vision impairments. Specific requirements vary based several factors, including the content displayed, as such it is advisable to consult both the ADA Standards and the US Access Board Revised ICT Accessibility 508 Standards and 255 Guidelines to determine specific needs.
- Remote Content Management: It is recommended that the displays are networked together and utilize a single connection to access the BRT system's data sources. Use a direct connection to the agency's CAD/AVL scheduling system for accurate and up-to-date information of real-time information displays, and a central content management software for the remote content management of infotainment displays.

3.1.5. Performance Requirements

The performance requirements for station displays should include:

- Display Readability: Ensure that displays are easily readable under various lighting conditions, including direct sunlight, nighttime, and artificial lighting. A general recommendation for the display to provide a minimum brightness level of 600cd/m^2 and a contrast ratio between text and its background of at least 4.5:1. (ADA)
- System Reliability and Uptime: Establish targets for system reliability and uptime to minimize display outages and ensure consistent access to real-time information. This could be ensured through remote health status monitoring or remote content viewing platforms.

3.1.6. Future Outlook

The future of station displays in the MCDOT BRT system will be driven by the evolving needs of passengers and advances in display technology. As transit agencies continue to adapt to changing customer expectations and technology trends, the direction of station display technology is likely to focus on enhancing the overall passenger experience and optimizing the delivery of real-time information towards a simplified yet informative content display.

The selection of display types will play a significant role in shaping the customer experience and reinforcing the BRT branding. MCDOT should aim to choose display technologies that offer both high visibility and an aesthetically pleasing design to create a cohesive and recognizable identity that enhances passenger satisfaction.

3.1.7. Challenges and Opportunities

MCDOT has the potential to leverage a unified content management platform across all its station displays, streamlining the process of disseminating information and reducing operational complexities. By utilizing a single platform, MCDOT can maintain consistency and efficiency in managing content across various display types, such as real-time arrival information, maps, and service alerts.

Another opportunity lies in harnessing the advancements in display technology to enhance the user experience. MCDOT can explore options such as interactive touchscreens, dynamic content, and innovative wayfinding solutions to improve customer engagement and satisfaction. Additionally, incorporating accessibility features, such as audible announcements and visual aids will ensure that the information provided is accessible to all passengers, including persons with disabilities.

3.1.8. Related Elements

- Safety Camera System
- Networking/Communications and Monitoring

3.1.9. Reference Documentation

- Transit Cooperative Research Program (TCRP) reports and best practice guides

- Americans with Disabilities Act (ADA) requirements and best practices for ensuring accessibility of station displays
- US Access Board Revised ICT Accessibility 508 Standards and 255 Guidelines, which provide comprehensive guidelines for electronic and information technology requirements

3.2. Fare Payment and Collection

The fare payment and collection system is responsible for collecting fares from passengers, processing payments, managing revenue accounting, and ensuring the security of transactions.

The main objectives of a modern fare payment and collection system are to enhance the customer experience by providing secure and convenient payment options, improve operational efficiency through streamlined processes, and offer valuable data insights for informed decision-making.

3.2.1. General Guiding Principles

The proposed general guiding principles to MCDOT's current fare collection protocol are:

- SmarTrip Validators: Implement SmarTrip validators at all doors to effectively support all door boarding on BRT vehicles.
- On-Board Farebox: BRT buses should be pre-wired to accept fareboxes for potential future retrofits. To improve transfer experience of cash paying riders, explore the option to provide a printed receipt as a proof of payment.
- Paid Fare Zone: Designate the bus as a paid fare zone and consider using fare ambassadors to encourage off-board payment compliance.
- Off-Board TVMs: Ensure the installation of at least one off-board TVMs per station. For high-volume stations, it is recommended to deploy two TVMs per station to help reduce delays related to on-board fare processing.
- TVM Capabilities: Ensure that the TVMs are capable of accepting and reloading SmarTrip cards, if possible, and coordinate with other regional operators on this feature.

While the SmarTrip system currently employed by MCDOT positions the agency well for cross-agency operations and a unified regional open fare payment system, the following design guidelines are recommended should MCDOT consider transitioning to a new system that better meets agency needs and goals in the future:

I. TYPES OF FARE PAYMENT SYSTEMS

Each system has its advantages and drawbacks, and MCDOT should evaluate them based on convenience, security, cost-effectiveness, and compatibility with existing infrastructure.

Fare Payment System	Advantages	Disadvantages	Cost	Operational Complexity	Business Intelligence Capability
Smart card Rechargeable cards tapped on a reader for fare payment	Faster than cash-based payments Secure Can be integrated with other transit services	Requires card distribution and management infrastructure Some passengers may not have access to smart cards	Medium	Medium	High
Mobile ticketing Passengers purchase and display tickets using smartphones	Convenient; No need for physical cards Can integrate with other mobile services	Requires smartphone access and connectivity Potential technology barriers for some users	Medium	Medium	High
Account-based Payment methods linked to an account for automatic charges per ride	Seamless and convenient Reduces the need for physical cards or tickets	Requires account setup and management Privacy concerns	High	Medium	High
Open-loop Contactless payment methods (e.g., credit cards, mobile wallets) used directly for fare payment.	High convenience No need for proprietary cards or accounts Can integrate with other contactless services	May require infrastructure upgrades Potential security concerns	High	High	High

II. SYSTEM CONFIGURATION

The configuration of the fare payment and collection system should be designed around efficiency and speed, as BRT systems typically experience higher ridership and necessitate expedited boarding processes to maintain schedule adherence. Onboard fare payment systems allow passengers to pay their fares while onboard the vehicle, typically requiring a ticketing or payment validation device to be present on-board, such as a fare-boxes, smart card readers, or mobile payment terminals. In contrast, station-side fare payment systems require passengers to pay their fare before boarding the vehicle, typically at a ticket vending machine, and often include markings within the station designated as paid fare zones to enable fare payment validation. Station-side systems may reduce delays during boarding, by allowing riders to settle their fare prior to the bus arriving at the station, onboard fare processing can help reduce fare evasion. A hybrid fare payment system, which includes onboard and station-side components seeks to combine the benefits of both configurations, aiming to improve efficiency and compliance.

III. CHOOSING A FARE PAYMENT SYSTEM

When selecting a fare payment and collection system, MCDOT should consider the following key factors:

- Compatibility with existing infrastructure
- Agency and regional technology and legislature direction
- Implementation and operational costs
- Security features to prevent unauthorized access or fraudulent transactions
- Ease of use for passengers and accessibility
- Data collection and analysis capabilities for ridership patterns and revenue collection

MCDOT also may consider implementing a hybrid fare payment system, which combines different payment capabilities and/or includes both onboard and station-side elements. With careful planning, this approach can provide greater flexibility and convenience for passengers while maintaining fare enforcement. A hybrid approach also may serve as an interim middle ground solution for the agency until an agency- or regionwide direction is fully developed. However, it is worth considering that a hybrid system may introduce increased complexity in operational and maintenance efforts as well as confusion among passengers due to the presence of multiple payment options and validation points.

3.2.2. Roles and Responsibilities

- Equipment Ownership: Due to heightened security requirements associated with fare payment processing equipment, it is common for the fare payment system provider to retain ownership of the necessary hardware, software, and services. However, this ownership model is not universal, and depending on the terms of the contractual agreement, ownership may be assumed by MCDOT.

- Operations and Maintenance: MCDOT transit operator staff shall be responsible for day-to-day operations, including fare enforcement, general maintenance, and providing physical assistance to passengers. Staff also may provide input on system design and requirements based on operational experience. It is possible that due to security considerations, maintenance activities of equipment are reserved for trained payment system provider technicians.

- Payment System and Policy Configuration: Due to the secure nature of the payment system, the provider is usually responsible for the implementation and configuration of the system. MCDOT shall be responsible for setting fare policies and ensuring system compliance with regulations.
- Performance Oversight: MCDOT shall oversee system performance, maintenance, and customer support activities.
- Third-party Access: Specific aspects of the fare payment and collection system, such as mobile ticketing applications, back-end data processing, and customer support services may be providers by contractors. Third-party access may be also granted to local and regional agencies to support the coordination of fare policies, system integration, and interoperability with other services.

3.2.3. Physical Requirements

A well-designed fare payment and collection system should prioritize user-friendliness and accessibility. This includes accommodations for passengers with disabilities or special needs, such as wheelchair-accessible fare stations, audio announcements for visually impaired passengers, and tactile or Braille signage where appropriate. The physical aspects of the fare payment and collection system commonly include:

- TVMs: These devices should feature a user-friendly interface, a pushbutton display or touchscreen, a numpad to facilitate the entry of account and payment information, a card reader, and an audio speaker for verbal instructions or feedback. Optionally, they may be equipped with a card printer for issuing new fare media and a receipt printer to provide transaction proofs.
- Validators or Card Readers: These are compact, often tablet-sized, with the primary feature being the scan area for smart cards, mobile tickets, or contactless payments. An audio speaker can be used to signal successful validation. A small screen may also be included to offer visual confirmation of the validation process.
- Paid Fare Zones: Physical barriers and/or markings to control access to paid fare zones for electronic fare systems, within which enforcement is applicable.
- Signage and Wayfinding: Clear, visible signage to guide passengers in using the fare payment and collection system, including instructions for purchasing, validating, and using fare media.
- Accessibility: The TVM shall adhere to the applicable Americans with Disabilities Act (ADA) requirements. In general, this includes installation without obstructions, ensuring the display height is accessible (between 48 and 60 inches), and the inclusion of tactile signs. The TVM

should also support speech output for enhanced usability by individuals with vision impairments.

3.2.4. Functional Requirements

Streamlined design also should follow the functional capabilities of the system. From a traveler's point of view, the process should be intuitive and easy to understand and require the fewest steps possible. Special considerations should also be placed to allow (audio) assisted operations. The benefits of a consistent and streamlined process also extend to the operation and maintenance of the fare system. In general, the functional characteristics of a fare payment and collection system shall include:

- Streamlined Processes: Ensure the system processes employed by the fare payment system support quick transaction times, to minimize passenger wait times and expedite the boarding process.
- Fare Calculation: The fare payment system shall accurately and efficiently process fares based on predefined rules, such as passenger type, distance traveled, and transfer policies.
- Payment Processing: The system shall support secure and reliable handling of transactions, including authorization, settlement, and reconciliation with various payment methods (e.g., cash, credit cards, mobile wallets).
- Revenue Management: It is imperative that the fare payment system supports revenue management functionalities including revenue tracking, reporting, and auditing processes, as well as revenue allocation processes among involved agencies, if applicable.
- Data Security: The system should employ data security practices that ensure compliance with data protection standards and regulations, including secure storage, transmission, and handling of personal and financial information.
- System Compatibility: Ensure that the system supports streamlined integration with other transit services or modes, as well as integration with related ITS components, such as real-time passenger information systems and operations control centers.
- Accessibility: The TVM shall be equipped with a voice module with adjustable volume control to allow visually impaired customers to perform any transaction by following interactive voice instructions, both following displayed messages and providing supplemental messages as needed. Given the variability in requirements, consulting the latest editions of the ADA and the US Access Board's ICT Accessibility 508 Standards and 255 Guidelines is advised to ensure compliance and up-to-date implementation of accessibility features.

3.2.5. Performance Requirements

Performance requirements for a fare payment and collection system include targets for transaction speed, system reliability, data accuracy, and security standards. Key considerations when implementing the system should include:

- Transaction Speed: The system shall ensure that fare validation and payment processing occur within an acceptable time frame to minimize passenger delays. Fast processing times are especially important for electronic systems to prevent failed transactions:
  - Contactless payment systems, such as credit card or mobile wallet transactions, are designed to be fast and secure. A common timeout threshold range for contactless payments is between 500 milliseconds to 1 second. However, the specific threshold may vary depending on the system's infrastructure, communication technology, and security requirements.
  - For smart card systems, the timeout threshold may be slightly longer, ranging from 1 to 5 seconds. This is because smart card transactions generally involve reading and writing data to the card, which can take more time than a simple contactless payment.
- System Reliability: The system shall maintain an uptime percentage above a predefined threshold to ensure consistent and reliable service. Recommended threshold is 99.5 percent availability.
- Data Accuracy: Fare calculation, revenue management, and reporting processes shall be performed with upmost accuracy and allow for minimal tolerance of errors. Recommended threshold is 99% accuracy.
- Security Standards: The system shall be compliant with all applicable data protection and financial industry standards, such as the Payment Card Industry Data Security Standard (PCI DSS), the Maryland Personal Information Protection Act (MPIPA), and others.

3.2.6. Future Outlook

Continued emphasis on regional operability of the fare payment system should prevail as a priority. MCDOT must ensure that its fare payment system remains compatible and interoperable with those of neighboring transit agencies, allowing for seamless travel experiences across various jurisdictions and between transportation modes. By working closely with other transit agencies and stakeholders in the region, MCDOT can develop a fare payment system that is adaptable and capable of integrating with various modes of transportation, such as rail, bike-share programs, and ride-hailing services.

In the long run, with the rapid advancement of technology and the growing popularity of mobile payment solutions, it is highly likely that fare payment systems will continue to shift towards mobile-based platforms. MCDOT should be well-positioned adapt to this trend by investing in the development and implementation of mobile payment solutions that are secure, user-friendly, and compatible with existing fare payment infrastructure. This transition will require ongoing research, collaboration with technology providers, and engagement with passengers to ensure a smooth and successful integration of mobile payment options into the fare payment system.

3.2.7. Challenges and Opportunities

The implementation of a new fare payment and collection system specifically for a BRT system may present some challenges related to integration with existing infrastructure or other transit modes.

Funding and budget constraints can make it challenging to implement and maintain such systems, while ensuring the security and privacy of passengers' personal and financial information remains a continuous concern. Additionally, rapidly evolving technologies may require constant adaptation and upgrades, and it can be challenging to ensure that the fare payment system is equitable and accessible to all passengers, including those with disabilities or limited access to technology.

A well-designed fare payment system presents opportunities to enhance the customer experience by providing quicker and more convenient payment options. It can also improve operational efficiency by streamlining fare collection processes, reducing dwell times, and minimizing the need for manual fare enforcement. Advanced fare payment systems can protect revenue by minimizing losses due to fraud, evasion, or inefficiencies. The data collected through these systems can be used for informed decision-making in service planning, demand management, and targeted marketing efforts. Furthermore, a fare payment system that is compatible with other transit modes or services is an imperative step in promoting intermodal transportation and removing access barriers for new transit users.

3.2.8. Related Elements

- Station Displays
- Safety Camera System
- Networking/Communications and Monitoring
- Business Intelligence and Performance Metrics

3.2.9. Reference Documentation

- American Public Transportation Association (APTA) standards and guidelines
- Federal Transit Administration (FTA) resources and guidance
- National ITS Architecture and associated standards
- WMATA IT Security Standards
- Payment Card Industry Data Security Standard (PCI-DSS), the Maryland Personal Information Protection Act (MPIPA), and other relevant data security and privacy regulations.
- Americans with Disabilities Act (ADA) requirements and best practices for ensuring accessibility of station displays
- US Access Board Revised ICT Accessibility 508 Standards and 255 Guidelines, which provide comprehensive guidelines for electronic and information technology accessibility requirements

3.3. Safety Camera System

Safety cameras support the safety and security of passengers as well as agency assets. Safety cameras can promote the perception of safety for transit customers and can lower agency risks and liability. In more advanced deployments, safety camera footage can be used to gain insight on performance of transit operations.

Figure 4.12: MCDOT Safety Camera (source: MCDOT Ride On Promotional Video)

3.3.1. General Guiding Principles

The design of the safety camera system must prioritize comprehensive coverage of critical areas, utilize reliable cameras with high resolution and low-light capabilities, and incorporate robust system redundancy. Keeping privacy concerns in mind, the system should be designed with a focus on secure operations, including strict access control measures, data storage, and footage retention policies that comply with legal requirements and industry best practices. Camera placement should ensure proper coverage of all critical areas and minimize blind spots. The visible presence of cameras also can act as a deterrent, as such, high-mounted camera placement is recommended for increased visibility, reduced overt blind spots, and minimized risk of vandalism or tampering. Increasingly, safety camera systems are being equipped with high-resolution cameras to enable video analytics and automation for various use cases, such as automated incident sensing, or schedule adherence/platform occupancy monitoring. The decision to employ cameras in this manner depends on the agency's direction, and it is essential to consider that increased integration points may introduce system vulnerabilities. Selecting a system with trusted and available integrations is highly recommended.

3.3.2. Roles and Responsibilities

- Equipment Ownership: The transit agency must take responsibility for ensuring that the surveillance cameras at BRT stations are properly installed, maintained, and used.
- Operations and Maintenance: MCDOT should appoint qualified staff to oversee all aspects of the camera system, including its installation and maintenance, as well as case-by-case review of footage following incidents.
- Regional Collaboration: Access to the safety camera system footage and camera control may be granted to various agencies for incident and traffic management as well as for public safety and emergency response purposes. This may include MDOT SHA Statewide Operations Center, MDOT's Public Safety Answering Point (PSAP) and the Montgomery County Public Safety Headquarters and others.

3.3.3. Physical Requirements

The physical requirements of the safety camera system must be thoroughly evaluated to guarantee optimal performance and security:

- Camera Types: Utilize a combination of fixed and PTZ (pan-tilt-zoom) cameras to ensure comprehensive coverage of station areas. Fixed cameras can provide continuous monitoring of specific areas, while PTZ cameras can provide the additional capability for remote control and adjustment to focus on incidents or areas of interest as needed.
- Camera Placement: Placement shall be strategically selected to provide comprehensive coverage of station platforms with specific attention to critical areas, such as entrances, exits, and ticketing areas. Additionally, camera placement should minimize blind spots that may occur near station markers or other station elements and maximize visibility for proactive deterrence.
- Mounting Height: Proper mounting height is essential for clear and unobstructed camera field of view and to minimize the risk of camera vandalism or tampering. A higher mounting position can also improve the noticeability of safety cameras to promote the deterrence of security threats.
- Protective Housing: Cameras shall be housed in durable, weatherproof casings to protect them from environmental conditions and potential vandalism. This is particularly important as station shelters do not provide sufficient protection from harsh weather environments.
- Cabling and Power Supply: Ensure the safety camera system is designed with reliable, weather-proof cabling and power supply options to support continuous operation even during temporary power outages or other disruptions of up to eight hours. For simplified installation and maintenance, utilizing Power over Ethernet (PoE) is recommended. Cabling specifications, in accordance with these standards, may encompass outdoor-rated, gel-filled, shielded Cat6 with a drain wire to enhance durability and ensure sustained operation under diverse environmental conditions.
- Lighting: Adequate lighting should be provided in all areas covered by the safety camera system to ensure clear, high-quality images. MCDOT should consider using cameras with built-in infrared or low-light capabilities for areas with limited or fluctuating lighting conditions.
- Storage: Station-side, local storage can provide redundancy and ease of access to footage, while centralized storage allows for efficient management, data backup, and analysis. As station-side storage systems are at a higher risk of vulnerability, consider utilizing encrypted storage solutions that protect sensitive footage and maintain privacy standards.
- Control Room: To ensure the confidentiality and integrity, access to surveillance footage should only be facilitated through a controlled environment, equipped with robust physical and network security protocols, including necessary monitoring hardware such as monitors,

video recorders, and camera status tracking systems. For enhanced operational efficiency and public safety, select camera feeds should be broadcasted in real-time to the Transportation Management Center (TMC). Camera feeds may also be shared with MDOT SHA Statewide Operations Center, MDOT's Public Safety Answering Point (PSAP), and the Montgomery County Public Safety Headquarters, as appropriate.

3.3.4. Functional Requirements

The functional requirements of the safety camera system should focus on ensuring secure and optimal operations:

- Real-Time Access: The safety camera system shall support access to real-time streams on a case-by-case basis, allowing for prompt identification and response to incidents or security concerns.
- Data Storage and Retention: Ensure a robust data storage solution that complies with legal requirements and industry best practices is used by the system, including the secure storage of at least 30 days of footage at a central location, in the cloud, and/or at stations.
- System Reliability and Redundancy: Design the system with built-in redundancies to ensure continuous operation in the event of hardware failure or other issues.
- Video Analytics: Employing advanced video analytics capabilities may be considered, such as motion detection, object tracking, and crowd analysis, to support proactive security measures and operational efficiency. Even if video analytics are not implemented in the initial effort, the communications bandwidth and system design should allow for the implementation of cloud-based video analytics for higher activity locations at some point in the future without the need for substantial redesign or rework.
- System Integration: Integration with other security and operational systems such as alarms or the CAD/AVL system should be considered to further enhance operations.
- Compliance: The system should adhere to all applicable laws and regulations, including those related to data protection, privacy, and accessibility.

3.3.5. Performance Requirements

- Image Quality: The safety camera system shall provide optimal performance in varying lighting conditions and maintain image quality during day and night operation.
- System Reliability: The system shall demonstrate a high level of reliability, ensuring continuous operation, and a minimum of 99.9 percent uptime. Regular maintenance and monitoring should be performed to address any potential issues and maintain overall system performance.

- Live Feed Support: The system shall support a predetermined number of simultaneous live feeds, enabling authorized personnel to monitor multiple camera streams in real-time without any significant performance degradation.
- Camera Outage Monitoring/Notifications: The system should incorporate features to monitor camera status and promptly notify authorized personnel of any camera outages or performance issues. Maintain a camera outage percentage of less than 5 percent.

3.3.6. Future Outlook

Use cases for transit agency safety camera systems is steadily expanding as the underlying camera technology and supporting systems become more advanced. Incorporating advanced video analytics technologies can enable the safety camera system to provide real-time data on BRT vehicle adherence to schedules, headway management, and longer-term trend analysis. Additionally, the system can be used to monitor passenger flow and station crowdedness, enabling transit agencies to optimize resource allocation, station design, and service frequency. It is important to note that video analytics are quite distinct from visual biometrics and need not be a privacy concern in public space if properly deployed and supported by communications programs.

MCDOT should consider specific factors when deploying cameras to ensure compatibility with future implementation of video analytics and other use cases. These factors include selecting cameras with sufficient resolution and processing capabilities, as well as ensuring adequate network bandwidth and reliable network connectivity, to support real-time analysis and data transmission.

3.3.7. Challenges and Opportunities

Proper protection from temperature changes, sun damage, and adverse weather conditions (heavy rain, snow, and wind) is crucial to maintain camera functionality and prolong lifespan. MCDOT should consider investing in robust, weatherproof camera housings, and select appropriate locations for installation to minimize exposure to the elements. Certain mounting locations and methods on transit shelters can be problematic where the camera may be exposed to continuous run-off, icing, or glare. If this is a concern, separate mountings on nearby poles or other structures with the camera in a high-quality weather-proof housing (designed specifically for the selected model of camera) may be more effective.

Maintaining data privacy and compliance with evolving regulations, as well as addressing increased cybersecurity risks associated with the integration of more advanced technologies is another key consideration point. Opportunities lie in exploring innovative camera technologies, such as 360-degree cameras, which can further enhance the system's coverage and effectiveness.

3.3.8. Related Elements

- Station Displays
- Fare Payment and Collection
- Networking/Communications and Monitoring

- Business Intelligence and Performance Metrics
- Schedule and Headways Management
- Advanced Data Analytics using Machine Learning and Artificial Intelligence

3.3.9. Reference Documentation

- APTA standards and guidelines
- FTA resources and guidance
- USDOT Security Cameras/Security Systems Fact Sheet and related guidelines
- WMATA IT Security Standards

4. Vehicle/On-Board Elements

Vehicle/on-board elements are usually seamlessly integrated within the structure of the vehicles, maintaining a low profile but pivotal presence. Typically, these elements establish a direct connection with the Central Control Elements, serving as a vital link in the operational chain of a BRT system. From an operational standpoint, they are indispensable, bolstering intricate systems like CAD/AVL and voice communication systems. Although many of these systems operate behind the scenes, certain elements such as the on-board passenger information displays are explicitly designed for visibility, underscoring the dual role of these elements in supporting operational efficiency and passenger experience.

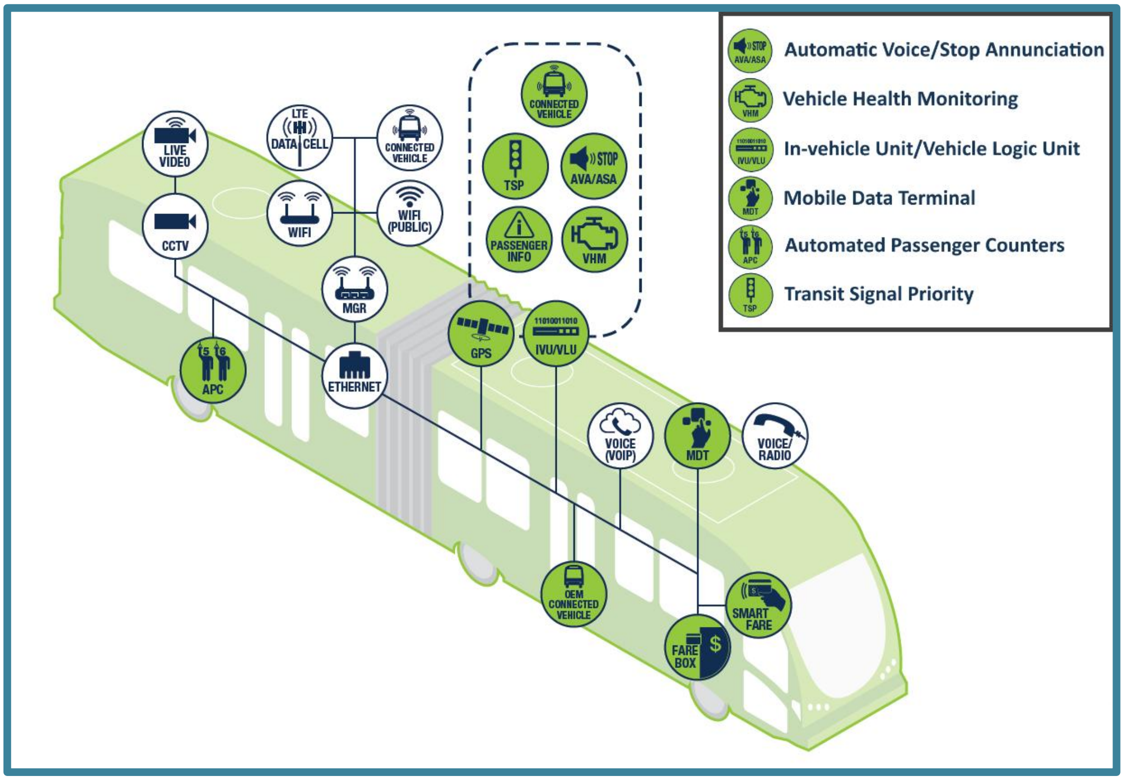


Figure 4.13: Overview of BRT Vehicle/On-board Elements

4.1. Voice Communications

Voice communications enable effective communication between operators and the central control room, in an auxiliary function to the CAD/AVL system. It is a central component of CAD/AVL systems, and the primary objective of the system is to ensure seamless coordination among different components of transit agencies. Voice communications typically utilize land mobile radio (LMR) or digital mobile radio (DMR) solutions. However, agencies are increasingly using data-based communications to support mobile Voice over IP (VoIP), which facilitate communication over the internet resembling the technologies used in modern office phone systems and allowing for a greater range of functionalities.

4.1.1. General Guiding Principles

MCDOT has recently upgraded to the P25 Phase II voice communication system, which is a significant step forward in improving communication capabilities. However, as this document is intended as a living resource, it is essential to acknowledge that technology is continually evolving, and future upgrades or replacements may become necessary.

As MCDOT staff assess future voice communication system options, it should consider the specific needs, requirements, and constraints of the system. Traditional LMR and DMR systems have been widely used and are known for their reliability and robustness in challenging environments. However, they may offer limited functionality compared to modern VoIP systems. VoIP solutions provide greater flexibility in deployment and customization, advanced features, and potential cost savings by leveraging internet-based communication infrastructure. On the other hand, such solutions may require a more robust data network and could be more susceptible to network disruptions or latency issues.

When time comes to evaluate future voice communication system options, MCDOT staff should assess factors such as system compatibility, functionality, reliability, cost, scalability, and regulatory compliance when deciding between LMR, DMR, and VoIP. Furthermore, it is worth considering the potential benefits of a hybrid solution that combines the strengths of both traditional radio-based systems and VoIP to meet the unique needs of the BRT operations. Accordingly, the following general guiding principles should be considered at that time:

4.1.2. Roles and Responsibilities

- Equipment Ownership: MCDOT is responsible for providing and ensuring proper installation of the voice communication system required for efficient BRT operations.
- Operations and Maintenance: MCDOT should designate trained staff to oversee all aspects of the communication system, including its installation, maintenance, and integration with existing infrastructure.

4.1.3. Physical Requirements

- Durable Design: All voice communications system equipment on BRT buses should be robust and designed for durability in a transit vehicle environment, ensuring reliable service.
- Resilient Backhauls: Voice communications backhauls should be robustly constructed to enable quick recovery from major events or incidents, minimizing service disruptions.

4.1.4. Functional Requirements

- Voice Communications: The voice communications system shall support reliable, two-way communication channels between the operators and the control center.
- Supervisory Management: The system shall support direct management of voice communications for supervisory personnel.
- Emergency Support: The system should support a covert listen-in function when an emergency or silent alarm is activated by the operator, unless provided by another system.
- Redundancy Review: Assess the potential need for redundant data communications (e.g., through a secondary cellular carrier or fallback LMR/DMR data solution).
- Bandwidth Management: If a VoIP system is utilized, implement a centralized Mobile Gateway Router (MGR) on board BRT vehicles to allow for configuration of data transfer priorities for the system, while also providing sufficient bandwidth to support vehicle location updates, live video look-ins, system status, and other related information.

4.1.5. Performance Requirements

- Voice Clarity: The voice communication system shall support clear and intelligible communication between operators and central control personnel.
- System Reliability: The system shall maintain a high level of system uptime and consistent performance with minimal disruptions.
- Emergency Response: The system should facilitate prompt and effective emergency response through the use of emergency support functions, such as covert listen-ins.

4.1.6. Future Outlook

MCDOT has recently transitioned from P25 Phase I to P25 Phase II at 800 MHz, which is expected to significantly improve voice communications. The P25 Phase II system offers several advantages over Phase I, including increased capacity for simultaneous conversations, better spectrum efficiency, and improved voice quality. This transition also positions MCDOT more favorably regionally, as WMATA is currently in the process of developing a resilient backbone for its P25 Phase II system. This alignment between regional partners can help ensure seamless coordination and improved communication capabilities across different transit agencies.

4.1.7. Challenges and Opportunities

Due to the proprietary nature of DMR systems, deployment and maintenance costs are rather expensive and require careful planning and resource allocation to reduce impact on the overall budget allocated for BRT operations. Furthermore, if MCDOT decides to transition to a different system architecture, such as VoIP, in the future, it will necessitate providing adequate training to staff on the new system's functionality.

4.1.8. Related Elements

- Schedule and Headways Management

4.2. On-Board Real-Time Passenger Information Displays

On-board real-time passenger information displays provide real-time updates for passengers enroute through an integration with the CAD/AVL system. By providing easily accessible location-based information, on-board displays not only contribute to increased passenger satisfaction but also support route transfers and connections with other transit modes.

Figure 4.14: Example of an On-board Passenger Information Display (source: Arcadis IBI Group)

4.2.1. General Guiding Principles

The design of on-board real-time passenger information displays should prioritize content clarity, seamless integration with existing systems, and durability to withstand the demands of a transit environment. The following general guiding principles should be considered to help ensure that information displays are designed to effectively communicate essential information and contribute to a positive transit experience for passengers:

- Visibility and Readability: Ensure that the displays are easily visible and readable from different seating and standing positions within the vehicle. Consider using high-contrast colors, large font sizes, and clear icons to enhance readability.
- Content and Format: Design the system to provide essential real-time information such as route, next stop, arrival times, transfer options, and service alerts. Consider using a combination of text, graphics, and symbols to effectively communicate the information.
- Integration and Adaptability: Utilize displays that can seamlessly integrate with the BRT's existing real-time information system, including connections to data sources, control centers, and other passenger information displays at stations.
- Durability and Maintenance: Choose displays that are resistant to wear and tear, vandalism, and harsh environmental conditions to ensure their longevity. Plan for regular maintenance and updates to keep the displays functioning optimally.

4.2.2. Roles and Responsibilities

The transit agency is typically responsible for most aspects of on-board displays, including installation, ownership, maintenance, and content management. In some cases, transit agencies may choose to contract out the content management aspect of on-board displays to private contractors. This approach can provide specialized expertise in content creation, branding, and distribution while allowing the agency to focus on core operational responsibilities.

4.2.3. Physical Requirements

The physical requirements for on-board passenger information displays should address the following aspects:

- Size and Dimensions: Use displays that are appropriately sized for the available space within the vehicle, taking into consideration various seating and standing positions of passengers.
- Mounting and Installation: Install displays in strategic locations throughout the vehicle, such as above doors, near seating areas, or in the line of sight for standing passengers. Consider using secure and tamper-resistant mounting hardware to prevent vandalism and unauthorized access.
- Visibility and Glare Reduction: Choose displays with anti-glare properties and adjustable brightness settings to ensure optimal visibility under various lighting conditions.

- Cabling and Wiring: Plan for the necessary cabling and wiring to connect the displays to the vehicle's electrical system, data sources, and control centers. Ensure that cables are well-organized, secure, and protected from potential damage.
- Environmental Resistance: Select displays that can withstand the BRT vehicle's operating environment, including temperature fluctuations, humidity, and vibration. The displays also should be resistant to dust, moisture, and potential exposure to sunlight.
- Compliance with Safety Regulations: Ensure that the displays and their installation adhere to relevant safety standards and regulations, including fire safety, electrical safety, and emergency egress requirements.

4.2.4. Functional Requirements

- Accurate and Timely Information: Ensure that the displays provide accurate and up-to-date information on route details, arrival, and departure times, stop announcements, and service alerts, preferably through an integration with real-time data sources and efficient data processing mechanisms.
- User-Friendly Interface: Design the displays with clear, legible text and graphics, using universally recognized symbols and easily understandable language. The information should be presented in a logical and organized manner.
- Accessibility: Incorporate accessibility features to cater to passengers with disabilities or special needs, such as audio announcements, large font sizes, and high-contrast color schemes. Compliance with ADA guidelines is essential.
- Multilingual Support: Provide information in multiple languages to accommodate the diverse linguistic needs of the ridership, ensuring that a wide range of passengers can understand and benefit from the displayed information.
- Customizable Content: The system should allow for flexibility in the content displayed, and support customized information according to specific routes, schedules, or special events. This feature should be easy to manage and update by authorized personnel.
- System Integration: Ensure seamless integration of the displays with other on-board systems, such as vehicle location systems, automated stop announcements, and passenger counting systems.
- Reliability and Maintainability: Select displays with a focus on durability and ease of maintenance, incorporating features that facilitate quick troubleshooting and repairs, as well as timely updates to software and hardware components.

4.2.5. Performance Requirements

- Display Accuracy: The on-board passenger information displays shall provide accurate and up-to-date information about upcoming stops, route information, current location, and connecting services.
- Update Frequency: The displays should be refreshed at regular intervals to ensure passengers receive timely and accurate updates.
- System Reliability: The system shall support continuous operations with minimal downtime.

4.2.6. Future Outlook

Agencies are increasingly adopting multimedia on-board (MMOB) displays to provide real-time information and other informational content. Such a shift enhances passenger experience while also catering to the growing need for context-related information, such as specific service changes or location-based notifications. For some transit agencies, on-board displays also may serve as platforms for advertising and public service announcements.

4.2.7. Challenges and Opportunities

Deploying on-board displays require careful consideration in ensuring continuous content updates through a central content management platform.

Opportunities for on-board real-time information displays include catering to new riders, such as tourists, by providing useful and easily understandable information. This could include estimated arrival times for key destinations and connecting services, instilling confidence in passengers and improving overall transit experience.

4.2.8. Related Elements

- 3.1 Station Displays Displays
- Vehicle Tracking
- Schedule and Headways Management
- Arrival Prediction
- Networking and Communications Monitoring

4.3. On-Board Passenger Wi-Fi

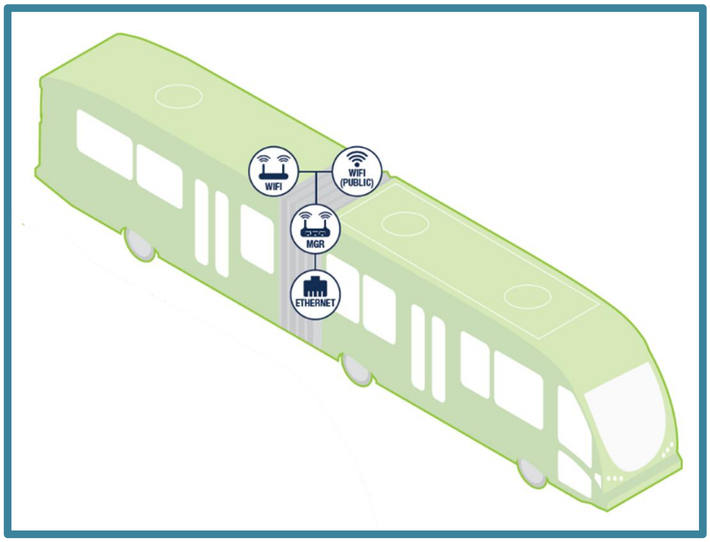


Figure 4.15: Illustration of Elements Related to On-board Passenger Wi-Fi

On-board passenger Wi-Fi has increasingly become a sought-after amenity for public transit systems across the United States, as agencies recognize the value it offers to passengers and the potential to enhance the overall travel experience. On-board passenger Wi-Fi allows riders to stay connected, productive, and entertained throughout their journey, thereby increasing overall satisfaction and promoting public transit as an attractive and convenient mode of transportation. Furthermore, Wi-Fi connectivity is particularly beneficial for smartphone-based ticketing and multimodal transit applications.

4.3.1. General Guiding Principles

Several guiding principles should be considered to ensure an optimal user experience and effective integration with other transportation services:

- Coverage and Capacity: The on-board passenger Wi-Fi system shall provide consistent and reliable coverage throughout the BRT network, with sufficient capacity to accommodate the anticipated number of users during peak travel times.
- Speed and Performance: The system should deliver adequate internet speeds to support common online activities, such as browsing, streaming, and using transit-related applications, while also maintaining consistent performance during periods of high demand.
- Security and Privacy: Design the system with robust security measures in place to protect users' data and privacy. This includes implementing strong encryption, secure authentication, and regular monitoring for potential threats.
- Cost-effectiveness: Design the system to balance performance and user experience with cost considerations, ensuring that the system delivers value for both the transit agency and passengers while minimizing operational expenses.

4.3.2. Roles and Responsibilities

The roles and responsibilities are entirely assumed by MCDOT. This includes system management, performance monitoring, and resolving any connectivity issues that may arise.

4.3.3. Functional Requirements

- Stable Internet Access: The on-board passenger Wi-Fi system shall provide a reliable and continuous internet connection for passengers throughout the BRT route, enabling riders to browse the web, access transit information, and utilize smartphone-based ticketing and transit applications.
- User Authentication: Implement an efficient user authentication process, such as a login portal or a captive portal, to control access to the Wi-Fi network and collect basic usage statistics while respecting user privacy.
- Bandwidth Management: Design the system to efficiently manage bandwidth, ensuring fair distribution of resources among users and preventing network congestion during peak usage times.
- Content Filtering and Security: Include content filtering features to block access to inappropriate or harmful websites and to protect the network from malware and other security threats.

4.3.4. Performance Requirements

- Connection Speed: Aim for a minimum download speed of 5-10 Mbps per user to provide a satisfactory browsing experience, adjusting this value based on the number of simultaneous users and overall network capacity.
- Latency: Maintain low latency levels (ideally, below 100ms) to ensure a smooth and responsive browsing experience, particularly for real-time applications like video streaming or online gaming.

4.3.5. Future Outlook

MCDOT's ongoing efforts in implementing on-board passenger Wi-Fi across its BRT bus fleet allows the agency to be well-positioned in meeting current and future connectivity demands. MCDOT should focus efforts on continually assessing and enhancing the quality and coverage of the service.

In the long-term, MCDOT also should explore potential partnerships with local internet service providers and technology companies to enhance the Wi-Fi offering on its BRT buses. By leveraging these collaborations, the agency can benefit from innovative solutions and/or cost saving while further optimizing the Wi-Fi experience for its passengers.

4.3.6. Challenges and Opportunities

Main consideration points for on-board passenger Wi-Fi primarily revolve around maintaining consistent connectivity and ensuring adequate bandwidth to accommodate the varying demands of passengers. This requires ongoing monitoring and investment in network infrastructure to guarantee a reliable and efficient service.

Opportunities for MCDOT include enhancing the overall passenger experience by providing a high-quality Wi-Fi service that enables users to stay connected, access information, and enjoy various forms of entertainment during their commute.

4.3.7. Related Elements

- On-Real-Passenger Information Displays
- Networking and Communications Monitoring

4.4. Vehicle Tracking

Accurate vehicle location is a cornerstone of a modern BRT system. By leveraging GPS or other positioning technology, the Vehicle Tracking System gathers and transmits data on a vehicle's position, speed, and direction to a central control center. This information serves multiple functions, from more general functionalities such as managing fleet operations, optimizing routing, and scheduling, and improving service reliability to more immediate functionalities that support the BRT operations, such as ensuring adherence to schedule and reducing headway irregularities. Furthermore, the data collected from these systems can be integrated with other ITS components and further enhance Advanced Traffic Management System (ATMS) processes.

4.4.1. General Guiding Principles

The vehicle tracking system should be designed around accuracy and reliability. As MCDOT moves forward with the implementation of an on-board vehicle tracking system for its BRT vehicles, the following core guiding principles should be considered:

- Existing CAD/AVL Solution: Wherever possible, leverage the existing CAD/AVL-based solution as the primary vehicle tracking system to ensure consistency, efficiency, and seamless communication between systems. MCDOT has recently implemented a CleverCAD CAD/AVL system that provides vehicle tracking and monitoring for the whole fleet. This system should be used for operational-based vehicle tracking needs.
- Supplemental Tracking Equipment: In cases where the existing fleet-wide CAD/AVL solution cannot support the required vehicle location update frequency (ideally every 10 seconds or less), deploy supplemental vehicle location/tracking equipment on BRT buses to provide accurate and real-time data for effective traffic management. For example, some agencies use additional location data supplemental from their Mobile Gateway Routers (MGRs) to support very high frequency tracking needs for TSP functions.
- Real-Time Data Accessibility: Ensure the vehicle tracking system provides real-time data access to relevant stakeholders, including dispatchers, traffic management centers, and other ITS components, to enable efficient decision-making and improve overall system performance.

- Interoperability and Standardization: Ensure that the system adheres to relevant ITS standards and specifications, promoting seamless integration with other ITS components and allowing for future system expansions or use cases.
- Scalability and Flexibility: In cases where the existing fleetwide CAD/AVL solution cannot support the specific needs of MCDOT, ensure that the alternative vehicle tracking system can easily scale with the growth of the BRT system and accommodate future technological advancements to provide long-term value for the investment.

4.4.2. Roles and Responsibilities

The responsibility of operating and maintaining vehicle tracking capabilities on BRT vehicles falls entirely on the agency.

4.4.3. Physical Requirements

- Compact Design: The vehicle tracking system components should require minimal space considerations and avoid interfering with other vehicle equipment.
- Power Efficiency: Implement a tracking system with low power consumption to minimize the impact on the vehicle's electrical system and ensure consistent performance during all operational conditions.
- Connectivity and Compatibility: Ensure that the tracking system components are compatible with existing onboard communication systems and can be easily connected to other ITS components, allowing for seamless data exchange and integration.
- Easy Installation and Maintenance: Choose a vehicle tracking system with components that can be easily installed, replaced, or serviced without requiring extensive vehicle downtime or specialized tools.

4.4.4. Functional and Performance Requirements

- Location Accuracy: The vehicle tracking system shall provide location accuracy within +/-10 feet to enable precise vehicle tracking and support efficient BRT operations. The system should utilize 32 or more channel GPS to ensure reliable and continuous tracking in various environments.
- Update Frequency: The system shall be capable of tracking and recording vehicle locations at least once per second, with event-driven positioning updates occurring every 10 seconds or faster.
- System Integration: The system shall be compatible with both legacy and cloud-based TSP/TSPaaS services to ensure seamless coordination of BRT operations.
- Timestamping and Vehicle Identification: Each vehicle location update should be timestamped and contain a recognizable vehicle ID to facilitate accurate tracking, analysis, and reporting of vehicle movements.

- Service Conditions: The tracking system should be flexible enough to accommodate varying location update frequencies based on the specific operational requirements of the BRT system.

4.4.5. Future Outlook

As the technology landscape continues to evolve, there will likely be a shift from on-board computing to cloud-based processing for vehicle tracking systems. This transition presents an opportunity to develop functions in a more modular fashion, including the creation of specific features tailored to BRT operations, such as guideway usage and headway management. In the future, some operational requirements may demand even more frequent location updates, possibly every 3–5 seconds, to enhance the accuracy and effectiveness of the tracking system.

4.4.6. Challenges and Opportunities

The vehicle tracking functionalities embedded in the existing CAD/AVL system can often fall short of the agency needs, necessitating system upgrades or modifications. Nonetheless, MCDOT's recent deployment of CleverCAD technology provides a good baseline for future enhancements that can be customized to better suit the specific needs of BRT routes. Additionally, sharing the same CAD/AVL system between BRT and fixed routes offers possibilities for improved integration between them, fostering more efficient and coordinated transit operations.

4.4.7. Related Elements

- Transit Signal Priority
- Ramp Meter Interrupt
- Voice and Data Communications
- On-Real-Passenger Information Displays

4.5. Automated Passenger Counters

Automated passenger counters (APCs) are used to accurately track service utilization, station- and route-level boardings, and other important performance metrics. These systems typically use sensors installed on buses to detect when passengers board or disembark and transfer the information to a central system via internet.

The key objectives of APCs include improving route planning by providing accurate ridership data, enhancing operational efficiency by identifying underutilized routes or vehicles, and increasing transparency through the provision of reliable and verifiable ridership reporting. APCs can help identify areas where service improvements are needed, such as high-demand routes that require additional resources. Additionally, APCs can provide general insights into areas that may experience a higher rate of fare evasion by comparing data from APCs with smart card usage figures. However, this evaluation should be treated as informational, given the various factors that impede precise data matching, such as the uncertainty in the number of transfers and instances of cash fare payments.

4.5.1. General Guiding Principles

- FTA Compliance: The APC system shall meet FTA's APC certification and benchmarking requirements, including the need for an independent third-party validation of the system's accuracy and performance.
- Strategic Sensor Placement: Place sensors strategically to capture accurate data, such as near the entrance or exit of vehicles, without obstructing passenger movement or causing inconvenience.
- Regular Calibration and Validation: Calibrate the APC system regularly to ensure accurate counting and reporting of ridership data and establish data validation schedules to maintain optimal system performance.
- Integration and Compatibility: Ensure that the APC system integrates seamlessly with existing systems, such as fare collection, CAD/AVL, and business intelligence tools used by MCDOT.
- Cost-Benefit Analysis: Perform a thorough cost-benefit analysis of implementing an APC system versus manual counting methods, taking into account the long-term operational efficiencies and potential benefits to the transit agency.

4.5.2. Roles and Responsibilities

- Equipment Ownership: Ownership is assumed by MCDOT. The agency may coordinate with bus manufacturers to install APCs on each BRT vehicle during manufacturing or retrofitting stages, ensuring seamless integration with existing infrastructure.
- Operations and Maintenance: MCDOT is responsible for inspecting, maintaining, and calibrating the APC system regularly to ensure optimal functionality, accuracy, and precise passenger count data. This also includes addressing any hardware or software issues that may arise.
- Performance Oversight: MCDOT is responsible for regular performance assessments and service reviews to evaluate the effectiveness of APCs in informing service planning and resource allocation. Analysis of APC data is also performed by the agency.

4.5.3. Physical Requirements

- Compact Design: The APC system shall support installation with minimal space requirements to avoid interfering with other vehicle equipment, passenger movement, or vehicle aesthetics.
- Sensor Placement: Sensors should be strategically placed to capture accurate data, such as near the entrance or exit of vehicles.

- Durability and Reliability: The system components should be durable and reliable, capable of withstanding the daily wear and tear of transit operations and various environmental conditions.
- Easy Installation and Maintenance: The system should be designed for easy installation, calibration, and maintenance, with minimal disruption to transit operations.

4.5.4. Functional Requirements

- Accurate Counting: The APC system shall provide accurate counting and reporting of boarding and alighting passengers, with minimal errors or discrepancies.
- Real-Time Data Collection: The system shall collect and transmit near-real-time passenger count data to the transit agency's central system.
- Data Storage and Analysis: The system shall support the storage of recorded data to allow for historical trend analysis, performance evaluation, and continuous improvement.
- Customizable Reporting: The system should support customizable reporting features, allowing the transit agency to generate ridership reports based on specific requirements, such as time periods, routes, or vehicle types.
- Automated Calibration: The system should have an automated calibration feature to ensure accurate counting and reporting of ridership data, with minimal manual intervention.

4.5.5. Performance Requirements

- Counting Accuracy: In accordance with FTA's guidelines, the APC system shall maintain a minimum counting accuracy of 95 percent for both boarding and alighting passengers. This accuracy level should be regularly verified through manual counts and calibration processes.
- System Uptime and Reliability: The system should maintain a system uptime of at least 99 percent to ensure continuous and reliable data collection during BRT operations.

4.5.6. Future Outlook

The significance of APC data in providing valuable insights into ridership patterns and enabling National Transit Database (NTD) reporting is expected to persist. Furthermore, the growing trend of utilizing data-driven performance measures and business intelligence (BI) tools in transit planning will further emphasize the importance of accurate ridership monitoring systems. As a result, it is expected that the use cases and functionalities APC systems will continue to evolve in an effort to meet growing demands of data-driven transit planning and performance management.

4.5.7. Challenges and Opportunities

Potential areas of growth in the realm of APC systems include the increasing adoption of video analytics technology, which could potentially lead to the evolution of traditional APC systems. Video analytics can offer similar or even more accurate ridership data while providing additional benefits, such as improved security and real-time monitoring. Furthermore, seamless integration with other transit data systems and business intelligence tools can be challenging, as ensuring compatibility and smooth data exchange is crucial for obtaining accurate insights and utilizing APC data effectively.

On the other hand, opportunities for APC systems lie in their ability to swiftly provide accurate ridership data during unplanned events or travel pattern changes. This information is essential for making informed decisions, adjusting services, and maintaining safe and efficient operations during such events. Although video analytics technology is on the rise, APC systems can still serve as a valuable complementary data source, providing transit agencies with an additional layer of data accuracy and reliability, particularly in situations where video analytics might face limitations.

4.5.8. Related Elements

- Fare Payment and Collection
- Schedule and Headways Management
- Business Intelligence and Performance Analytics

4.5.9. Reference Documentation

- FTA: NTD Reporting
- APTA: APC White Paper

4.6. Automated Bus Lane Enforcement

The automated bus lane enforcement system (ABLE) is an advanced technology that monitors and enforces dedicated bus lanes to ensure their proper utilization and efficient BRT operations. The system may employ various detection methods such as cameras, sensors, and license plate recognition, to identify unauthorized vehicles in dedicated bus lanes and capture violation. With proper legislation and regulations in place, the system also may automatically issue appropriate penalties. The main benefit of this system is to maintain the exclusive use of dedicated bus lanes, thereby significantly enhancing the reliability, speed, and overall performance of the BRT route.

4.6.1. General Guiding Principles

- Regulatory Framework: Ensure that the implementation and operation of the ABLE are in accordance with local and federal laws, regulations, and guidelines.
- System Selection: Choose between a static enforcement system, which is more complex and expensive, or an onboard bus camera system that extends the capabilities of existing cameras used by bus operators. The choice should be based on the agency's needs, budget, and existing infrastructure.
- Curbside Running Enforcement: Ensure that the system is primarily focused on identifying and penalizing parked vehicles that obstruct bus lanes while also distinguishing between right-turning vehicles that may momentarily use the lane.

- Privacy and Data Security: Implement appropriate measures to protect personal and vehicle information collected by the system, ensuring compliance with data protection laws and regulations.
- Public Awareness and Education: Implement outreach campaigns to inform the public about the automated bus lane enforcement system, its purpose, and the consequences of violating bus lane restrictions. This will promote voluntary compliance and acceptance of the system.
- Performance Monitoring and Evaluation: Regularly assess the effectiveness of the automated bus lane enforcement system in improving bus lane compliance, reducing congestion, and enhancing BRT performance. Make adjustments to the system as needed based on the evaluation findings.

4.6.2. Roles and Responsibilities

Implementing ABLE requires collaboration among the transit agency, local law enforcement, local traffic departments, and potentially private companies for payment processing. The transit agency advocates for ABLE and collaborates with local authorities for system management. Local law enforcement enforces bus lane violations, while local traffic departments handle the installation, maintenance, and operation of ABLE infrastructure. Legislative changes may be necessary for ABLE implementation and enforcement, with local agency councils taking the lead. Some transit agencies may contract private companies to handle payment processing for ABLE-related fines, ensuring secure and efficient transactions.

4.6.3. Physical Requirements

- Camera Placement: Install cameras and sensors in strategic locations, such as intersections and high-traffic areas, to effectively monitor bus lane usage and capture violations. For onboard enforcement systems, install cameras on the front and sides of the BRT vehicle to capture violations from multiple angles, ensuring comprehensive coverage of the surrounding area.
- Signage: Install clear and visible signage to inform operators about the presence of the automated bus lane enforcement system and the rules surrounding bus lane usage.
- Power Supply: Provide a reliable and efficient power supply for the enforcement system, including backup power sources to ensure continuous operation during power outages or emergencies.
- Durability: Ensure that all equipment, including cameras, sensors, and communication devices, are designed to withstand extreme weather conditions and general wear and tear to maintain consistent performance over time.

4.6.4. Functional Requirements

- Accurate Detection: The system shall accurately detect and identify vehicles violating bus lane restrictions in various traffic and weather conditions.
- Vehicle Classification: The enforcement system shall be able to differentiate between authorized vehicles (e.g., buses, emergency vehicles) and unauthorized vehicles using the bus lane.
- Image and Video Capture: The system shall capture high-quality images and videos of the violating vehicles, including license plates, to facilitate enforcement actions and serve as evidence if needed.
- Data Processing and Analysis: The system shall process and analyze collected data efficiently, enabling quick decision-making and appropriate enforcement actions.
- Real-time Alerts: The system should provide real-time alerts to a central control center or directly to law enforcement agencies for prompt response to detected violations.
- Reporting and Analytics: The system should provide comprehensive reporting and analytics capabilities to support performance evaluation, trend analysis, and data-driven decision-making for improved traffic management and bus lane enforcement.

4.6.5. Performance Requirements

- Detection Accuracy: The system shall maintain a high detection rate of unauthorized vehicles entering or obstructing bus lanes. Aim for a target of at least 95 percent accuracy.
- Enforcement Efficiency: The system shall facilitate a prompt enforcement response time, with violations processed and notifications issued within a specified timeframe, such as 24 hours.
- Compliance Rate: Aim for a target compliance rate of at least 90 percent, reflecting a reduction in unauthorized vehicles using bus lanes as a result of the enforcement system.

4.6.6. Future Outlook

ABLE is an evolving technology that aims to improve the efficiency and reliability of dedicated bus lanes by detecting and penalizing unauthorized vehicles that enter or obstruct them. As the technology continues to advance, its adoption can help transit agencies like MCDOT maintain the effectiveness of their BRT systems.

The deployment of an automated bus lane enforcement should include a thorough evaluation of the available technologies and their applicability to the specific characteristics of the BRT corridors. MCDOT should consider partnering with technology providers and regulatory agencies to develop customized enforcement solutions that are both efficient and compliant with local regulations.

4.6.7. Challenges and Opportunities

ABLE presents several opportunities for MCDOT, such as improved BRT efficiency by significantly reducing unauthorized vehicles in bus lanes, which leads to faster and more reliable BRT services. Enhanced safety is another benefit, as reducing bus lane violations can decrease the risk of accidents involving buses and unauthorized vehicles. Furthermore, increased revenue can be generated through fines collected from violators.

However, there are challenges to consider. Implementing ABLE might require adjustments to local laws and regulations, which could involve a time-consuming process. Addressing public perception is essential. Educating the public about ABLE and addressing concerns related to privacy and surveillance will help garner support.

4.6.8. Related Elements

- Guideway Control
- Safety Camera System
- Networking and Communications Monitoring
- Video Analytics

4.6.9. Reference Documentation

- District Department of Transportation's (DDOT) report on Automated Enforcement of Bus Lanes and Zones

5. Control Center, Operations, and Data Elements

Control center, operations, and data elements perform a diverse array of functionalities and systems critical to the efficient and reliable operation of the BRT network. The control center operates as the primary coordinating unit, overseeing overall system operations and coordinating its various components. Operations cover crucial functional elements that enhance the efficiency of the service, including schedule and headways management, arrival prediction, vehicle health management, and yard management. The data elements, on the other hand, are the backbone of strategic decision-making, underpinned by business intelligence and performance analytics, and video analytics.

5.1. Schedule and Headways Management

Schedule and headways management is often performed within the central Automatic Vehicle Location (AVL) system, and it involves the creation, implementation, and monitoring of schedules and headways to help maintain consistent intervals or spacing between BRT vehicles and reduce instances of bus bunching or gaps in service. In practice, the central AVL system continuously tracks the real-time location of each BRT vehicle within the network and compares their actual positions with predefined schedules to identify deviations from the expected headways. The system detects discrepancies in headways, such as buses arriving too close together (bus bunching) or too far apart (gaps in service), which can arise from various factors, including traffic congestion, vehicle breakdowns, or delays in boarding and alighting passengers.

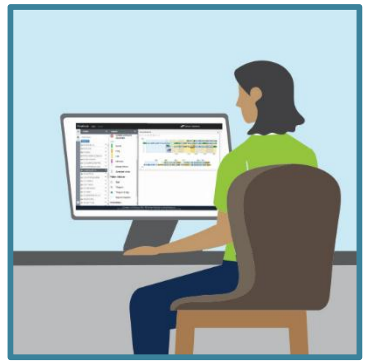


Figure 4.16: Illustration of Schedule & Headways Management Terminal

If schedule discrepancies are identified through this process, MCDOT transit operators or control center staff can make necessary adjustments to restore optimal headways. In conditions without traffic congestion, the “target up/target down” strategy is often preferred, where operators adjust travel speeds to maintain desired headway. During heavy traffic, strategies such as holding buses at predesignated points, or inserting additional vehicles into the service line may be employed. The above strategies are not exhaustive, as headway management is a dynamic and multifaceted practice, with various other methods employed as needed. The central AVL system supports these strategies by communicating timely instructions to operators, either via in-vehicle displays, audio announcements, or direct communication with the control center.

5.1.1. General Guiding Principles

- Existing Technology: Leverage existing technology tools (CleverCAD) for management and monitoring of headways, such as GPS tracking systems.
- Development of SOPs: Establish SOPs that detail headway management procedures, including methods to address gapping and bunching. These should be tailored to service specifics and environmental characteristics, ensuring they are practical and applicable to environmental characteristics of the service lines. In general
- Controlled Departures and Strategic Hold Points: Manage departures from the terminus and establish quick hold points at interim locations, considering factors such as traffic congestion and construction. Offer guidance on waiting a specific amount of time at each station when running Flash service lines to ensure proper headway management and maintain service reliability.
- Average Dwell Time: While aiming for average dwell times of 10 seconds or less can improve efficiency, consider the potential impact on passengers using TVMs or requiring additional boarding time. Strive to strike a balance between minimizing delays and accommodating passenger needs.
- Holding Point Considerations: Take physical factors into account when determining holding locations during headway operations.

- Weather-Related Schedule Adjustments: Develop contingency plans and protocols for reverting to schedule-based operations in response to severe weather or other unforeseen circumstances. Establish procedures for resetting headways from the terminus and communicating changes to passengers and staff.
- Labor Considerations: Establish partnerships, communication strategies, and incentives to prevent labor violations, such as break time violations, while maintaining efficient headway management and service quality.

5.1.2. Roles and Responsibilities

MCDOT assumes all primary responsibilities for schedule and headways management, including monitoring, alerting, and adjusting operations as needed. Some agencies may choose to use private contractors for performing more thorough scheduling optimization tasks, which may include analysis, modeling, and proposing operational improvements.

5.1.3. Physical Requirements

Although there are no specific physical requirements for operations, it is recommended to have shared visibility across controllers for key BRT operating segments on a large, communal display. This will enable effective coordination and communication among controllers. During peak periods of BRT operations, it may be beneficial to designate a controller position explicitly for monitoring and managing BRT service. Ideally, the dedicated BRT controller should provide easy access to other controller positions to facilitate seamless collaboration and information exchange.

5.1.4. Functional Requirements

- Headway Management Tool: A monitoring and alerting tool should be deployed, either separately or as part of a CAD/AVL system, to manage headways effectively. Traditional CAD/AVL headway management tools utilize "target up" or "target down" instructions to operators to mitigate bunching and gapping. These methods work well unless vehicles are impeded by heavy traffic or other conditions. In such cases, a "hold point" strategy, where operators pause at specified locations, proves effective. In extreme cases of severe gapping, an additional "insert vehicle" might be needed. MCDOT should assess the characteristics of the operating corridor and the headway policies set by the agency to evaluate the adequacy of existing tools, potentially requiring additional modifications or functions.
- Headway Monitoring Display: Bus communications supervisors should have access to a headway management and monitoring display, such as a route ladder, to show the relative spacing of all buses along the BRT corridor.
- Operator Displays: Bus operators should have access to headway management displays to assist in maintaining appropriate headways.
- TSP and Headway Integration: The TSP functionality should be integrated with headway management to create a balanced approach that alleviates bunching while maximizing the benefits of TSP efficiencies.

- Semi-Autonomous Functions: If applicable, headway control could be integrated with automated speed control systems for buses in exclusive dedicated guideways, while operators retain full steering control and command over the bus.

5.1.5. Performance Requirements

- Headway Consistency: Maintain a consistent headway between buses, with a target of at least 90% of buses operating within a ±3-minute range of their designated headway during peak hours.
- Schedule Adherence: Aim for a minimum of 90 percent of buses to adhere to their schedule, arriving within a ±5-minute window of their scheduled time at stops.
- Bunching Reduction: Strive to reduce instances of bus bunching, with a target of no more than 5 percent of buses arriving at stops within a 1-minute window of the preceding bus.
- Layover Efficiency: Monitor layovers and ensure that at least 95 percent of buses depart from layover points within their designated layover time range.
- Passenger Wait Time: Target a maximum average passenger wait time of 10 minutes during peak hours and 15 minutes during off-peak hours.

5.1.6. Future Outlook

One vital step for the future is to consistently assess the performance of headway management tools, such as CleverCAD, and explore opportunities to upgrade or integrate with innovative technologies that improve real-time monitoring and decision-making capabilities. Another crucial aspect involves addressing the concerns about passengers potentially being left behind due to short dwell times. This may involve fine-tuning the balance between dwell time efficiency and accommodating passenger boarding needs, potentially through the implementation of real-time passenger counting and boarding assistance technologies.

Additionally, MCDOT should develop comprehensive contingency plans for weather-related disruptions and other unexpected events that may necessitate reverting to schedule-based operations. This includes establishing explicit protocols for resetting headways from the terminus and effectively communicating changes to both passengers and staff.

5.1.7. Challenges and Opportunities

Upgrading existing infrastructure and ensuring compatibility between various systems are among the main factors to consider as part of improving schedule and headways management. While the integration of ITS and connected vehicle technology is expected to further enhance schedule and headways control in the coming years.

5.1.8. Related Elements

- Guideway Control
- Ramp Meter Interrupt

- Station Displays
- Voice Communications
- On-Real-Passenger Information Displays
- Vehicle Tracking
- Arrival Prediction

5.2. Arrival Prediction

Arrival prediction combines real-time vehicle location information, schedules, and advanced algorithms to offer passengers improved estimates of arrival times. With the implementation of GPS-enabled AVL technology within a CAD/AVL framework, MCDOT can effectively track buses for various purposes, including the providing of accurate arrival time predictions based on factors such as schedule compliance, the bus's progress along the route, historical performance data, and any identified issues or bottlenecks. Offering passengers predictions through mobile applications and other communication methods enables them to adjust their plans in the event of delays before arriving at their origin/stop. This information allows passengers to explore alternative transportation options or simply modify their arrival times at the stop, reducing wait times and total trip duration. For those already at the stop, having access to predicted arrival times can help decrease the perceived waiting time during delays.

5.2.1. General Guiding Principles

- Accuracy and Timeliness: Ensure that the arrival prediction system generates accurate and timely information, with predictions updated regularly based on real-time vehicle locations and changing conditions.
- Standardization and Integration: Adopt the industry-standard GTFS-Realtime format for data feeds, allowing seamless integration with existing GTFS schedule data and compatibility with third-party applications.
- Accessibility: Make arrival prediction data accessible and easy to understand for passengers, facilitating informed decision-making, and reducing perceived wait times during delays.
- Continuous Improvement: Implement analytics and monitoring tools to assess the accuracy of arrival predictions, identifying areas for improvement, and optimizing the system over time.
- Open Data: Encourage collaboration with third-party developers and mobile applications by providing standardized data feeds, fostering innovation, and promoting the development of user-friendly tools for accessing arrival prediction information.

- Passenger Experience: Prioritize the enhancement of the passenger experience by providing reliable arrival predictions, enabling riders to plan more effectively and adjust their schedules in response to real-time transit conditions.

5.2.2. Roles and Responsibilities

- Equipment Ownership: MCDOT or a contractor should be responsible for installing tracking systems on vehicles, ensuring reliable and accurate arrival prediction equipment is in place.
- Operation and Maintenance: MCDOT or a contractor should conduct regular checks and maintenance on tracking devices and transmission systems to maintain optimal performance. Review and sharing of updated arrival information should be facilitated through the operations center, ensuring that the predictions are communicated effectively to passengers.
- Performance Oversight: MCDOT should continuously monitor the quality of predicted arrival times, comparing predictions against actual arrival times, and adjusting the system as needed to maintain accuracy. MCDOT should implement analytics and tools necessary to evaluate the accuracy of arrival times by stop, allowing for data-driven improvements to the prediction system.

5.2.3. Physical Requirements

- Standard Data Feed: The arrival prediction system should generate a standard data feed that streamlines the consumption of data by various communication channels and third-party developers or mobile applications. The industry-standard data format for real-time transit information is GTFS-Realtime. This format allows for seamless integration with GTFS schedule data, providing meaningful information to applications that consume the data.

5.2.4. Functional and Performance Requirements

- Timeframe for Predictions: The arrival prediction system should generate predicted arrival times at least 30 minutes before the trip begins, allowing passengers ample time to adjust their plans.
- Vehicle Location Updates: The system should provide the most recent vehicle location coordinates every 30–60 seconds, ensuring that predictions remain current and accurate.
- Continuous Reevaluation: As the vehicle progresses along the route and conditions change, the system should continually reevaluate and update the predicted arrival times for each stop.
- Accuracy Thresholds: Predicted arrivals must adhere to predefined accuracy thresholds, with predictions compared to actual arrival times to ensure reliability. As the vehicle approaches a stop, the accuracy of the predicted arrival times should improve.

- Evaluation Tools: MCDOT should implement appropriate analytics and tools to evaluate the accuracy of predicted arrival times by stop, allowing for continuous improvement and optimization of the prediction system.

5.2.5. Future Outlook

The future of arrival prediction will likely see further advancements in technology, enabling more accurate predictions and improved passenger experience. As data-driven decision-making becomes more prevalent, MCDOT can leverage the wealth of information generated by the arrival prediction system to optimize routes, schedules, and operations. The integration of emerging technologies, such as artificial intelligence, can lead to improved prediction algorithms.

5.2.6. Challenges and Opportunities

Challenges associated with arrival prediction include maintaining accurate and reliable predictions, integrating with existing systems, and managing the costs and resources required to support these systems. However, the arrival prediction system presents opportunities to enhance passenger experience, encourage public transit usage, and facilitate data-driven decision-making.

5.2.7. Related Elements

- Transit Signal Priority
- Guideway Control
- Ramp Meter Interrupt
- Station Displays
- Voice Communications
- On-Real-Passenger Information Displays
- Vehicle Tracking
- Schedule and Headways Management

5.3. Vehicle Health Management

Vehicle health management (VHM) systems play a critical role in monitoring the health and performance of BRT vehicles, enabling transit operators to optimize fleet maintenance and improve overall system reliability. By collecting and analyzing data from various on-board electrical and mechanical components, VHM systems support proactive maintenance and reduce unexpected breakdowns, particularly in all-electric vehicle fleets.

5.3.1. General Guiding Principles

While electric buses frequently come with a VHM system, the functionalities and integration capabilities of these built-in systems may not fully meet agency needs. With the increasing number of ready-made Software-as-a-Solution (SaaS) applications specializing in VHM, it is recommended to consider certain key principles in the selection and deployment of a standalone VHM system. The main guiding principles include:

- Compatibility and Integration: Ensure the VHM system is compatible with on-board, central, and maintenance systems, allowing for seamless integration and data sharing across all relevant platforms.
- Scalability and Flexibility: Choose a VHM system that can easily scale with the growth of the fleet and accommodate future technological advancements, providing long-term value for the investment.

5.3.2. Roles and Responsibilities

Generally, the transit agency is responsible for implementing and maintaining VHM systems, while bus manufacturers should provide the necessary VHM tools and interfaces for their vehicles, ensuring compatibility with the transit agency's existing systems and processes.

5.3.3. Physical Requirements

- Centralized Dashboard: Install screens and workstations in a control center to enable operators to monitor the network's health and receive alerts. Ensure that the dashboard is user-friendly, customizable, and secure.
- Space Efficiency: Ensure VHM system components require minimal space on the vehicle and do not interfere with other on-board equipment.

5.3.4. Functional Requirements

- Real-Time Alerts: The VHM system should provide near-real time alerts on critical vehicle health elements, enabling quick identification and resolution of potential issues.
- Remote Access: The system shall allow authorized maintenance personnel to access vehicle health data and perform diagnostics remotely.
- Comprehensive Data Collection: The system should collect and store comprehensive vehicle health status and diagnostics information for analysis and reporting purposes.

5.3.5. Performance Requirements

- Reliability and Accuracy: To enable timely and efficient maintenance, the VHM system should operate with high reliability and accuracy, and responsiveness in detecting and reporting vehicle health issues.
- Compatibility: Design the system to support the unique operational and maintenance requirements of both hybrid and all-electric vehicles.

5.3.6. Future Outlook

MCDOT is currently working towards having an emissions-free fleet by 2035, with an increasing reliance on VHM systems to support the operation and maintenance of all-electric vehicles. As solar bus charging infrastructure continues to evolve, VHM systems will play a vital role in optimizing energy consumption and managing battery health for all-electric BRT vehicles. It is recommended that MCDOT use a VHM solution capable of providing detailed information on vehicle health, enabling informed decision-making and proactive maintenance practices.

5.3.7. Challenges and Opportunities

As MCDOT deploys its VHM system, it should be mindful of potential integration challenges with existing systems and the diverse range of vehicle technologies within its fleet. Careful planning and selection of a flexible VHM system can help mitigate these concerns. The integration of Internet of Things (IoT) and advanced connected systems presents opportunities to further enhance the capabilities of VHM systems, enabling more sophisticated maintenance checks and diagnostics. This will ultimately contribute to improved fleet performance and system reliability.

5.3.8. Related Elements

- Schedule and Headways Management
- Networking and Communications Monitoring
- Business Intelligence (BI) and Performance Analytics
- Video Analytics

5.4. Yard Management

Yard management systems encompass the software and hardware components necessary for tracking, assigning, and managing pull-in/pull-out processes for BRT vehicles, particularly in situations where BRT vehicle types are unique and yard space is constrained. These systems are essential for maintaining an organized and efficient vehicle yard while ensuring vehicles receive timely preventative maintenance.

5.5.1. General Guiding Principles

In deploying a yard management system, MCDOT should consider the overall efficiency, ease of use, and adaptability of the system to ensure seamless integration and optimization of yard operations. Some key guiding principles to consider include:

- Comprehensive Functionality: Choose a yard management system that offers a comprehensive set of features and capabilities to address all aspects of yard operations, from vehicle tracking and assignment to personnel management and system integration.
- User-Friendly Interface: Select a system with an intuitive and user-friendly interface to ensure that operators can efficiently manage yard operations without extensive training or expertise.

- Integration with Existing Systems: Ensure the yard management system can seamlessly integrate with existing transit management systems, such as maintenance and vehicle health management systems, to support streamlined operations and data sharing.
- Standardization and Interoperability: Select a system that adheres to relevant industry standards and specifications, promoting seamless integration with other systems and allowing for future system expansions or use cases.

5.5.2. Roles and Responsibilities

- Equipment Ownership: MCDOT or a contractor can be responsible for the installation and ownership of yard management software and hardware, depending on the chosen solution.
- Operations and Maintenance: MCDOT should provide operations staff to manage the yard management solution. Maintenance of the yard management software and hardware, as well as the development and maintenance of system interfaces, can be the responsibility of MCDOT or a contractor, depending on the contract developed.

5.5.3. Physical Requirements

A comprehensive yard management system relies on a combination of physical components to ensure accurate and efficient tracking and management of vehicles within the yard. Key physical requirements for such a system include:

- Consistent coverage: The system should provide reliable and comprehensive vehicle tracking coverage throughout the yard with near real-time vehicle position utilizing:
  - Transponders: Installed on vehicles to facilitate identification and tracking, ensuring that each vehicle can be accurately located and managed within the yard.
  - GPS: Utilizing existing technology for accurate vehicle location tracking within the yard, enabling precise positioning and assignment of vehicles.
  - Triangulation using wireless routers: Employing alternative location tracking methods can enhance tracking accuracy and provide redundancy in case of GPS signal loss or interference.
- Robust backhauls: Implement a robust backhaul network for reliable data communication, ensuring that vehicle tracking and management information is consistently available to operators.

5.5.4. Functional Requirements

- Updated Vehicle Positions: The yard management system should provide up-to-date vehicle positions for accurate tracking and assignment.
- BRT Vehicle Identification: The system should be capable of differentiating between regular transit and BRT vehicles for proper assignment and tracking.

- Vehicle Entry/Exit Tracking: The system should monitor and log vehicle entry and exit events for accurate yard management.
- Operator and Vehicle Assignments: The system should allow for managing operator and vehicle assignments efficiently to optimize yard operations.
- Yard Map Configuration: The system should allow the configuration of yard maps to accurately represent the layout and features of the vehicle yard.
- Support for BEB/ZEB Fleet: The industry's shift toward battery electric buses (BEBs)/zero-emission buses (ZEB) is evident in the evolving product offerings of vendors. Yard management solutions are now increasingly incorporating features that facilitate communication with charge monitoring and management systems. Although the trend is moving towards interoperability among diverse systems, it remains essential to ensure compatibility with original equipment manufacturers (OEMs) when selecting a yard management solution.
- Interface with Other Agency Systems: The system should support the integration with other agency systems to streamline operations and enhance overall performance.

5.5.5. Performance Requirements

Yard management systems should demonstrate high reliability, accuracy, and responsiveness in tracking and managing vehicles, enabling efficient yard operations and timely preventative maintenance.

5.5.6. Future Outlook

Yard management serves as the backbone of vehicle availability, and subsequently, BRT operations. As MCDOT continues on the path of fully adopt ZEBs, it is essential that ZEB vehicle management becomes a central component of the yard management system, rather than merely a supported integration. This approach ensures that the unique requirements of managing ZEBs are addressed from the outset, promoting efficient yard operations and optimal vehicle availability.

To guarantee the successful deployment and utilization of the yard management system, MCDOT should closely collaborate with maintenance and operations staff, mapping out their needs, goals, and insights. By engaging with these key stakeholders, MCDOT can ensure that the system addresses their concerns and facilitates their daily tasks, ultimately resulting in a well-utilized and effective yard management system that supports the BRT operations.

5.5.7. Challenges and Opportunities

One of the challenges in implementing a yard management system lies in striking a balance between providing comprehensive management capabilities and minimizing system complexity. It is essential to ensure that the system is both user-friendly and effective in managing yard operations, without burdening users with unnecessary features or overly complex processes.

On the other hand, integrating IoT and smart systems presents a significant opportunity to enhance yard management capabilities, and allow additional functionalities such as vehicle health management, video analytics, and predictive maintenance tools to be used.

5.5.8. Related Elements

- Safety Camera System
- Vehicle Tracking
- Schedule and Headways Management
- Vehicle Health Management
- Networking and Communications Monitoring
- Business Intelligence (BI) and Performance Analytics
- Video Analytics

5.5. Networking and Communications Monitoring

The networking and communications monitoring system provides real-time monitoring and analysis of MCDOT system network components—usually through a single platform and dashboard. The key objectives of this system include improving the reliability and availability of critical communication systems, reducing downtime due to network outages or failures, and providing transit agencies with valuable insights into network performance and usage patterns.

5.6.1. General Guiding Principles

- System-wide Monitoring: Ensure that the system provides real-time monitoring of all components in the network infrastructure, including links, switches, routers, and servers, and is integrated with other systems used by the transit agency, such as ticketing and scheduling systems, validators, cameras, and other station devices.
- Centralized Dashboard and Alerting: Create a centralized dashboard to monitor the health of all devices in the network infrastructure, including cameras, validators, and stations, and implement an alerting mechanism to notify staff members when an issue is detected in the network infrastructure.
- Remote Access and Maintenance: Allow remote access for authorized personnel to perform maintenance or troubleshooting tasks from anywhere.
- Scalability: Ensure that the system is scalable to support additional devices or systems as needed, and choose a solution based on the agency's needs, budget, and existing infrastructure.

- Security and Privacy: Design the system with security in mind, including data encryption and access control mechanisms, and implement appropriate measures to protect personal and network information, ensuring compliance with data protection laws and regulations.
- Performance Monitoring and Evaluation: Regularly assess the effectiveness of the network and communications monitoring system in maintaining the integrity of the BRT network, reducing downtime, and enhancing system performance. Make adjustments to the system as needed based on the evaluation findings.

5.6.2. Roles and Responsibilities

The roles and responsibilities typically fall under the agency's information technology (IT) staff. They are responsible for deploying, managing, and maintaining network monitoring systems to ensure the stability and performance of the transit agency's network infrastructure. These IT professionals also are tasked with troubleshooting and resolving any network issues that may arise.

However, as Platform-as-a-Service (PaaS) solutions gain popularity, transit agencies are increasingly adopting them for their networking and communications monitoring needs. PaaS solutions provide a more flexible and scalable approach, allowing transit agencies to focus on their core operations while the service provider takes care of the underlying network infrastructure and monitoring systems. Nonetheless, the transit agency still retains oversight and management responsibilities to ensure the effectiveness and reliability of the network monitoring system in place.

5.6.3. Physical Requirements

- Network Infrastructure: Ensure that the necessary networking hardware, such as routers, switches, and other devices, are appropriately sized and compatible with the existing infrastructure. Consider the scalability of the network to accommodate future expansion.
- Server and Data Storage: Plan for centralized servers to store, process, and host applications related to network and communication monitoring. Ensure adequate data storage capacity, processing power, and redundancy to maintain reliability and performance.
- Centralized Dashboard: Install screens and workstations in a control center to enable operators to monitor the network's health and receive alerts. Ensure that the dashboard is user-friendly, customizable, and secure.
- Power Supply and Backup: Provide an uninterruptible power supply (UPS) system and backup generators to ensure continuous operation of networking and communications equipment during power outages.
- Network Security: Incorporate firewalls, intrusion detection systems, and other security appliances to protect the network from unauthorized access and cyber threats.
- Physical Security Measures: Implement access control systems, surveillance cameras, and secure server rooms to safeguard networking and communications equipment.

5.6.4. Functional Requirements

- Real-Time Monitoring: Ensure that the system can continuously monitor the status of network components, including links, switches, routers, and servers as well as other connected devices such as validators, cameras, and station equipment.
- Network Performance Analysis: Enable the system to analyze network performance metrics, such as latency, throughput, and packet loss to identify potential issues and maintain optimal performance.
- Alerting and Notifications: Implement a mechanism for the system to generate alerts and notify appropriate personnel when issues are detected in the network infrastructure, enabling timely response and resolution.
- Centralized Management: Provide a centralized dashboard for monitoring the health of all devices in the network infrastructure and displaying relevant information, such as device status, alerts, and performance metrics.
- Remote Maintenance and Troubleshooting: Allow authorized personnel to remotely access and manage the network infrastructure to perform maintenance tasks, troubleshoot issues, and apply updates or configuration changes.
- Reporting and Analytics: Enable the system to generate reports and provide data-driven insights into network performance, equipment health, and potential areas for improvement.
- Scalability and Flexibility: Ensure compatibility and seamless integration with other transit agency systems, including ticketing, scheduling, passenger information, and security systems. Design the system to be easily scalable, allowing for the addition of new devices, systems, or services as needed, while maintaining performance and reliability.

5.6.5. Performance Requirements

- Network Uptime: Maintain a network uptime of at least 99.7 percent.
- Fault Detection and Resolution: Implement proactive fault detection and resolution mechanisms and monitor the mean time to detect and resolve faults.

5.6.6. Future Outlook

The increasing number of smart and connected systems used by MCDOT necessitates the implementation of a reliable monitoring solution, particularly as BRT operations become more reliant on real-time data from various systems. A single, unified monitoring solution would be most efficient, reducing the risk of missing alerts and streamlining network management. MCDOT should consider using a system that supports the integration of current and planned systems that are essential to BRT operations.

5.6.7. Challenges and Opportunities

Deploying and integrating a systemwide monitoring solution may pose significant challenges, particularly in terms of the number of integrations needed and the potential complexity of the system. This challenge may require a considerable investment in trained IT staff to manage the deployment, maintenance, and troubleshooting of the monitoring system.

5.6. Business Intelligence (BI) and Performance Analytics

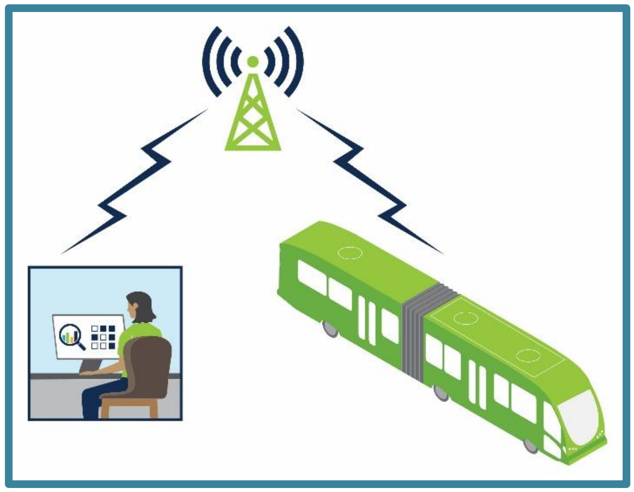


Figure 4.17: Illustration of General Elements Related to Business Intelligence and Performance Analytics

BI and performance analytics use data-driven insights, analytics, and performance metrics to optimize BRT operations, enhance system efficiency, and improve the overall passenger experience. These components are designed to facilitate informed decision-making by providing a comprehensive understanding of the BRT system's performance in real-time and over time, allowing MCDOT to identify trends, address operational challenges, and ensure alignment with agency goals and objectives. The BI and performance analytics system can integrate data from various ITS elements, such as vehicle tracking, APC, and fare collection systems, to generate actionable insights and performance indicators, enabling MCDOT to continually assess and improve the BRT system's effectiveness and adapt to evolving demands and circumstances.

5.7.1. General Guiding Principles

- Data Integration: Ensure seamless integration of data from various ITS elements and subsystems, such as vehicle tracking, fare collection, automated people counting, and other operational data sources, to create a comprehensive and unified view of the BRT system's performance.
- Data Accuracy and Quality: Establish processes and protocols to maintain data accuracy, quality, and consistency across the system, enabling reliable analysis and decision-making.
- Customization: Implement a flexible and customizable analytics platform that can be tailored to meet MCDOT's specific needs, goals, and objectives.
- Real-Time and Historical Analysis: Enable real-time monitoring of the BRT system's performance, as well as the ability to analyze historical data and trends to support strategic decision-making and long-term planning.

5.7.2. Roles and Responsibilities

- Equipment Ownership and Management: MCDOT should ensure that the necessary hardware and software infrastructure for BI and performance analytics is properly acquired, installed, and maintained. This includes data servers, network connections, and workstation setups.
- Operations and Maintenance: MCDOT should have a dedicated team of in-house analytics professionals responsible for managing and maintaining the BI and performance analytics platform. This team should work closely with other departments to ensure that the analytics solutions align with their needs and objectives.
- Data Integration and Quality: Agency IT staff should be responsible for integrating data from various sources, ensuring data quality and consistency, and maintaining data security and privacy. This includes addressing any data discrepancies, cleaning data, and implementing data validation processes.
- Performance Oversight: MCDOT should continuously monitor the performance of the BI and analytics platform and ensure that it meets established performance benchmarks and KPIs. This includes identifying areas for improvement and implementing necessary changes to optimize system performance.
- Collaboration with Other Departments: MCDOT operations staff should collaborate with other departments to understand their analytics requirements and provide customized BI solutions that address their specific needs. This includes regular communication and coordination to ensure that the analytics solutions remain relevant and up to date.

5.7.3. Physical Requirements

- Server: MCDOT should ensure that the necessary hardware infrastructure is in place to support the data storage, processing, and retrieval required for BI and performance analytics. This includes data servers, network connections, and workstation setups.
- Data Security: Secure access to data and systems should be maintained through appropriate authentication methods, such as password protection, two-factor authentication, and role-based access control.

5.7.4. Functional Requirements

- Data Analysis: MCDOT should implement a BI and performance analytics platform that supports data collection, storage, processing, and visualization, enabling effective analysis of transit system performance.
- Data Integration: The platform should enable integration with various data sources, such as real-time vehicle tracking, passenger counts, and operational data.
- Custom Dashboards: The platform should support customizable reporting and dashboard creation to meet the specific needs of different stakeholders within MCDOT.

5.7.5. Performance Requirements

- Data Accuracy: MCDOT should ensure that the BI and performance analytics platform provides accurate and up-to-date insights into transit system performance, enabling data-driven decision-making and continuous improvement.
- Scalability: The platform should be scalable and adaptable to handle the increasing volume and variety of data generated by MCDOT's transit system.

5.7.6. Future Outlook

The continual expansion of the agency's transit system and the incorporation of emerging technologies elevates the opportunity of BI and performance analytics. Harnessing the power of data will enable MCDOT to make informed decisions, optimize operations, and enhance the overall passenger experience. As the field of BI and performance analytics continues to rapidly evolve, the use of machine learning and predictive analytics as part of the BI analytics is expected.

5.7.7. Challenges and Opportunities

An important consideration in implementing BI and performance analytics is ensuring data accuracy, reliability, and security. Integrating disparate data sources and maintaining data quality are crucial to obtaining meaningful insights. At the same time, keeping up with rapidly evolving technologies and best practices in BI and analytics requires continuous learning and adaptation.

On the other hand, BI and performance analytics present significant opportunities for MCDOT. By leveraging data insights, MCDOT can optimize resource allocation, improve operational efficiency, and identify areas for improvement. Furthermore, the adoption of advanced analytics techniques can help MCDOT uncover hidden patterns and trends, enabling proactive and data-driven decision-making.

5.7.8. Related Elements

- Fare Payment and Collection
- Automated Passenger Counters
- Schedule and Headways Management
- Arrival Prediction
- Vehicle Health Management
- Yard Management

5.7. Video Analytics

The primary function of a video analytics system is to automate camera monitoring processes, including the ability to identify and distinguish between various types of events, such as security incidents, accidents, or operational issues. These systems are predominantly software-based, enabling a seamless integration with MCDOT's existing safety camera system. The integration of a video analytics system offers multiple benefits. Firstly, it facilitates continuous monitoring and prompt incident alerting, without the need to staff employees. Additionally, it can provide MCDOT with valuable business intelligence insights related to incidents and operational efficiency.

5.8.1. Roles and Responsibilities

- Event Differentiation: Ensure accurate identification and differentiation of various types of events, enabling swift and appropriate response.
- Risk-Based Deployment: Prioritize deployment based on security concerns, location, and station type, focusing on areas with higher potential for vandalism or other security threats.
- Privacy and Data Protection: Implement robust measures to protect the privacy of individuals captured in video footage and ensure compliance with data protection laws and regulations.
- Continuous Improvement: Stay informed of advancements in video analytics technology and best practices, incorporating these developments into the system as appropriate.

5.8.2. Physical Requirements

While there are no specific physical requirements for video analytics operations, it is essential to ensure that controllers have shared visibility across key BRT operating segments. To achieve this, displays should be installed in control rooms, allowing for easy monitoring and management of video analytics data. During peak periods of BRT operations, it may be beneficial to designate a controller position solely dedicated to BRT service monitoring and management.

5.8.3. Functional Requirements

- Real-Time Analysis: The video analytics system should be capable of processing and analyzing video footage in real-time, allowing for prompt detection and response to incidents.
- Object Recognition: Advanced object recognition capabilities should enable the system to accurately identify and track individuals, vehicles, and other objects within the video footage.
- Behavior Analysis: The system should be able to detect and analyze unusual or suspicious behavior patterns, such as loitering, trespassing, or vandalism.
- Crowd Monitoring: Video analytics should be capable of monitoring crowd levels at stations and identifying potential safety concerns, such as overcrowding or congestion.

- Integration: The video analytics system should seamlessly integrate with other security and operational systems, such as CCTV, access control, and emergency response systems.

5.8.4. Performance Requirements

- Detection Accuracy: The video analytics system should maintain a high level of accuracy in detecting and identifying various types of events.
- False Alarm Reduction: Advanced algorithms should minimize the occurrence of false alarms, allowing for more efficient resource allocation and response.
- System Scalability: The system should be scalable, enabling the addition of new cameras and analytics capabilities as needed.
- System Reliability: The system should be designed with built-in redundancies to ensure continuous operation and minimize downtime.
- Reporting and Notifications: The system should generate timely and accurate notifications and reports for security and operations personnel, facilitating swift response to detected incidents.

5.8.5. Future Outlook

As video analytics technology continues to advance, there will be increased opportunities for MCDOT to leverage these developments to enhance security and operational efficiency within the BRT network. Potential areas for future growth include the use of machine learning and artificial intelligence algorithms to improve detection accuracy and reduce false alarms as well as the integration of additional data sources, such as social media or public alerts, to provide a more comprehensive understanding of real-time events.

5.8.6. Challenges and Opportunities

Challenges associated with the implementation of video analytics systems include ensuring data privacy and protection, staying current with technological advancements, and maintaining system reliability.

Opportunities arise from the potential to deploy video analytics technology across various areas within the BRT network, prioritizing high-risk locations and enhancing overall security. Additionally, the integration of video analytics with other security and operational systems can improve overall system efficiency and resource allocation.

6. Emerging ITS Technologies

The landscape of ITS is constantly evolving as new technologies and innovative solutions emerge, offering unprecedented opportunities to enhance the efficiency, safety, and sustainability of BRT systems. This section discusses cutting-edge technologies and systems that are in planning, pilot, or initial deployment phases, such as advanced data analytics and automation, guided busway systems, and autonomous buses. The section also provides guidance on evaluating and integrating these emerging technologies into the BRT system as they mature, enabling MCDOT to stay ahead of the curve and capitalize on these advancements to better serve their passengers and communities.

Figure 4.18: Illustrative Representation of Emerging ITS Technologies

6.1. Advanced Data Analytics Using Machine Learning and Artificial Intelligence

Machine learning (ML), involves the development of algorithms that enable computers to learn from and adapt to data inputs, improving their performance over time, while artificial intelligence (AI) refers to the development of computer systems capable of performing tasks that usually require human intelligence, such as pattern recognition, data-driven decision making, and language-based processes. ML and AI can be applied to various use cases within the BRT system, such as predicting passenger demand, optimizing fleet scheduling and routing, identifying potential maintenance issues, and enhancing traffic management strategies. This field is rapidly evolving, and future applications of these systems may be in conjunction with other ITS technologies, such as V2X communication and autonomous vehicles, to enable advanced analytics and management techniques to be performed in automated fashion.

6.1.1. General Guiding Principles

As MCDOT explores the potential of incorporating ML and AI technologies into its BRT system, it is crucial to recognize that the success of these advanced methods largely depends on the quality and accuracy of the input data. Ensuring high-quality data is essential for developing precise models and minimizing biases that could negatively impact the effectiveness and reliability of these solutions. Accordingly, general guiding principles for implementing ML/AI should primarily focus on data quality, model development, and transparency with other critical factors following:

- Data Quality and Availability: Ensure that the ML/AI systems have access to high-quality, accurate, and diverse data to effectively train and validate the models. Reliable data sources and data preprocessing techniques should be employed to maintain data integrity and minimize biases.
- Transparency: Design ML/AI models to be transparent and explainable, allowing stakeholders to understand the decision-making process and rationale behind the model's outputs. This will promote trust and acceptance of the technology among users and decision-makers.
- Ethical Considerations: Develop ML/AI models with ethical considerations in mind, ensuring that the systems are designed to be fair, unbiased, and respect privacy. Establish ethical guidelines and governance frameworks to guide the development, deployment, and monitoring of ML/AI applications in the BRT system.
- Security and Privacy: Implement robust security measures, such as encryption and access control, to prevent unauthorized use of the developed systems.

6.1.2. Challenges and Opportunities

The potential applications for these technologies in BRT systems are expected to evolve and become more refined in the coming years. Nonetheless, some of the earliest opportunities and challenges associated with implementing ML/AI in BRT operations are highlighted below. It is important to note that while these examples showcase the potential benefits of ML/AI integration, the technology landscape is rapidly changing, and new applications will likely emerge:

- Demand Prediction: ML/AI algorithms can analyze historical ridership data, traffic patterns, weather conditions, and other relevant factors to accurately predict passenger demand at different times and locations. This helps BRT operators optimize fleet size, frequency, and scheduling to better match service levels with passenger needs, thereby reducing wait times and overcrowding. Potential challenges that may arise with ensuring data accuracy, handling diverse data sources, and addressing privacy concerns.
- Route Optimization: Machine learning algorithms can analyze traffic patterns, congestion levels, and other real-time data to optimize bus routes and minimize travel times. This could enable the BRT system to dynamically adjust to changing traffic conditions, providing faster and more reliable service for passengers. Challenges may arise with integrating ML/AI with

existing transportation systems, addressing infrastructure constraints, and managing changing traffic conditions.

- Predictive Maintenance: ML/AI can be used to analyze data from sensors installed on buses and other BRT infrastructure, such as stations and guideways, to identify potential maintenance issues before they become critical. Challenges with implementing ML/AI may relate to sensor data quality, managing false positives/negatives, and balancing maintenance costs.
- Traffic Signal Priority: ML algorithms can analyze real-time traffic data to optimize traffic signal timings and prioritize BRT buses at intersections, reducing delays and improving overall system efficiency. This could enable the implementation of an ML enhanced TSPaaS. Potential challenges may include coordination with local traffic management systems, integration with legacy TSP systems, and maintaining system robustness.
- Passenger Information Systems: AI can be used to enhance passenger information systems by providing real-time information on bus arrival times, delays, and alternative routes, allowing passengers to make more informed decisions, and improving overall customer satisfaction. The predictive/generative nature of AI may introduce challenges with ensuring data and information accuracy, addressing potential biases in the information provided, and maintaining system reliability and security.

6.2. Dynamic Wireless Charging Infrastructure

Dynamic wireless charging is a cutting-edge technology that enables electric buses to charge wirelessly while in motion, using inductive charging pads embedded in the road. Several transit agencies across the United States have begun experimenting with this technology to varying degrees, recognizing its potential to enhance electric BRT systems. Dynamic wireless charging can reduce charging times, extend the range of electric buses, and support the potential to contribute to the long-term sustainability and effectiveness of BRT systems.

6.2.1. General Guiding Principles

While dynamic wireless charging is still in the developmental stage, significant advancements are being made in the technology, and it holds considerable promise for the future of electric BRT systems. As the technology matures, it is expected that the efficiency, reliability, and cost-effectiveness of dynamic wireless charging systems will improve, making it an increasingly viable option for transit agencies.

Some agencies utilize charging pads at specific points, such as yards or stations, for top-up charging while buses are stationary. Pilot programs also test more spread-out charging configurations. To successfully implement and benefit from dynamic wireless charging technology, MCDOT should consider the following guiding principles:

- Collaboration and Research: Work with technology providers, researchers, and industry partners to stay informed about advancements in dynamic wireless charging and its potential applications in BRT systems. Conduct pilot projects to test the feasibility, efficiency, and effectiveness of dynamic wireless charging in specific BRT routes and contexts.

- Integration and Compatibility: Develop standards and guidelines for the integration of dynamic wireless charging infrastructure within the existing BRT network. Ensure that the adoption of dynamic wireless charging technology is compatible with the existing fleet of electric buses and other electric vehicles in the transit system.

6.2.2. Challenges and Opportunities

Due to the relatively early age of this technology, the high upfront investment costs required for installing dynamic wireless charging infrastructure are one of the primary obstacles that also complicates the integration of this technology within the existing systems.

However, there are significant opportunities to be seized with the implementation of these technologies. The reduced charging times for electric buses can lead to improved operational efficiency and reduced downtime in BRT systems. Furthermore, an extended range for electric buses may potentially eliminate the need for additional charging infrastructure along BRT routes.

6.3. Guided Busway System

Guided busway systems are designed to offer an efficient and more cost-effective alternative to light rail transit (LRT) systems. Guided busway systems are characterized by buses equipped with guidance technology that allows them to traverse along a prescribed path with great precision and reliability. The three most common guidance technologies are: curb-guided systems (which rely on small guidewheels positioned in front of the main wheels to follow along a track equipped with vertical curbs), automatic electronic guidance systems (which rely on electric signals transmitted to the bus via parallel running underground cable system), and optical guided busways (which rely on bus-mounted sensors and cameras for guidance.

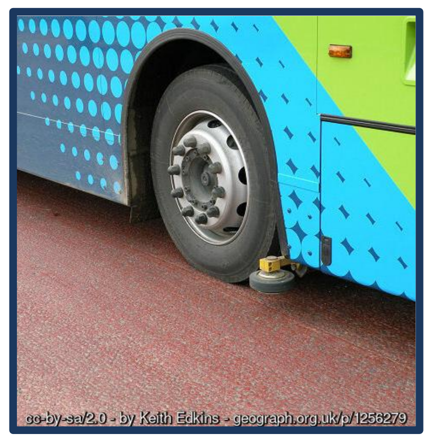


Figure 4.19: Cambridge Guided Busway Sensor Wheel (source: © Keith Edkins)

The benefits of guided busway systems are multifold, combining the advantages of LRT with the cost-effectiveness of BRT. Notably, their dedicated pathways enable buses to run without fear of traffic interruptions, while the guidance technology allows them to safely travel narrower paths. Moreover, advanced systems allow for a greater autonomy from bus operators and may eventually open the door to fully automated public transit—a technological breakthrough likely to be pioneered by guided busway technologies.

6.3.1. General Guiding Principles

- Alignment and Route Selection: Choose optimal alignments and routes for the guided busway system that maximize connectivity, accessibility, and ridership potential, while minimizing impacts on existing land use, traffic patterns, and the environment.

- Safety and Accessibility: Design the guided busway system with safety and accessibility as top priorities, incorporating features such as cordoned BRT rights-of-way, gated pedestrian and cyclist crossings, and clear signage and lighting.
- Technology Integration: Incorporate state-of-the-art technologies, such as connected/autonomous vehicle solutions, real-time passenger information systems, and advanced traffic management systems.
- Efficient and Sustainable Design: Implement design principles that promote resource and energy efficiency, sustainability, and resiliency, such as the use of environmentally friendly materials, green infrastructure, and stormwater management systems. This will help minimize the environmental impact of the guided busway system and contribute to long-term sustainability goals.

6.3.2. Challenges and Opportunities

The construction of guideways and related operational infrastructure often proves significantly more expensive than traditional bus routes, as the costs not only encompass the physical infrastructure but also extend to the integration of necessary guidance technologies within the buses. Additionally, while guided busway systems have seen several global deployments, the supporting technology remains relatively undeveloped. This may lead to challenges when integrating with OEM buses equipment or substantial performance decreases during inclement weather conditions. Visual-based guidance technologies are particularly susceptible, as heavy rain or snow can obscure the necessary cues the system relies on. Therefore, successful integration and operation of guided busway systems on a wider scale are largely dependent on the development of more mature, robust, and reliable guidance technologies that employ a complete list of multi-modal sensing mechanisms, such as visual sensors and radars, high-definition GPS, and physical detection mechanisms.

Despite these challenges, the emergence of guided busway systems presents MCDOT with several exciting opportunities. Notably, the guidance technology enables buses to safely operate on narrower lanes, presenting an effective solution in areas where the deployment of traditional dedicated lanes is not feasible due to space constraints. The introduction of guided busway systems could also aid MCDOT in addressing the issue of bus operator shortages as these systems utilize advanced guidance technologies that can pave the way towards automated buses that require minimal human intervention. Lastly, the rapid advancement of connected vehicle technologies, such as vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications, can further enhance the capabilities of guided busway systems, and may even facilitate the transition towards fully autonomous public transit systems in the future.

6.4. Connected and Autonomous Vehicles

Connected and autonomous vehicles technology offers the potential to transform the way BRT systems, and on a greater level, transit systems are operated. Autonomous vehicles, or self-driving buses, can significantly optimize route planning through their ability to use data in every aspect of operation, from traversing on the route at the most efficient speed, to processing and reacting to real-time data faster than operators. The integration of autonomous vehicles into a BRT system can pose as an effective way to introduce this technology into MCDOT's transit network. The exclusive rights-of-way and limited interaction with general traffic inherent to BRT systems provide a conducive environment for testing and implementing autonomous vehicles. Moreover, autonomous vehicles can operate in platooning mode, wherein multiple buses travel closely together. This approach can significantly improve traffic flow and reduce fuel consumption, as well as increase the overall capacity and efficiency of the transit system.

6.4.1. General Guiding Principles

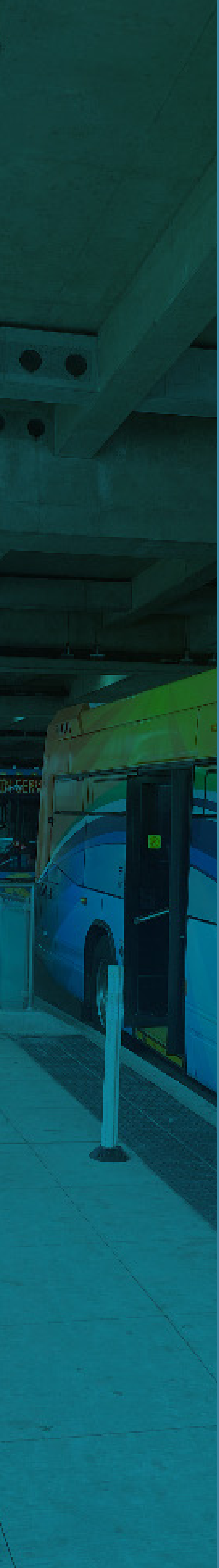
As autonomous vehicle technology continues to evolve, MCDOT must carefully consider a variety of factors when planning to integrate this technology into its BRT routes. Currently, the state of this technology is promising but still in development. While there have been several successful deployments of autonomous vehicles, they are primarily in controlled environments and over short distances. Key principles MCDOT should consider include:

- Safety: Autonomous vehicles should prioritize the safety of passengers, pedestrians, and other road users. This involves rigorous testing and validation of autonomous systems, and the implementation of robust fail-safe mechanisms.
- Regulatory Compliance: Ensuring compliance with all relevant regulations and standards is crucial. This includes vehicle safety standards, data privacy laws, and any forthcoming regulations specifically related to autonomous vehicles.
- Infrastructure: Deployment of autonomous vehicles requires necessary infrastructure changes. This includes communication infrastructure for V2I and V2V interactions as well as physical infrastructure to accommodate autonomous vehicle operations.
- Interoperability: Autonomous vehicles should be capable of seamless integration with other components of the transit system. This includes ATMS, safety elements, TSP, guideway controls, the scheduling system, and other applicable systems.
- Public Acceptance: Gaining public trust and acceptance of autonomous vehicles is critical. This can be achieved through transparency, public outreach, and education about the safety and benefits of autonomous vehicles.

6.4.2. Challenges and Opportunities

While the adoption of autonomous vehicle technology presents a host of possibilities, it also brings certain challenges. The technology is still in the developmental stages, and while progress is rapid, there are still technical hurdles to overcome. In addition to the technical aspects, regulatory and ethical challenges must also be addressed, including questions about liability in the event of an accident.

Connected and autonomous vehicles promise to enhance efficiency and safety, with the added potential of drastically reducing operational costs over time. With the ability to operate for extended periods without human intervention, autonomous vehicles could lead to significant savings in labor costs.



Chapter 5:
BRT Vehicles

Chapter 5 – BRT Vehicles

Introduction

The distinctive vehicles of the Flash Bus Rapid Transit (BRT) system are an integral part of its customer experience, branding, and operations. Numerous features of the BRT fleet are unique within the Montgomery County transit system and impact infrastructure and operations.

Figure 5.1: Montgomery County Flash articulated BRT vehicle, featuring distinctive branded livery

As the County's BRT system grows, a common approach to vehicles provides consistency in customer expectations, economies of scale and operational efficiency, and interoperability of the BRT fleet across multiple corridors, including the critical vehicle-platform interface. This chapter discusses vehicle guidelines to support these objectives.

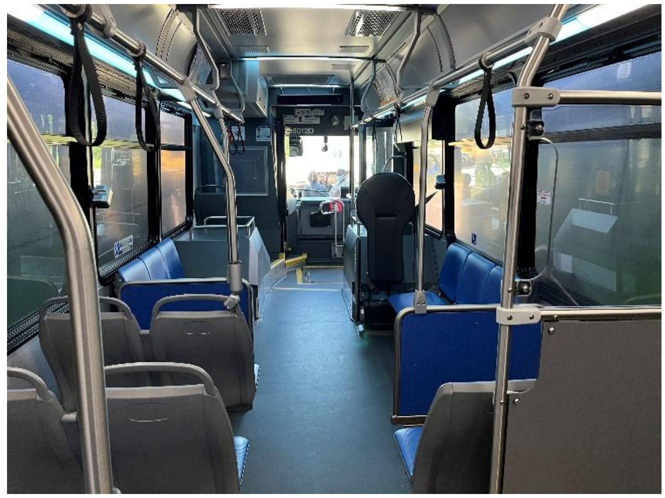
Compared to BRT infrastructure like stations and guideway, BRT vehicles are a relatively short-lived asset, with an expected useful life of approximately 12 to 16 years. Many aspects of vehicle design also are governed by manufacturers and the marketplace, as compared to factors more directly within the County's control, such as station design. For these reasons, BRT designers should anticipate changeover of vehicle fleets over the lifetime of infrastructure assets. There may be a need to accommodate modified door locations, variations in turning radius, and changes in vehicle dimensions over the years. Infrastructure which is too precisely designed for a particular opening year design vehicle may fail to adapt to future changes as the vehicle fleet evolves.

Note that onboard technology components are addressed in Chapter 4 – BRT Intelligent Transportation Systems (ITS).

1. Standard BRT Vehicle Specifications

1.1. Vehicle Description and Key Characteristics

Table 5.1 summarizes key characteristics of the Flash BRT fleet. The initial U.S. 29 BRT corridor was deployed with low-floor articulated buses built by Nova Bus (*LFS Artic* model). This bus manufacturer is no longer active in the US transit vehicle market; however, the general BRT vehicle configuration developed for the U.S 29 BRT established many of the design precedents that are expected to be carried forward through future corridors and bus procurements, irrespective of the specific bus manufacturer.



Figures 5.2-5.3: Interior views of the Flash BRT vehicle, facing forward and aft.

The Flash BRT fleet is optimized for high-volume passenger loads along trunk corridors in the County transit system where BRT services are deployed. The wide doors, aisles, and vestibules are designed to improve interior circulation and reduce station dwell time, thereby improving operational performance.

Open areas increase capacity of standees making relatively short trips through the corridors. Roll-aboard bicycles and convenient securement positions also help to create a more rail-like passenger experience.

Table 5.1: Summary of Flash BRT Key Characteristics

Flash Vehicle Characteristic	Standard Specification
Vehicle Type	60-foot articulated
Propulsion	Diesel (existing fleet) Future Fleets: Zero emissions (technology to be specified in the future by the County)
Doors	3-door configuration, 48-inch-wide door internal swing All-door boarding operations
Floor Height	Low floor, compatible with 12-inch, near-level-boarding stations Aft compartment raised behind rear door, with steps
Ramps	Front Door: Manual deployed ADA ramp Middle and Rear Door: automatic ramp/bridge plate, or similar technology to assist with bridging the gap between the vehicle and platform to assist roll-aboard strollers, carts, and mobility devices.
Capacity	Approximately 80 passengers
Seating	Approximately 40 passengers 3-seat flip-up benches in ADA securement area Standees only in bellows area
ADA Securement	Two securement positions, including one automated rear-facing securement device
Bicycles	Onboard roll-aboard bicycle racks, rear door Vertical orientation racks with securement Three securement positions
Fare Collection (Preferred Future Configuration)	Provide space/cabling for retrofit of an Onboard cash farebox (front door), should MCDOT migrate to onboard cash fare collection in the future. SmarTrip smartcard validators (all doors)
Pedestrian Warning System	Automatic pedestrian detection/warning equipped (Mobileye)
Kneeling Feature	Kneeling equipped BRT mode to override kneeling for proper ramp operations at level boarding stations
Structure	Stainless steel
Exterior	Fiberglass and thermoplastic panels

Overall Dimensions[1] (Based New Flyer xcelsior CHARGE NG XE60 Battery-Electric)	Length: nominal 60 feet; 60 feet, 10 inches actual Height: nominal 11 feet; 11 feet, 1 inch actual Width: 102 inches
Turning Radius[2] (Based on New Flyer Xcelsior CHARGE NG XE60 Battery-Electric)	Approx. 44 feet

1.2. Door Configuration Guidelines

1.2.1. Door Configuration – Right Side Only

All Flash BRT vehicles are expected to use a right-hand-only door configuration, similar to the existing U.S. 29 corridor and a conventional Ride On fixed-route transit bus. While some BRT systems use BRT vehicles with both right- and left-side doors (allowing, for example, center island stations), there are a number of practical reasons to maintain a right-side-only fleet.

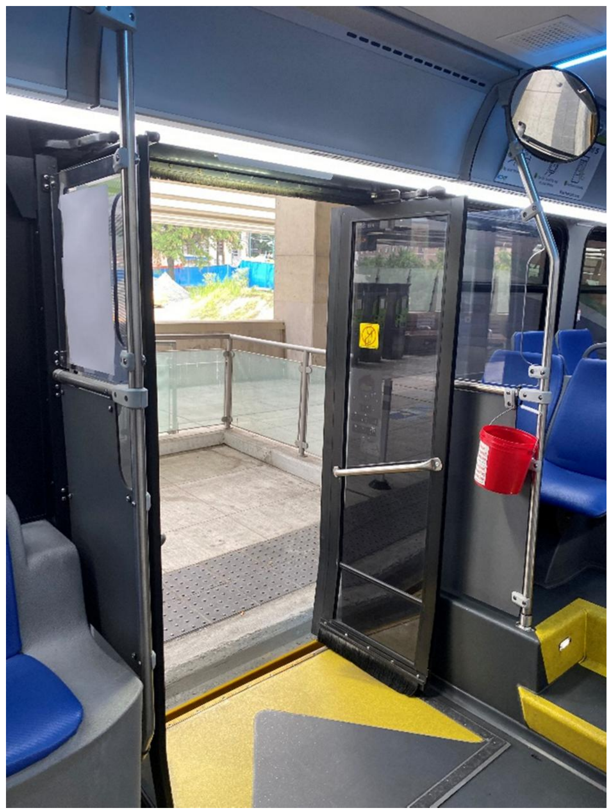


Figure 5.4: Rear door position showing near-level boarding with the station platform, deployable bridge plate, and wide doors to reduce doorway congestion

These benefits include:

- Lower capital costs of a three-door right-side fleet versus a five-door right- and left-side vehicle
- Reduced maintenance costs, particularly related to doors and associated mechanical Americans with Disabilities Act (ADA) ramp and fare collection equipment
- Additional passenger seating
- Additional mobility aid/bicycle storage
- Ability to add or substitute conventional fixed-route vehicles if needed, without closing left-side stations

[1] Source: Nova Bus, LFS Artic Specifications

[2] Source: Nova Bus, LFS Artic Specifications

- Access to onboard farebox payment though the front, right-side door (dual-side vehicles have only middle and rear doors on the left side)
- Ability to maintain a single consistent BRT fleet across corridors given the right-side door design of the U.S. 29, Veirs Mill Road (MD 586), and MD 355 corridors
- Avoids creating specialized sub-fleets that are not interchangeable, increasing operational flexibility and improving spare ratio
- Greater range of manufacturers and vehicle models that can meet the right-side door requirement, particularly when zero-emissions propulsion options also are considered

All Flash BRT stations should be designed for right-side boarding only to support this requirement. Designers are cautioned to carefully consider the fleet and long-term operational implications of any future modification of this guideline, and to fully exhaust all opportunities to place BRT stations on the right hand/curb side of the running way.

1.3. All-Door Boarding Guidelines

Flash BRT operates using all-door boarding for each of the three right-side doors. This means that passengers can board or alight at any door unless the passenger has a reason to interact with the farebox located at the front door (to pay an onboard cash fare).

The majority of Ride On passengers pay fares electronically using the regional SmarTrip smartcard. Each door of the coach shall be equipped with onboard smartcard validators, as discussed in Chapter 4.

Figure 5.5: Onboard placard informing passengers of the specialized boarding functions of the front, middle, and rear Flash vehicle doors. With the migration to onboard cash fare payment in the future, the front door will also serve as the boarding door for cash-paying customers.

Every Flash BRT station should be designed to accommodate all-door boarding through each of the three doors. This creates a consistent customer expectation that all doors of the coach will open at all stops. It also supports the door designations for mobility aids, strollers, and bicycles, providing convenient access to the designated onboard seating and stowage areas for both boarding and alighting, at all stops, on all BRT corridors.

1.4. Door Utilization Guidelines

As an all-door boarding operation, each of the three right-side doors on the BRT coach are preferred boarding locations for specific customer types, based on the interior configuration of the coach.

Encouraging passengers to use the appropriate doorway reduces inconvenience and congestion during boarding and alighting, while reducing station dwell time. Passenger cues and signage located on the platform (e.g., platform markings), on the vehicle exterior, and inside the coach should be used to inform passengers of the most appropriate boarding location for their needs.

Table 5.2: Flash BRT Door Utilization and Fare Collection

Door Position (Right Side)	Door Attributes	
	Mobility Needs	Fare Media Accepted
Front Door	▪ General Boarding ▪ Wheeled Mobility Device/Wheelchair Access Via Ramp	▪ Cash Fare Payment at Farebox[3] ▪ SmarTrip Smartcard (using platform or onboard validator) ▪ Mobile Ticket ▪ Paper Ticket, Pass, Transfer, or other Proof of Payment (POP)
Middle Door	▪ General Boarding ▪ Strollers and Other Mobility Aids	▪ SmarTrip Smartcard (using platform or onboard validator) ▪ Mobile Ticket ▪ Paper Ticket, Pass, Transfer, or other Proof of Payment (POP)
Rear Door	▪ General Boarding ▪ Roll-aboard Bicycles	▪ SmarTrip Smartcard (using platform or onboard validator) ▪ Mobile Ticket ▪ Paper Ticket, Pass, or other Proof of Payment (POP)

Flash BRT door utilization is shown in Table 2. Note that all doors support Proof of Payment (POP) fare collection using SmarTrip smartcards, mobile tickets, or other physical fare media. Only the front door supports onboard cash fare collection at the farebox.

[3] Supports future Flash BRT migration from offboard cash fare payment using platform TVMs to onboard cash payment using an onboard farebox.

Cash fare customers using the rear doors for bicycle stowage can approach the farebox after stowing their bicycles onboard. Stroller and mobility aid customers have the option of using the front door for accessible access to the farebox, instead of using the middle door.

The relatively high penetration of SmarTrip smartcards (stored value and pass customers) suggests that most Flash BRT customers will be able to take advantage of all-door boarding, without interacting with the farebox.

The impact of increasing use of smartcard and mobile payment systems is expected to further reduce cash fare payment in the future. This may result in removal of ticket vending machines (TVMs) on most Flash BRT platforms, replaced by onboard cash payment through a farebox. This approach will reduce overall capital and operating costs of cash fare payment across the Flash BRT system.

1.5. Mobility Device Guidelines

1.5.1. Doors and Ramps

All doors of the BRT vehicles shall be equipped with a deployable ramp or bridge plate to accommodate use of wheelchairs (front door only) or other mobility devices at near-level BRT station platforms.

Special consideration should be given to maintaining the required vehicle floor height to ensure proper ramp operations. The original U.S. 29 fleet, for example, requires the bus to be raised above normal ride level for proper wheelchair operation at elevated stations. For other vehicles, the ability to disable or override kneeling features may be necessary to ensure proper operation of the ramps.

The front right-side door (nearest the driver and farebox) shall incorporate a ramp that can be manually deployed to roadway pavement level to support bus boarding/alighting and evacuation of ADA passengers. This feature is necessary if the bus stops at a location without a raised platform or elevated curb in the event of an emergency, station construction, or other irregular circumstances.

1.5.2. ADA Securement Areas

Securement areas for mobility devices shall be provided in the front passenger area of the coach, typically immediately behind the front axle wheel wells and driver compartment. Specifications of the layout of the securement area are contingent upon the specifics of the vehicle manufacturer. The accessible front boarding door should coincide with vehicle exterior and station markings indicating the appropriate boarding door for customers requiring these devices.

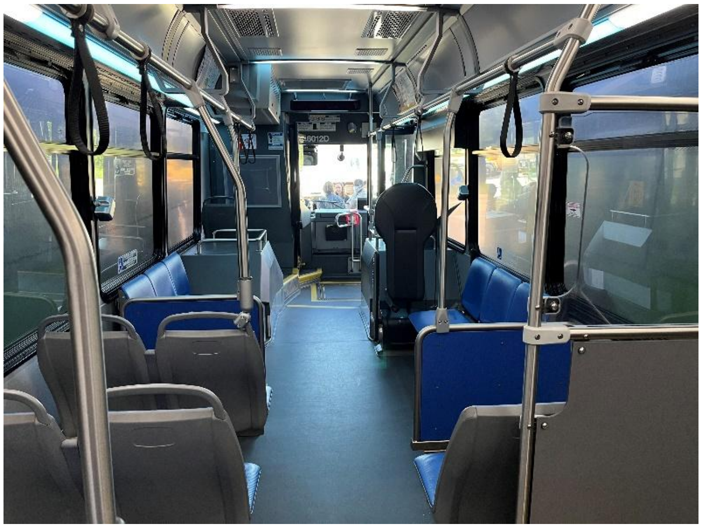


Figure 5.6: Overview of ADA securement area in the front of the Flash vehicle, showing two securement positions with flip-up bench seating and the rear-facing Q'straint Quantum automatic securement position (right side of image).

The preferred configuration for securement areas provides for forward-facing seating for passengers in the secured position. This provides improved orientation for passengers, facing in the direction of travel, better communications with the coach operator, if needed, and views of visual automatic stop annunciation (ASA) displays, which typically face the rear of the coach.

Coaches shall provide securement capacity for a minimum of two wheelchair/mobility aid passengers in the front ADA securement area.

Figure 5.7: Automated rear-facing ADA securement position with flip-up bench seating

Flash coaches are currently equipped with a rear-facing automated securement system (Q'straint Quantum system). This system is recognized to have disadvantages in usability, maintenance, and passenger orientation (rear-facing seat). While the system can potentially speed up the securement process and reduce dwell time, improved alternative systems should be considered in future bus procurements.

Flexible seating systems, employing flip-up seats to accommodate either conventional ambulatory seating or ADA securement, is desirable to maximize flexibility in customer accommodations.

Vehicles shall include a push button or touch strip in the securement areas so that passengers can request a next stop and/or request operator assistance.

1.5.3. Other ADA Requirements

Designers should note additional ADA requirements addressed in other chapters of this document. Examples including the station/platform interface and clearance requirements for near level boarding at stations, and the implementation of visual/ASA onboard the coaches.

Current ADA/USDOT statutes, regulations, and guidance always takes precedence and override the guidelines presented in this document.

Furthermore, active engagement of the disability community (e.g., as a design advisory board or test riders) is strongly encouraged when designing or modifying BRT vehicles, facilities, and technologies.

1.6. Operator Compartment and Partition

The primary role of Flash BRT coach operators is to provide for the safe and comfortable travel of customers. Operators achieve these goals by maintaining situational awareness and concentration on the roadway and the onboard environment. As a matter of customer service, operators are available to answer questions or provide instructions to customers when it is safe to do so.

It is Ride On practice that operators do not directly enforce fare policy; however, the future location of the onboard farebox next to the operator will facilitate interactions with the customer to answer any questions about fare payment and operation of the farebox.

The operator compartment should be outfitted with agency and industry standard provisions to maintain driver comfort, focus, and ergonomics when operating the coach. For BRT vehicles, this includes line of sight or technology assist (e.g. camera monitors) to properly operate and observe all-door boarding, safely deploy the ramp, and ensure precision docking/door alignment at BRT stations within acceptable standards.

Figure 5.8: Operator Compartment, with portion of the protective partition visible in the foreground.

The operator compartment shall be outfitted with a protective partition between the operator seat and the cabin/farebox area, designed to provide physical protection from assault as well as shielding from infectious diseases (e.g., COVID-19).

The partition shall be specified for use in the public transit industry, and resistant against forced entry by a belligerent passenger. The partition also shall use transparent glazing to not interfere with the operator's view of the coach exterior or interior, including mirror views. The partition shall also not provide unreasonable interference with verbal communications or hand gestures between the operator and a customer to provide instructions or answer questions.

1.7. Roll-Aboard Bicycle Guidelines

Roll-aboard bicycles are a defining characteristic of Flash BRT, creating a more rail-like experience and speeding the boarding/alighting process of customers bringing bicycles. Bicycles provide a convenient first/last mile connection to transit for many customers.

Roll-aboard bicycles also facilitate the use of raised curbs at BRT stations. With a conventional, front end mounted exterior bicycle racks, customers would be required to step off the elevated curb to mount or dismount their bicycles. This is a potentially hazardous condition that also extends station dwell times. Therefore, the use of exterior bicycle racks is to be avoided.

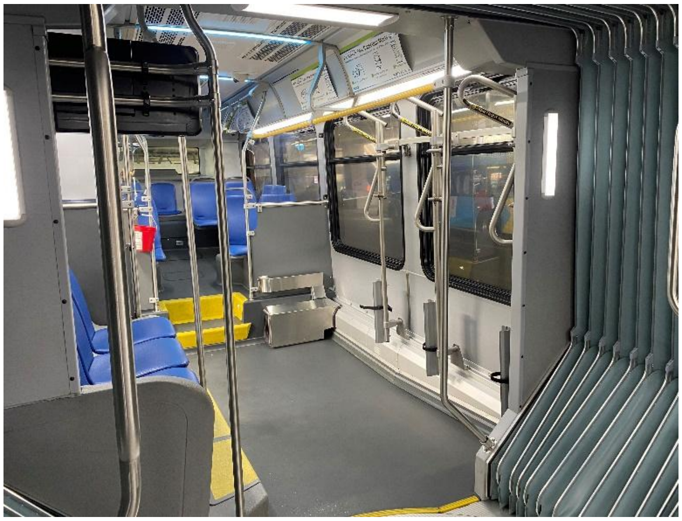


Figure 5.9: View of the roll-aboard bicycle stowage area opposite the rear door.

Flash BRT vehicles shall include a designated bicycle storage area located in the aft of the vehicle near the rear right-hand door. This door shall be designated through exterior signage as the bicycle loading door.

The interior bicycle storage areas shall provide securement for a minimum of three roll-aboard bicycles. For ease of loading and maximum clearance for circulation, the preferred location of the bicycle storage area is immediately opposite the aft right-side door.

Flash BRT vehicles shall incorporate a secure onboard bicycle rack system of current design, specified for transit usage. For consistency and customer familiarity, it is preferable to use a consistent bicycle rack system across the entire BRT fleet. The bicycle racks shall be designed for ease of use under typical transit conditions, preferably with one-handed operation so the customer can use the other hand for holding the bike, stabilization, packages, etc. Labeling or signage in the interior bicycle storage area shall be used to indicate the instructions for loading, securing, and unloading the rack.

When in use, the loaded bicycle racks shall not interfere with adjacent seating or passenger circulation, or otherwise create a hazardous condition for customers or operators.

Current MCDOT policy is to accommodate both conventional bicycles as well as battery-assist bicycles and scooters onboard the coach. Customers are expected to use the provided racks or otherwise maintain secure control of their devices without impeding movement and seating of other passengers.

1.8. Fleet Standardization and Interoperability Guidelines

The Flash BRT fleet is distinctive from other fixed-route buses in the Ride On fleet. For example, a clear difference is the use of 60-foot, 3-door, articulated coaches versus the typical 40-foot, 2-door coaches of the main Ride On fixed-route fleet.

The BRT fleet has operational and maintenance requirements that are unique to the Flash BRT fleet. These include the need additional wheel lifts, BRT-specific spare parts, operator/maintenance training, and technology. Flash vehicles also have a distinctive brand and exterior livery, meaning that these vehicles should not be interchanged with the mainline Ride On fleet except in extraordinary circumstances.

It is to the County's advantage to maintain consistency of key technical and operating requirements across the BRT fleet as it expands, and to avoid creating BRT sub-fleets that are not interchangeable across the Flash BRT corridors. For example, it is not desirable to introduce a sub-fleet with incompatible features such as 40-foot length BRT vehicles, left-handed doors, a lack of all-door fare payment equipment, or alternative interior configurations for ADA securement or bicycles.

1.8.1. Future Fleet Variations

Despite this guiding principle, designers should be aware that certain variations are to be expected and must be managed through the fleet planning and design process. Specifically, these include:

- Variations across Model Years: Minor variations across fleets due to changes by the vehicle original equipment manufacturer (OEM) from model year to model year. This may result in issues such as distinctive spare parts requirements, changes to the operator console requiring training, operations and maintenance (O&M) impacts, or minor variations in the onboard customer experience. Many of these manufacturer-dictated changes are not under the County's control, at least not without creating undesirable and potentially costly variations of standard engineering and manufacturing processes.

- Separate Manufacturers: Variations from one manufacturer to another are to be expected if the County chooses to procure future fleet vehicles from a different manufacturer than the existing fleet.

- Zero-Emissions Transition: Variations due to the changeover to a zero emissions fleet. For example, a future battery electric fleet that requires en-route charging may not be interoperable on all Flash corridors, unless they have been outfitted with the appropriate en-route chargers as the respective termini. Zero-emissions transition issues are discussed further later in this chapter.

Each of these factors is a caution not to tailor BRT infrastructure, stations, maintenance facilities, or charging infrastructure—all of which will span successive generations of BRT vehicles—too closely to a specific BRT vehicle make or model.

1.9. Station-Vehicle Compatibility

The vehicle-station interface is an important consideration in any BRT system, particularly those using near-level boarding with articulated vehicles. Vertical and horizontal alignment of the vehicle floor and platform surface are generally not within ADA specifications for acceptable alignment. Therefore, ramps or bridge plates are a key feature of any vehicle operating in a “near level” boarding environment, both at front and rear doors.

Figure 5.10: Example of Flash vehicle body panel damage immediately behind the articulating bellows. The damage is caused by the outward sweep of the rear body skirt during sharp turns adjacent to stations. Designers should always be mindful of vehicle-station compatibility and approach/departure geometry when modifying BRT stations or procuring new BRT fleets.

The presence of scrapes and damage to the lower exterior shell of many vehicles in the current Flash fleet highlights the need to consider geometric design and vehicle sweeps in development of station areas. The current observed damage, typically on the rear section body panel immediately behind the articulating bellows, is caused by the vehicle body striking station platforms when the rear section sweeps outward during a turn.

For this reason, approaches and departures to stations and curbing should be as straight as possible, avoiding the need for sharp turning movements close to the curb. Other vehicle features, such as bumpers, protruding wheel lug nuts, and kneeling features, can also contribute to vehicle-station compatibility issues. Designers should be aware of this potential during future station design exercises and vehicle procurements.

The County may consider conducting testing of new vehicle prototypes and/or mockups of future station modifications to identify and reduce vehicle/station compatibility risks in the future.

2. Fleet Estimation and Spare Ratio Guidelines

2.1. Fleet Estimation Guidelines

Fleet estimation is a key part of project cost estimation as well as operational planning for the future BRT corridor and garage/maintenance facilities. Realistic fleet estimates should be calculated and updated through each stage of project development to maintain an accurate current reflection of fleet requirements based on the current project and service plan.

The BRT fleet requirement shall be based on peak-hour service demands, considering expected running times, layover/recovery, and (if relevant) battery electric vehicle charging to reflect realistic blocking assumptions. This maximum fleet requirement is known as vehicles operated in maximum service (VOMS).

If appropriate, fleet requirements for both opening year and any future phasing or full build should also be calculated, noting the potential for changes in BRT travel time due to congestion or implementation of transit priority measures and guideway.

Analysis should be coordinated with any traffic modeling or simulation that predicts future corridor conditions. Any range constraints or limitations of future zero emissions technology must also be considered, so that the future fleet requirement reflects any range limitations requiring additional vehicles to deliver the service. The requirement for additional battery-electric fleet may be mitigated with proactive use of en-route charging to extend vehicle range (see discussion in the following sections).

When estimating VOMS fleet requirements based on the forecast service plan, the fleet requirement should always be rounded up to the next highest integer. For example, a 17.3 calculated ratio is rounded up to a fleet requirement of 18 vehicles, plus spares.

2.2. Spare Ratio Guidelines

A minimum spare ratio of 20 percent shall be maintained across the Flash BRT fleet. This ratio should be maintained both for the total BRT fleet (across all corridors), as well as for the estimated additional fleet required to operate service in each specific corridor.

When estimating spares based on 20 percent calculations, the spare ratio should always be rounded up to the next highest integer. For example, a 5.2 calculated spare ratio is rounded up to a spare fleet requirement of 6 vehicles.

The development of distinctive “sub fleets” (e.g., different vehicle lengths) that are not interoperable across all BRT corridor is strongly discouraged without a full consideration of passenger, operational, cost, and risk implications across the fleet lifecycle.

For corridor fleets of less than 10 vehicles, a minimum spare ratio of at least 3 vehicles is recommended (13 total vehicles). This is based on prior County and peer agency experience that maintaining a minimum pull-out while also performing preventative and unplanned maintenance can be challenging when there are too few spare vehicles in the fleet. While “borrowing” spares from other corridors will become more feasible as the total BRT fleet expands in size, it is best that each fleet addition includes appropriate spares to avoid this situation.

3. BRT Zero-Emissions Bus Requirements

At the time of writing, the County is undertaking a separate study to guide its future transition to zero-emissions vehicles across the entire Ride On transit fleet. Zero-emissions technologies under consideration including both battery-electric bus (BEB) and hydrogen fuel cell electric bus (FCEB) alternatives.

While several BRT projects using battery-electric technology are in operation around the US, a preferred propulsion technology has not been identified yet for the County’s future BRT. Examples of peer BRT systems using BEB technology include IndyGo (Indianapolis, IN), Spokane Transit

(Spokane, WA), and ABQ (Albuquerque, NM). Hydrogen fuel cell bus pilot projects are underway in Europe and Japan, with a North American pilot proposed in Mississauga, ON. Extensive experimentation and implementation of zero-emissions BRT technology is expected over the life of this document and updates to these guidelines will be made, as appropriate.

Future considerations in selecting a preferred technology include meeting the demanding BRT duty cycle; commercial availability of vehicle options in the County's preferred configuration; garage and maintenance impacts; operational issues like the potential for en-route charging; and total lifecycle operating and ownership costs.

3.1. Montgomery County Climate Action Plan Zero Emissions Mandate

While the evaluation and recommendation of a preferred zero-emissions technology is beyond the scope of these guidelines, the procurement and use of zero-emissions buses should be assumed based on the Montgomery County Climate Action Plan (CAP, June 2021)[4].

The CAP stipulates that all public and private transit in Montgomery County must use zero-emissions technology by 2035. Considering the BRT project development cycle and the minimum FTA lifespan of a transit vehicle, any future procurement of BRT vehicles must be zero-emissions technology to meet the goal of a zero-emissions fleet in 2035.

3.2. Guidelines for Zero Emissions Implementation

Any future use of hydrogen FCEB technology is unlikely to directly impact the design of BRT line termini, stations, or runningway. These vehicles are generally fueled at the depot with the expectation of all-day range, similar to a conventional diesel or diesel electric hybrid bus.

However, peer agency precedent suggests that use of battery-electric BRT technology at present performance levels will require en-route charging at one or more BRT termini for each route pattern within the corridor. En-route charging extends the range of battery-electric BRT vehicles to meet the long service hours and block lengths typical of frequent, all-day BRT service patterns.

En-route BEB charging uses high-power Level 3 DC charging (350kW or higher, typically operating at 400-1000V). These systems quickly "top off" the energy charge of the vehicle within the span of a typical layover period of approximately 5-15 minutes. Both direct contact (e.g., pantograph) and inductive charging options are available on the marketplace.

By combining depot charging (before/after the service day) and en-route charging (during the service day), the vehicle can maintain an acceptable level of charge to meet the demand of an extended BRT service block under variable operating and climatic conditions during the year.

[4] See Montgomery County Climate Action Portal, https://www.montgomerycountymd.gov/climate/

En-route charging also may form part of an overall agency energy strategy to balance charging demands and constraints on the power grid and/or depot charging equipment. It also may contribute to system resiliency in the event of an extended power outage in another part of the system.

A corridor-level analysis should be performed for future BRT projects to understand zero-emissions energy demands and alternatives as a basis for selection and layout of any required charging or fueling facilities. The analysis should be based on a realistic future service plan, considering both opening day and full build service levels.

State of practice zero-emissions energy modeling accounts for factors such as battery degradation over the life of a vehicle (reducing the amount of energy store and therefore range), route grades, and climatic factors that generate additional energy demands for heating and cooling. Energy rates, peak demand charges, and grid constraints also may inform modeling assumptions.

Understanding of energy demand based on the future service plan can guide engineering development of power grid infrastructure, maintenance garage modifications, en-route charging opportunities, and specification of vehicles (e.g., range, battery capacity). The potential need for utility coordination, site identification and layout, coordination with other transit operators, and/or maintenance facilities planning suggests that an initial analysis of these requirements should be begin no later than preliminary engineering.

The following sections discuss BRT considerations for implementation of en-route battery electric technology should this propulsion technology be selected for a future BRT corridor.

3.3. En-Route Battery Electric Charger Guidelines

If BEB propulsion is selected for a BRT corridor, operational and energy analysis is likely to show a need for en-route charging based on BRT duty cycles and current battery technology. This section provides an overview of design considerations when selecting locations for en-route charging along BRT corridors. A full-scale discussion of charger engineering and technical requirements is beyond the scope of these guidelines.

3.3.1. Site Selection

The preferred location for en-route BRT charging activity is in an off-street location at one or both BRT terminals, as stipulated by energy and route modeling analysis. Given the frequency of BRT arrivals and the priority of this service, it is anticipated that stand-alone chargers are appropriate for BRT termini in most locations.

Where possible, en-route charging equipment should be located on property owned or controlled by Montgomery County, or another suitable public entity. Equipment located on the property of other transit operators (e.g., WMATA) will require an interagency agreement regarding space utilization, power supply, O&M responsibilities, and other conditions such as liability. Chargers shared with other operators will require further agreement on utilization, priority, energy charges, and management technology.

On-street locations may be acceptable provided there is sufficient vehicle layover space, adequate space for power equipment, and sufficient security and separation from general vehicular and pedestrian traffic. If a terminus is highly constrained, designers may consider locating charging equipment at the opposite route terminus if practical.

3.3.2. Site Layout and Design

In BRT charging site design, consider both opening day and future expansion of service, such as future phases or additional BRT lines using the terminus. These considerations may result in providing space for future charging/power equipment, additional vehicle positions, and/or preemptive implementation of transformer pads, conduits, foundations, or enclosures to simplify future equipment expansions.

Separation of charging and passenger areas (e.g., boarding/alighting platforms) is preferred so that charging and layover activities do not interfere with boarding/alighting of BRT vehicles in service. This allows, for example, a trailing vehicle to “leapfrog” a charging vehicle without interference to operations. Separation of passenger and charging areas also provides a buffer between public passenger activities and back of house areas including chargers, power equipment, emergency shutoff controls, and driver support facilities.

Where possible, at least one BRT layover position, separate from active charging areas, should be provided for extended layovers, disabled/bad order vehicles, or pre-positioning of extra service fill buses. Extended blockage of charging positions by BRT vehicles not actively charging is discouraged.

3.3.3. Charging Equipment Redundancy

Redundant charging equipment should be provided at each en-route charging location. This eliminates the single point of failure should a particular charger fail or be taken offline for maintenance.

At larger sites (e.g., transit centers with large numbers of electrified routes and chargers), it may be appropriate to provide for on-site charger redundancy through the shared pool of chargers available to all routes at the location, instead of a dedicated BRT backup charger. A BRT terminus in a shared transit center provides the opportunity to implement shared and interoperable charging equipment across BRT and other fixed route services. Even if under normal operations, a certain number of chargers are typically dedicated specifically to the BRT vehicles.

Resiliency in the event of a charger failure is another reason to separate charging equipment from BRT passenger boarding and alighting platforms. Otherwise, these platforms may need to be taken out of service during charger failures or maintenance closures.

When primary or redundant chargers are shared with shorter 40-foot coaches, the larger physical size of BRT vehicles and their unique maneuvering characteristics need to be considered in accessing the shared backup charger(s) at the site.

3.3.4. Maneuverability in Charging Areas

In geometric layout, designers should consider the maneuvering requirements of 60-foot articulated BRT vehicles, as well as the need to align BRT vehicles with the conductive charging pantographs or inductive charging pads. Difficult maneuvers into charging positions may result in failed alignments with charging equipment, requiring drivers to re-align or exit and re-enter the charging position.

Direct and straight approaches to charging positions are preferred to minimize charger alignment concerns, with straight run pull-through charging configurations being the most optimal.

An internal recirculation loop, free of interference with other vehicles involved with boarding, alighting, charging, or layover, should be provided in the event of a charger failed alignment necessitating a re-entry attempt.

Chargers should be arranged to allow for independent movement of BRT vehicles at each charger site. Any vehicle should be able to enter or exist any charger position, regardless of whether the other charger positions are occupied by other vehicles. This is a particular concern for charging sites arranged in “head to toe” configurations, where extensive linear curb is required to provide sufficient clearance for maneuvering the articulated coaches in and out of position, while ensuring good alignment with the charger itself.

3.3.5. Charging Equipment Selection

Use of conductive (e.g., pantograph-style) or indicative charging should be guided by overall design criteria set forth by the County for the Ride On fleet, with an emphasis on interoperability and systemwide resiliency across County transit fleets. Interoperability across regional agencies may also be a consideration in shared sites.

For consistency and ease of maintainability, charging equipment at BRT termini should adhere to any charging technology standards adopted by the County in the future.

3.3.6. Charging Management and Optimization

As the scale and number of independent routes charging at a site increase, it may become necessary to consider charging management technology to prioritize and optimize charging activity. The system algorithm can help inform dispatch decisions and communicate charging/layover instructions to operators of the arriving buses.

Depending on the operational requirements and system sophistication, optimization of shared charging infrastructure may take into account factor such as: vehicle state of charge; predicted energy to complete the vehicles' duty cycle; schedule adherence/pull-out time; out of service equipment constraints; and/or variable energy rates of daytime en-route charging versus overnight charging.

3.4. BRT Charging – Terminal Concept of Operations

A BRT terminus equipped with en-route charging requires consideration of the flow of operations involving the passenger, vehicle layover/recovery, driver support, and charging. As much as the physical and technical requirements for en-route charging are discussed above, these operational considerations may dictate the layout, and potentially the overall feasibility, of a particular terminal location.

The following is a high-level concept of operations showing the overall flow of BRT vehicles through a terminus under multiple scenarios. In larger and more complex terminals with high rates of vehicle arrivals and/or shared charging equipment, there may be a need for a more detailed and tailored discussion of charging prioritization among arriving vehicles, the dispatch decision tree to guide operator activities, and/or the implementation of charge management tools to provide charging decisions support and driver communications based on real-time energy state and service conditions.

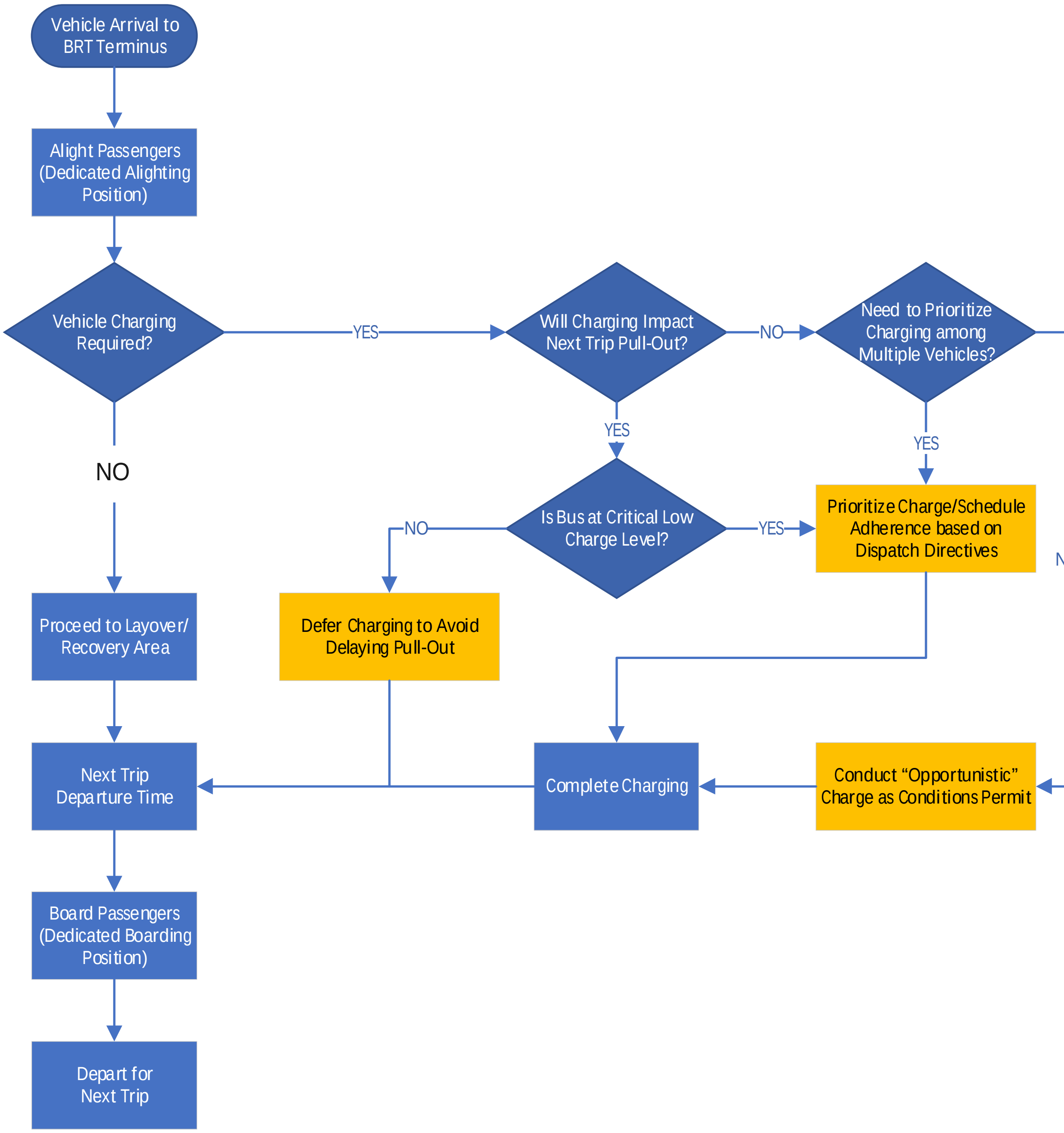


Figure 5.11: BRT Terminus Concept of Operations with En-Route Charging

Arrival and Alighting: The process begins with the inbound arrival of a BRT vehicle to the terminus location at the end of its route. The initial step is to alight passengers at the BRT terminal so the vehicle can exit revenue service. A dedicated alighting position (or multiple positions, if a high-volume terminal) is recommended so that there is always a place for passengers to alight without queuing, delay, or interference from outbound passenger boarding. In some terminals, an alighting position shared by multiple flash routes may be considered. Following boarding, arriving vehicles should move away from this position as quickly as possible to either a charging or layover position to make room for subsequent vehicles.

Charging Prioritization: For most trips, as scheduled layover and schedule adherence allow, BRT vehicles should take advantage of “opportunistic” charging to maintain the highest feasible state of charge. Agency operating roles and cost factors (e.g., energy costs by time of day) will inform standard operating procedures and schedule development to accommodate charging.

Similarly, agency operating procedures and vehicle performance specifications will define a “critical” state of charge at which a vehicle must undertake en-route charging to continue service. In a well-designed system, this should be a rare occurrence. If the scheduled layover is insufficient, or a vehicle is running behind schedule, this may result in an unfortunate situation where the vehicle’s next pull-out is delayed or cancelled. In some circumstances, dispatchers may have the option to allow the training bus to “leapfrog” in order to maintain schedule or insert a fill bus while the critical charge occurs.

In larger or more complex terminals, there also may be the need to prioritize use of shared chargers by multiple arrivals. In this case, operating decisions based on relative vehicle duty cycles, states of charge, schedule adherence, and other operating factors will play into the decision of how to prioritize or defer en-route charging.

Next Trip Pull-Out: Following charging and/or the layover period, the departing vehicle proceeds to the boarding platform for its BRT route. Again, separation of charging/layover and passenger boarding areas is strongly preferred to avoid interference of end-of-line activities with passenger boarding and timely departure.

4. Vehicle Guidance and Safety Technology

Future BRT fleet procurements are likely to continue the industry trend toward technological solutions to increase the safety and maneuverability of BRT coaches. These solutions include, but are not limited to, lane guidance systems, station precision docking, pedestrian detection and warning, collision avoidance/braking, and automated driver assist.

Chapter 4 addresses these emerging technologies in greater depth. At present, these features are not standard specifications for BRT vehicles, pending further research, industry development, and possibly pilot testing by MCDOT and/or peers prior to large-scale implementation.

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Chapter 6: Station Access

Figure 6.1: Photo by the Montgomery County Department of Transportation.

Chapter 6 – Station Access Guidelines

Introduction

This chapter introduces multiple guidelines for effectively integrating Flash Bus Rapid Transit (BRT) stations into their built environments. Each station's planning, design, and construction process should ensure that pedestrians, people with disabilities, cyclists, micromobility and microtransit users, transit vehicles, and private vehicles can all safely and efficiently access the station, and that these modes can all safely interact with each other.

"Access" refers to all the different methods that pedestrians, cyclists, micromobility and microtransit users, transit vehicles, and private vehicles use to enter and exit stations. Not all access methods are appropriate for all stations – for example, vehicular access to on-street stations may not be necessary – but this chapter still introduces all methods comprehensively.

This chapter focuses primarily on *local access,* which refers to the streetscape elements adjacent to or immediately around the station. These elements include sidewalks, crosswalks, bike facilities, roadways and driveways for various vehicles, and various other first-/last-mile accommodations for entering and exiting the station. Station-adjacent streets and blocks with fine-grained, interconnected street grids, continuous sidewalk networks, multimodal street accommodations (complete streets), and dense, mixed-use development all support local access.

While the station's *regional access* also is important, it is not a focus of this chapter, since regional access involves considering larger-scale (countywide) planning policies, coordinating land uses, and evaluating regional roadway networks, all of which are beyond the scale and scope of the streetscape elements immediately around the station. As far as stations being shared with other entities, a joint operating and maintenance agreement for use of any BRT facilities is needed with further guidance from MCDOT.

Note that the access and circulation elements *within* Flash BRT stations are covered separately in Chapter 2, to which this chapter refers throughout as needed.

To prescribe local access guidelines for Flash BRT stations, this chapter explores these topics:

Figure 6.2: Station Access

Guidelines for each topic are described in the following sections and correspond to specific callouts on each section's accompanying guideline diagram.

Local and National Policy Context

Transit-related guidance from Montgomery County and the State of Maryland are reviewed and summarized to ensure that the guidelines in this chapter are consistent with and support the recommendations in existing county and state resources.

Pedestrians

In addition to providing guidelines for sidewalks and walkways, this section discusses crosswalks, first-/last-mile connectivity, connecting to adjacent development, general amenities for pedestrian comfort, and sizing pedestrian accommodations for ridership growth.

Bikes and Micromobility

Guidelines for cycling and micromobility cover dedicated travel facilities (including dedicated lanes, sidepaths, and trails) and dedicated short- and long-term storage facilities (including secure shelters, sheds, racks, docks, and corrals).

Vehicles

Guidelines for vehicles include parking for buses (layovers and bus bays), carshare vehicles, and private vehicles (park-and-rides). They also address pick-up and drop-off needs for private vehicles (kiss-and-rides), microtransit and paratransit, and trucks and other delivery vehicles.

Transfer Considerations

An easy, comfortable transfer experience—one that reduces walking distances, maximizes protection from the elements, and minimizes confusion—can reduce aversion to transfers. This section provides guidelines for making transfers as quick and easy as possible.

Safety Considerations

This section provides guidelines for sightlines, conflict points, traffic calming and road diets, crash protection for vulnerable roadway users, lighting, and police/closed-circuit television (CCTV) enforcement.

Transit-Oriented Development (TOD)

Many Flash BRT stations draw ridership from the development around each station, and the development's built form determines if and how riders take transit. This section provides guidelines for creating and supporting TOD near stations.

Wayfinding and Placemaking

This section explores accessible circulation routes, accessible signage, and other accessible design elements to orient riders. The section also explores station-adjacent public spaces, sustainable design in the station area, and station-adjacent public artwork.

1. Local and National Policy Context

1.1. Local Policy Context

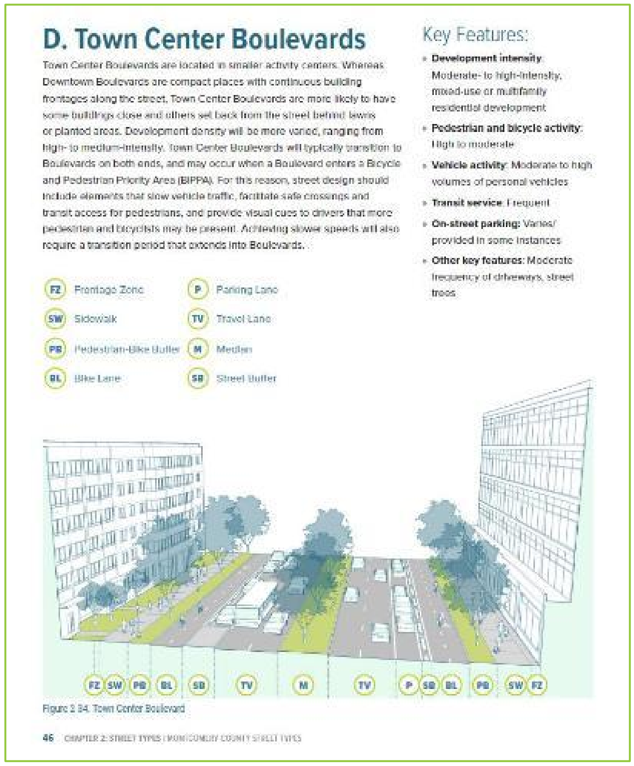

Figure 6.3: Montgomery County's Complete Streets Design Guide defines 12 street types for use across the county.

1.1.1. Montgomery County Complete Streets Design Guide[1]

This guide defines the streets, intersections, and bikeways that are recommended by and employed in Montgomery County. Most significantly, the guide introduces 12 street types that are used across the county depending on the local land use context, and the guide contains design specifications for the components within each street type. This guide informed numerous guidelines in this chapter.

1.1.2. Montgomery County Countywide Transit Corridors Functional Master Plan[2]

In this plan, Montgomery County identifies corridors to create a countywide Flash BRT network. Since the plan's publication, several of these corridors have proceeded into planning, design, and/or construction. The plan also identifies several (but not all) Bicycle and Pedestrian Priority Areas across the county and describes best practices for their implementation.

[1] *Montgomery County Complete Streets Design Guide. Montgomery* County Department of Transportation, 2021. https://montgomeryplanning.org/wp-content/uploads/2022/03/Montgomery-County-CSDG_Approved-2021.pdf

[2] *Montgomery County Countywide Transit Corridors Functional Master Plan.* Montgomery County Planning Department, 2013. https://www.montgomeryplanning.org/transportation/highways/documents/countywide_transit_corridors_plan_2013-12.pdf

1.1.3. Montgomery County Vision Zero 2030 Action Plan[3]

Montgomery County's vision for zero traffic fatalities by 2030 prescribes several Culture of Safety Action Items with concrete steps for transforming the county's roadways into safer complete streets. The guidelines in this chapter were written to align with the action items in the vision.

1.1.4. Montgomery County Bicycle Master Plan[4]

After providing an overview of different bike facilities, the plan identifies design recommendations for specific roadways in the county's Bicycle and Pedestrian Priority Areas. To align with these recommendations, this chapter's Pedestrians and Bikes and Micromobility sections refer readers to the Bicycle Master Plan to check if a Flash BRT station has any area-specific recommendations that can be incorporated into the station's access elements.

Figure 6.4: Montgomery County's Bicycle Master Plan contains recommendations for multiple Bicycle and Pedestrian Priority Areas.

1.1.5. Montgomery County Pedestrian Master Plan[5]

To complement the Bicycle Master Plan and provide further guidance for Bicycle and Pedestrian Priority Areas, the county is currently (as of late 2023) developing a Pedestrian Master Plan. Draft design, policy, and programming recommendations include items such as "shade pedestrian pathways," and the guidelines in this chapter were written to align with recommendations in the pedestrian master plan.

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[3] *Montgomery County Vision Zero 2030 Action Plan.* Montgomery County, 2022. https://www.montgomerycountymd.gov/visionzero/Resources/Files/vz2030-plan.pdf

[4] *Montgomery County Bicycle Master Plan.* Montgomery County Planning Department, 2018. https://montgomeryplanning.org/wp-content/uploads/2019/09/Bicycle-Master-Plan-Web-Version.pdf

[5] *Montgomery County Pedestrian Master Plan.* Montgomery County Planning Department, 2022. https://montgomeryplanning.org/planning/transportation/pedestrian-planning/pedestrian-master-plan/plan-recommendations/

1.1.6. Montgomery County Zoning Ordinance[6]

In 2014, Montgomery County undertook a zoning ordinance revision that expanded the previous ordinance's Floating Zones category. Floating Zones offer more flexible development opportunities—particularly for TOD—than conventional Euclidean zones. The revision also reduced parking minimums in some areas by allowing on-street parking to count toward the minimums, disincentivized surface parking in some areas, and reinforced mixed-use development. These 2014 reforms support the guidelines in this chapter, which generally call for mixed uses and increased density around Flash BRT stations.

1.1.7. Montgomery County Department of Transportation (MCDOT) Ride On Reimagined[7]

A comprehensive redesign of the Ride On bus network is in study as of late 2023, and the study seeks to reform Ride On's network structure and operations. The study may recommend increased transfers between some routes to redirect resources into new Flash BRT services and into improved service frequencies. Any potential for increased transfers requires special attention to the physical accommodations for transfers (e.g., sidewalks, crosswalks, bus shelters, and wayfinding), so this chapter contains a Transfer Considerations section to address these physical accommodations.

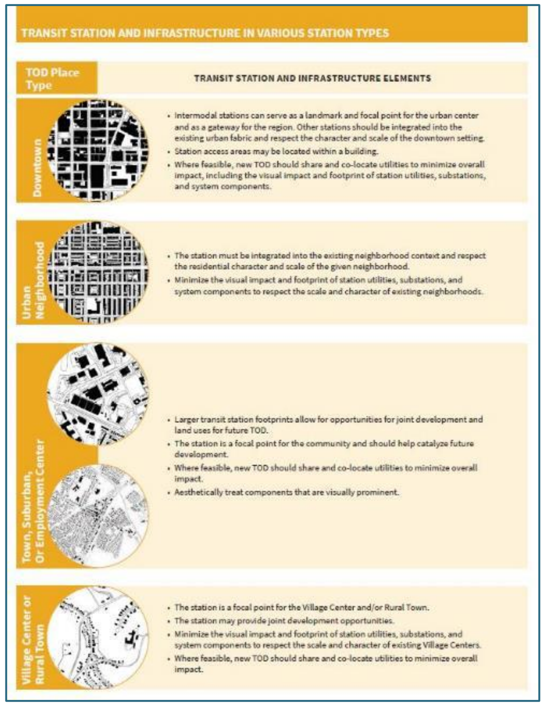

Figure 6.5: MDOT MTA's TOD Guidelines identify four TOD place types, with recommendations for integrating transit into each TOD place type.

1.1.8. Planning and Designing Streets to be Safer and More Accessible for People with Vision Disabilities[8]

This guide helps Montgomery County design its transit facilities, bikeways, sidewalks, and other public spaces with better accessibility considerations. As of late 2023, an effort is underway to create new

[6] *Montgomery County Zoning Ordinance.* Montgomery County Planning Department, 2014 Revision. https://montgomeryplanning.org/development/zoning/

[7] *Ride On Reimagined.* Montgomery County Department of Transportation, 2022. https://www.montgomerycountymd.gov/DOT-Transit/reimagined/

[8] *Planning and Designing Streets to be Safer and More Accessible for People with Vision Disabilities.* Montgomery County Planning Department, 2021. https://www.montgomerycountymd.gov/DOT/Resources/Files/MC%20Designing%20Streets%20for%20PVD%20Toolkit_20211007_ADA.pdf

accessibility guidelines to supplement and expand upon this guide.

1.1.9. Maryland Department of Transportation Maryland Transit Administration (MDOT MTA) Transit-Oriented Development Guidelines[9]

In addition to overseeing all transit operators in Maryland, MDOT MTA operates some transit in Montgomery County, including commuter buses and MARC Train service. As such, MDOT MTA's guidelines provide uniform statewide recommendations for TOD by identifying four TOD Place Types based on the concept of the transect,[10] and by describing the best practices for transit within each TOD Place Type. The guidelines in this chapter were written to align with MDOT MTA's best practices recommendations.

1.2. National Policy Context

1.2.1. Complete Streets Best Practices

Since they prioritize Complete Streets best practices across all design recommendations, the National Association of City Transportation Officials' (NACTO's) three design guides—the Transit Street Design Guide,[11] Urban Street Design Guide,[12] and Urban Bikeway Design Guide[13]—were all referenced extensively for the guidelines in this chapter. In addition to referring to Montgomery County's Complete Streets Design Guide for more detailed specifications, the sections in this chapter often reference one or more of the NACTO design guides above.

1.2.2. TOD Best Practices

While there is no corresponding definitive guide for TOD best practices, the Institute for Transportation and Development Policy (ITDP) publishes a TOD Standard[14] that was reviewed to develop the TOD guidelines in this chapter.

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[9] *Designing for Transit: Transit-Oriented Development Guidelines*. Maryland Department of Transportation Maryland Transit Administration, 2020. https://s3.amazonaws.com/mta-website-staging/mta-website-staging/files/Transit%20Projects/TOD/TOD_Design_Guidelines_Jan2020.pdf

[10] *The Transect.* Center for Applied Transect Studies. https://transect.org/transect.html

[11] *Transit Street Design Guide.* National Association of City Transportation Officials. https://nacto.org/publication/transit-street-design-guide/

[12] *Urban Street Design Guide.* National Association of City Transportation Officials. https://nacto.org/publication/urban-street-design-guide/

[13] *Urban Bikeway Design Guide.* National Association of City Transportation Officials. https://nacto.org/publication/urban-bikeway-design-guide/

[14] *TOD Standard.* Institute for Transportation and Development Policy, 2017. https://itdpdotorg.wpengine.com/wp-content/uploads/2017/06/TOD_printable.pdf

2.Pedestrians

2.1. Description

Figure 6.6: Photo by Google Street View.

Since many transit riders are pedestrians, sidewalks and walkways serve as the most fundamental means of connecting Flash BRT stations to their immediate surroundings. Low-stress[15] sidewalks and walkways also are essential first-/last-mile connections to/from neighborhoods and points of interest that are farther away.

In addition to providing guidelines for sidewalks and walkways, this section provides guidelines for implementing crosswalks, connecting to adjacent development, providing amenities for pedestrian comfort, and sizing pedestrian accommodations for Flash BRT ridership.

2.2. Key Considerations

2.2.1. Are there desire paths to any existing buildings, developments, and points of interest?

Desire paths are informal dirt walking routes that have been worn into the turf by pedestrians in places where sidewalks and walkways are absent.

2.2.2. If a station is incorporated into or adjacent to a sidewalk, is the sidewalk width adequate for existing and anticipated ridership?

This question applies both to existing sidewalks, which may need to be widened to accommodate new stations, and future sidewalks planned in tandem with new stations.

2.2.3. If a station is in a median, are riders able to safely cross the travel lanes to get to the curbside sidewalks?

Wherever possible, median stations should attempt to provide crosswalks to curbside sidewalks on *both ends* of the station. Providing several entrance and exit points can reduce a pedestrian's impulse to take shortcuts from various points across the street to reach the station.

2.2.4. If a station contains side platforms on both sides of the street, is there a crosswalk to connect the two?

Wherever possible, side platform stations should be located near intersections with crosswalks since riders may use one platform for their morning commutes and arrive at the opposite platform for their evening commutes. If a station with midblock side platforms is necessary, add a midblock crosswalk if the walking distance to existing intersection crosswalks is significant.

[15] *Pedestrian Level of Comfort Map.* Montgomery County Planning Department. https://mcatlas.org/pedplan/

2.2.5. Are there sidewalks or walkways to all the station's services?

In addition to connecting the station's platforms to all curbside sidewalks, walkways should connect to other station services, such as pick-up/drop-off areas, bike racks and scooter corrals, commuter parking lots, and other station services.

2.2.6. How complete is the sidewalk and crosswalk network around the station?

Any gaps in the network should be prioritized for completion. A complete sidewalk network is the most essential component in first-/last-mile connectivity.

2.2.7. How complete and direct is the street grid around the station?

Even if a continuous sidewalk and crosswalk network is present, walking to/from the station is more difficult if the streets are circuitous and disconnected (dead ends), and if the blocks are very large. Smaller blocks overlaid onto straight, interconnected, gridded streets accommodate a wider range of walking/rolling abilities.

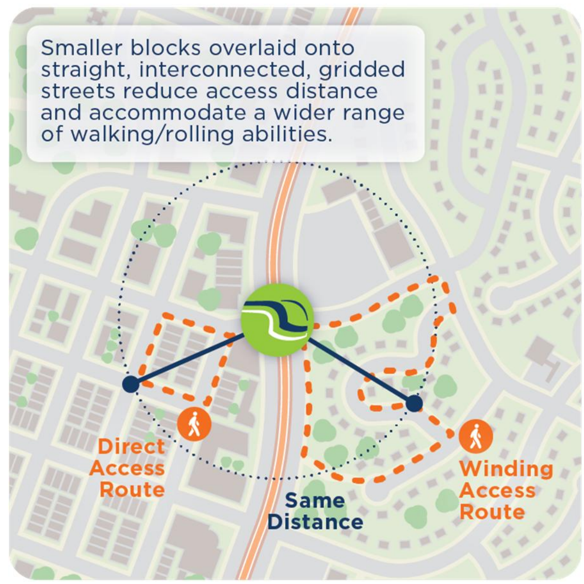

Figure 6.7: Station Access

2.3. Guidelines

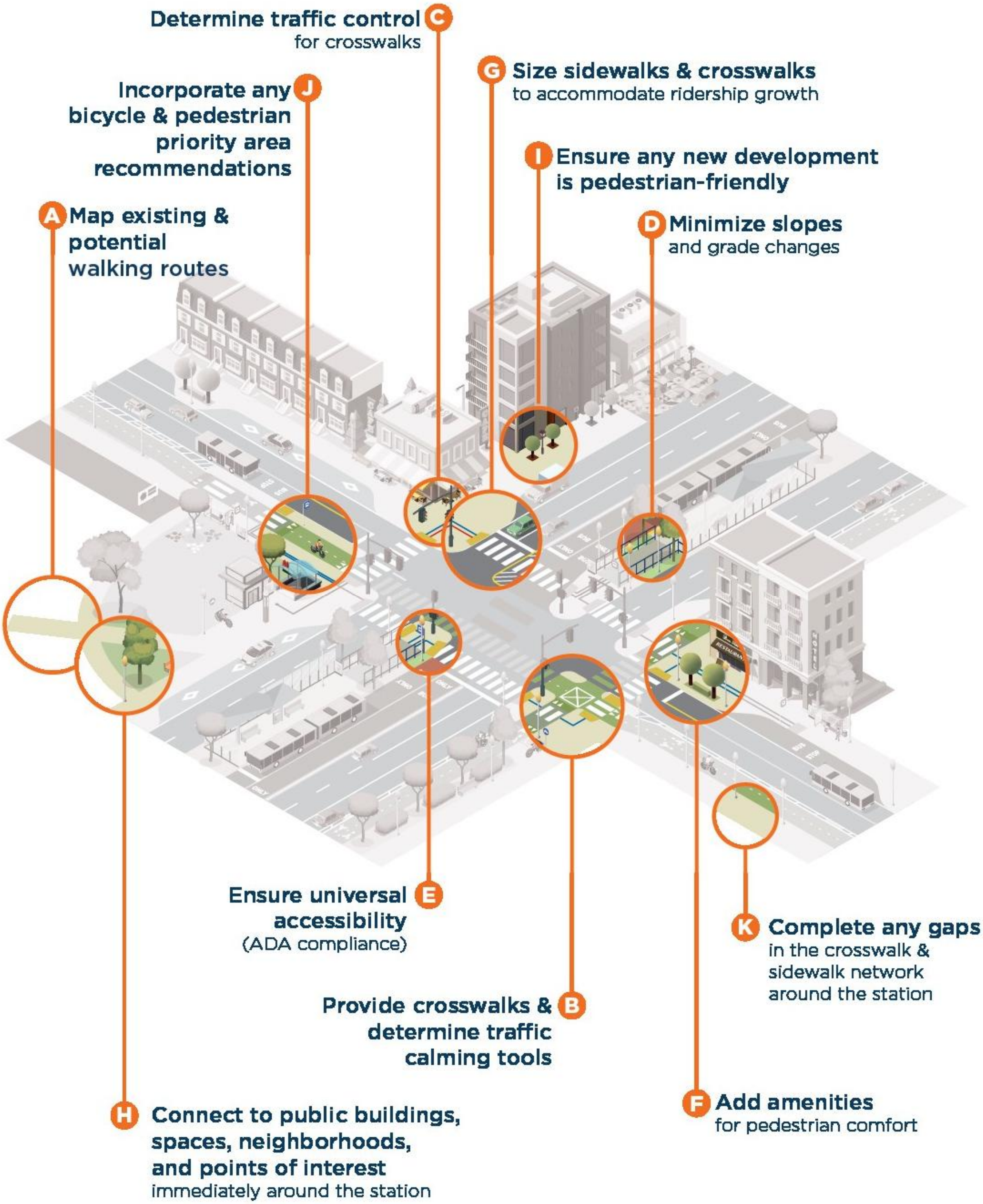

Figure 6.8: Station Access

2.3.1. Map all existing and potential walking routes within a half-mile of the station and adjacent streets and blocks.

Create a circulation diagram that maps all existing and potential pedestrian flows between the station platforms, station services, curbside sidewalks, and adjacent buildings and points of interest. Convert desire paths into walkways and ensure all walking routes are as straight and direct as possible. Otherwise, pedestrians may attempt to take shortcuts across any bike, transit, and vehicular travel lanes.

2.3.2. Provide crosswalks wherever walking routes cross bike, transit, and vehicular travel lanes, and determine which traffic calming tools to incorporate.

Crosswalks across wider roadways may benefit from pedestrian refuges (medians), and they also can incorporate raised intersections, bulbouts, and other traffic calming tools to slow vehicles and reduce pedestrian crossing distances. Crosswalks should be present on all four sides of an intersection and should be omitted only in the most extreme circumstances. See Chapter 6 of Montgomery County's Complete Streets Design Guide for more detailed specifications.

Additionally, to determine which traffic calming tools may be most effective in providing safe access to the station, review crash data for the streets around the station, especially pedestrian-vehicle incidents. Conduct a predictive safety analysis and a pedestrian level of comfort study that responds to pedestrian-vehicle crash data by identifying the roadway segments most in need of pedestrian safety improvements.

2.3.3. Determine the traffic control methods for crosswalks.

While signalized crosswalks may be necessary at many intersections, some midblock crossings or low-traffic intersections may be adequately served by unsignalized (push-button, flashing beacon, or signpost) crosswalks. Signalized crosswalks should minimize pedestrian wait times, and all crosswalks should be clearly marked. In urban areas or areas with high pedestrian volumes, pedestrian signals should be considered for recall (automatic operation).

2.3.4. Minimize slopes and grade changes.

Even though some station locations will inevitably have slopes and grade changes, minimize these to the greatest extent possible. Keep sidewalks, walkways, and crosswalks level, and minimize use of pedestrian overpasses and underpasses. Use ramps instead of steps wherever possible.

2.3.5. Ensure universal accessibility (Americans with Disabilities Act [ADA] compliance).

Ensure that all sidewalks, walkways, and crosswalks to/from the station meet or exceed ADA requirements for adequate widths, lighting, legibility and visibility, clearances (especially around obstacles such as lampposts, signposts, and telephone poles), slopes (especially at curb ramps), and surface conditions.

2.3.6. Add amenities for pedestrian comfort.

Provide protection from the elements by deploying shade trees, canopies, and other continuous protective structures, not just along sidewalks but also along the walkways to/from the station platforms and services. Also provide benches for resting and waiting.

2.3.7. Size sidewalks and crosswalks to accommodate ridership growth.

Sidewalks and crosswalks in and around the station may need to be widened to accommodate anticipated ridership. Review the station's projected passenger volumes and conduct station usage forecasts to project adequate sidewalk and crosswalk widths, then compare these with existing and proposed sidewalks and crosswalks to ensure they are of sufficient width.

2.3.8. Connect to the public buildings, public spaces, neighborhoods, and points of interest immediately around the station.

Ensure comprehensive first-/last-mile access by connecting the sidewalk network at the station to existing neighborhoods and pedestrian activity generators. In some cases, continuous sidewalks may not be enough; pedestrian-centric facilities such as parks, parking garages, shopping malls and shopping centers, schools and libraries, and other public or quasi-public facilities may benefit from dedicated walkways directly to/from the station.

2.3.9. Ensure that any new development around the station is pedestrian friendly.

In addition to ensuring that existing development's pedestrian facilities are adequately connected to sidewalks and walkways, ensure that any new and proposed development's pedestrian facilities will provide adequate connections. This may require coordinating with multiple developers and the Montgomery County Planning Department.

2.3.10. Incorporate any Bicycle and Pedestrian Priority Area recommendations.

Check to see if the station falls within one or more of Montgomery County's Bicycle and Pedestrian Priority Areas. Integrate any area-specific improvements into the pedestrian improvements proposed for the station.

2.3.11. Complete any gaps in the sidewalk and crosswalk network within a half-mile of the station.

Identify any gaps in the sidewalk and crosswalk network in the station area, then work with applicable localities to complete these gaps. Intersections should have high-visibility crosswalks on all four sides wherever feasible, and any faded crosswalks should be repainted. Any sidewalks in poor condition should be repaired, and any overgrowth/brush that interferes with clearances and visibility should be pruned. If soil or debris is present on sidewalks, it may indicate a need for drainage improvements or sidewalk regrading.

3.Bikes and Micromobility

3.1. Description

Figure 6.9: Photo by the Washington Area Bicycle Association.

If accommodated safely on the streets around a Flash BRT station, cycling and micromobility can be efficient first-/last-mile options to/from the station. Safe accommodations refer to cycling and micromobility facilities that are as low stress[16] as possible, and therefore as accessible as possible to the widest range of cycling abilities.

"Micromobility" refers to docked and dockless shared bikes and scooters, skateboards, Segways, and all other personal conveyances that supplement personal bikes.

The guidelines in this section cover dedicated travel facilities (including dedicated lanes, sidepaths, and trails) and dedicated short- and long-term storage facilities (including secure shelters, sheds, racks, docks, and corrals). These guidelines reinforce Montgomery County's vision to transform the county into a world-class cycling community.

3.2. Key Considerations

3.2.1. Is there cycling or microtransit activity at an existing station or in the location for a proposed station, and, if so, are existing or proposed storage facilities adequate?

Telltale signs of overloaded cycling and microtransit facilities include full or overflowing bike racks, scattered dockless shared bikes and scooters, high Capital Bikeshare activity, and bikes locked to railings, poles, and trees.

3.2.2. If a station connects to a bike lane, is the bike lane width adequate for existing and anticipated ridership?

This question applies both to existing bike lanes, which may need to be widened to accommodate new stations, and future bike lanes planned in tandem with new stations.

3.2.3. If a station is in a median, are cyclists able to safely cross the travel lanes to get to nearby bike lanes?

Wherever possible, median stations should attempt to provide connections to nearby bike lanes on both ends of the station. Providing several entrance and exit points can reduce a cyclist's impulse to take shortcuts from various points across the street to reach the station. Cycling connections

[16] *Bicycle Stress Map.* Montgomery County Department of Planning. https://mcatlas.org/bikestress/

between median stations and nearby cycling facilities can be shared with pedestrians and do not necessarily need to serve cyclists exclusively.

3.2.4. How complete is the cycling network around the station?

Any gaps in the nearby cycling, recreational, and trail networks should be prioritized for completion. A complete cycling network is a critical component in first-/last-mile connectivity. Gaps also can include existing bikeways that do not meet current standards for comfortable or low-stress cycling, such as unprotected bike lanes on major roadways, or shared-use paths less than 10 feet wide.

3.3. Guidelines

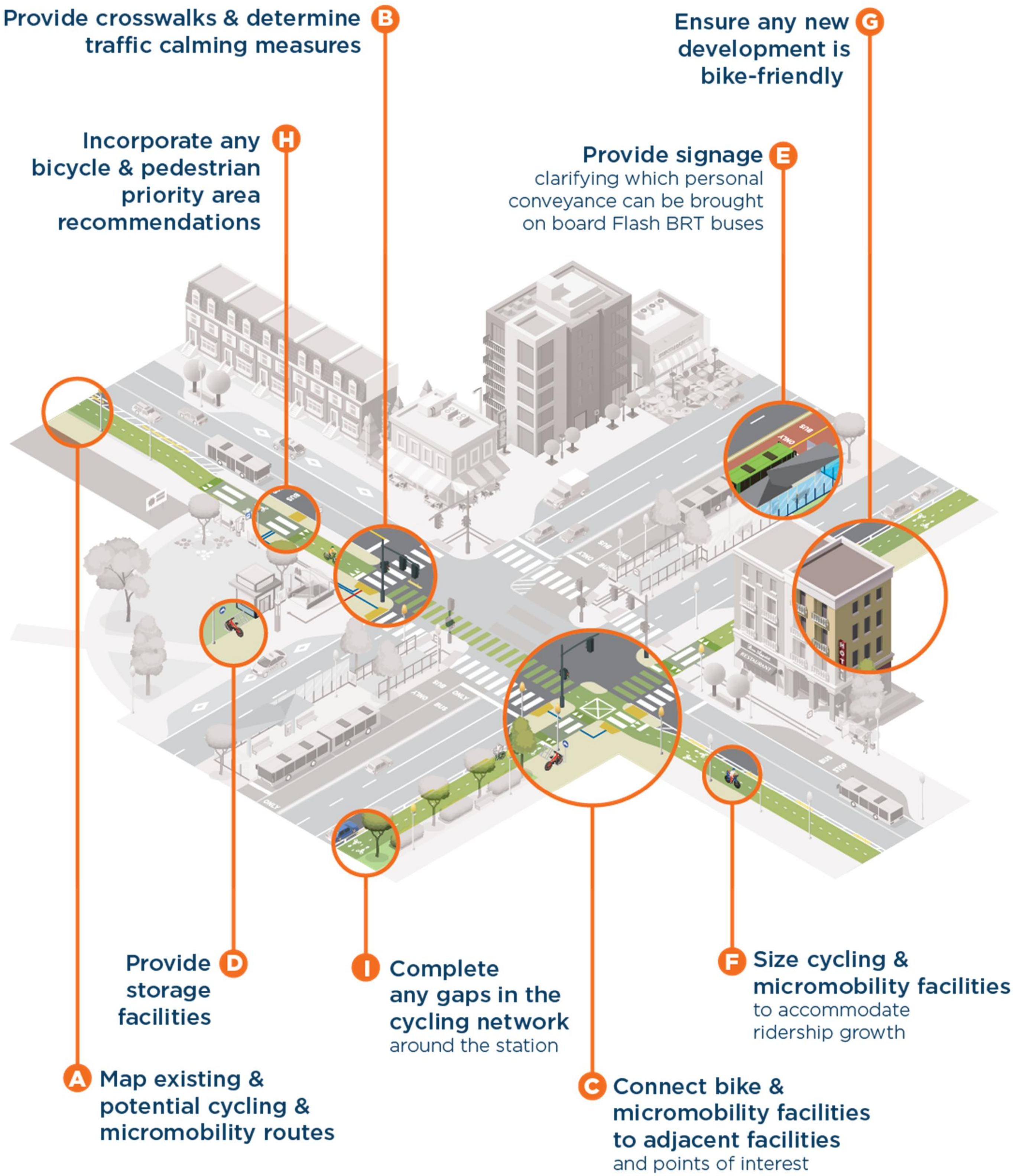

Figure 6.10: Station Access

3.3.1. Map all existing and potential cycling and micromobility routes within a mile of the station and adjacent streets and blocks.

Create a circulation diagram that maps all existing and potential bike and micromobility flows between the station platforms, bike and micromobility storage facilities, adjacent streets, and adjacent points of interest. Ensure all cycling routes are as straight and direct as possible. Otherwise, cyclists may attempt to take shortcuts across any transit and vehicular travel lanes.

3.3.2. Provide crosswalks or bike crossings wherever cycling and micromobility routes cross transit and vehicular travel lanes and determine which traffic calming tools to incorporate.

Crosswalks and bike crossings across wider roadways may benefit from refuges (medians), and they can incorporate other traffic calming tools to slow vehicles, reduce cycling stress, and reduce cycling crossing distances. To determine which traffic calming tools may be most effective at which locations, review crash data for the streets around the station and focus on bicycle-vehicle incidents. Wherever possible, include bike crossings alongside pedestrian crosswalks, following the guidelines in Section 6.11 of Montgomery County's Complete Streets Design Guide.

3.3.3. Connect the cycling and micromobility facilities at the station to adjacent facilities and points of interest.

If the roadways around the station have existing cycling and micromobility facilities (dedicated lanes, sidepaths, or trails), connect these to the station. Furthermore, existing cycling and micromobility facilities around the station may benefit from buffer retrofits, especially those along high-traffic roadways. See Chapter 5 in Montgomery County's Complete Streets Design Guide for further guidance. Note that any retrofits should seek to reuse and improve existing facilities to the greatest extent practical. Since these represent considerable investments, it is preferable to build upon existing facilities rather than to constantly rebuild or relocate them.

Additionally, check to see if the station is located along Montgomery County's Breezeway Network.[17] This is a continuous network of low-stress cycling facilities and streets between the county's major activity centers. Integrate the station's cycling facilities with those in the Breezeway Network.

Finally, connect to the cycling activity generators around the station—some cycling-centric facilities such as regional trails, parks, recreation centers, shopping malls and shopping centers, schools and libraries, and other public or quasi-public facilities may benefit from dedicated cycling and micromobility connections directly to/from the station.

3.3.4. Provide bike and micromobility storage facilities.

In addition to storage facilities provided directly at the station (see Chapter 2), there may be demand for storage facilities along the dedicated lanes, sidepaths, or trails surrounding the station.

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[17] *Montgomery County Breezeway Network.* Montgomery County Planning Department. https://montgomeryplanning.org/wp-content/uploads/2016/11/Bicycle_Breezeway-Network-Technical-Memo-1.pdf

Examine these surroundings for latent storage demand and provide secure shelters, racks, docks, and/or corrals as needed, following clearance guidelines in Section 3.3 of Montgomery County's Complete Streets Design Guide.

For bike racks, use "Inverted U" models, replacing any older models (such as grid racks) present at or near existing stations. Refer to Montgomery County's Bicycle Master Plan for adequate rack placement to avoid placing racks too close to walls or to each other, which can make them unusable. For bikeshare docks, work with the Capital Bikeshare program to determine if expansion or introduction of Capital Bikeshare docks is warranted at the station.

For stations anticipated to serve a high proportion of commuters, explore long-term secure bike storage that employs Crime Prevention Through Environmental Design (CPTED) principles. Long-term bike storage can include cages, sheds, rooms, and other secured, enclosed facilities that increase cyclist confidence in the security of long-term storage.

3.3.5. Provide signage clarifying which personal conveyance can be brought on board Flash BRT buses.

Provide signage at all bike and micromobility storage facilities that clarifies MCDOT's bring-on-board policies. For example, bikes are permitted on board Flash BRT vehicles,[18] but other personal conveyance may be prohibited, especially battery-powered conveyance.

3.3.6. Size cycling and micromobility facilities to accommodate ridership growth.

Cycling and micromobility facilities in and around the station may need to be widened to accommodate anticipated ridership. Review the station's projected passenger volumes and conduct station usage forecasts to project adequate facility widths, then compare these with existing and proposed widths to ensure they are sufficient.

3.3.7. Ensure that any new development around the station is bike friendly.

Coordinate with developers to ensure any new streets provide cycling and micromobility facilities, or that new streets are designed to be naturally bike friendly. Slow, narrow, quiet residential streets may not require dedicated facilities at all; rather, shared lane markings (sharrows) can inform cyclists to use the vehicular travel lanes. Traffic calming elements or "neighborhood greenways" may be appropriate in some areas. Also, remind developers that Montgomery County's zoning ordinance requires their developments to include bike racks (again, Inverted U models are preferred) and/or bike storage rooms.

3.3.8. Incorporate any Bicycle and Pedestrian Priority Area recommendations.

Check to see if the station falls within one or more of Montgomery County's Bicycle and Pedestrian Priority Areas. Integrate any area-specific improvements into the cycling improvements proposed for the station.

[18] *Wheels Welcome.* Montgomery County Department of Transportation. https://www.montgomerycountymd.gov/dot-transit/flash/wheels.html

3.3.9. Complete any gaps in the cycling network within a mile of the station.

Identify any gaps in the cycling, recreational, and trail networks in the station area, then work with applicable localities to complete these gaps. Any sections in poor condition should be repaired, and any overgrowth/brush that interferes with clearances and visibility should be pruned. If soil or debris is present on bikeways, it may indicate a need for drainage improvements or bikeway regrading.

4. Vehicles

4.1. Description

By separating Flash BRT buses from other vehicles, dedicated transit lanes help make transit service more reliable. These lanes are discussed in more detail in Chapter 3, while this section focuses instead on the broader context of microtransit vehicles, carshare vehicles, and private vehicles around which Flash BRT buses must efficiently maneuver.

Figure 6.11: Photo by Google Street View.

"Microtransit" refers to for-hire, curb-to-curb, pick-up and drop-off services, including taxicabs and app-based services such as Uber and Lyft. "Carshare" refers to short-term car rental services such as Zipcar.

The guidelines for vehicles in this section include parking for buses (layover spots and bus bays), carshare vehicles, and private vehicles (park-and-rides). They also address pick-up and drop-off needs for private vehicles (kiss-and-rides), microtransit and paratransit, and trucks and other delivery vehicles. Not all these vehicular access modes are appropriate for all stations, especially for on-street stations, but this section still introduces all potential vehicular access modes for thoroughness.

4.2. Key Considerations

4.2.1. What kinds of vehicles are attempting to access the station?

Besides the Flash BRT buses themselves, various other vehicles may need to access the station, including microtransit, paratransit, carshare, and private vehicles. At on-street stations, private vehicular access may not be necessary, while microtransit and carshare access may need to be accommodated on nearby streets rather than at the station itself.

4.2.2. Which vehicles only need to pick up or drop off riders, and which vehicles need to park for longer periods?

While many stations, particularly on-street stations, may not need to provide parking, some stations may still need to serve pick-ups and drop-offs from private vehicles, microtransit, and paratransit.

4.2.3. Can the roadways around the station accommodate existing and anticipated ridership?

Vehicles entering and exiting the station to pick up, drop off, or park may generate congestion on surrounding streets. If designated pick-up, drop-off, and parking spaces are not provided, drivers may block crosswalks, curb ramps, bike facilities, and/or critical sightlines as a result.

4.2.4. Is there potential for coordinating parking, pick-ups and drop-offs, and truck deliveries?

Private and microtransit vehicles traveling to/from on-street stations often use the curbside space on adjacent streets to park, pick up, or drop off. This can generate friction with nearby businesses and residents.

4.2.5. How complete and direct is the street grid around the station?

A fine-grained, interconnected street grid can distribute station traffic over more streets, though care should be taken to minimize traffic volume and speed on residential streets.

4.3. Guidelines

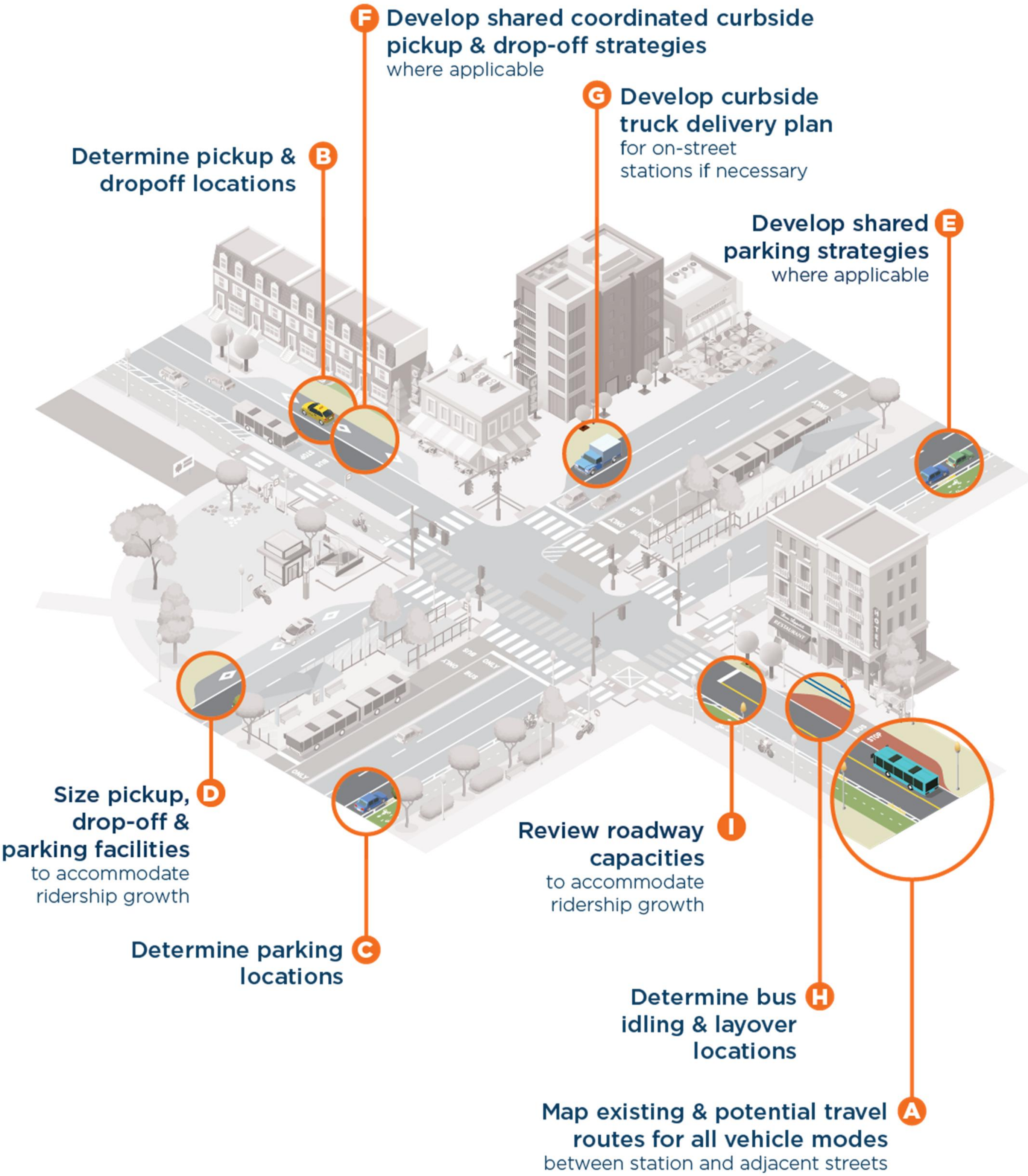


Figure 6.12: Station Access

4.3.1. Map existing and potential travel routes for all vehicular modes between the station and adjacent streets.

Create a circulation diagram that maps all existing and potential vehicular flows between the station and adjacent streets. Determine which vehicular access modes are necessary based on the station's context. For example, a station expected to see park-and-ride activity will require more vehicular access accommodations than an on-street station, which may not have *any* accommodations for vehicles other than FLASH BRT buses. As discussed in more detail in the Safety section, this helps determine potential conflict points between the various vehicular modes as well as between vehicles, cyclists, and pedestrians.

4.3.2. Determine locations for pick-ups and drop-offs.

While not every station offers commuter parking, some on-street stations may still see pick-up and drop-off demand from private, microtransit, and paratransit vehicles. If demand warrants, provide dedicated pullover space for these modes, preferably on nearby streets since the primary street hosting the Flash BRT service may not have available curbside space. Pullover space can be separated by mode if demand warrants, or combined if demand is low or if space is constrained. Provide dedicated pick-up and drop-off space wherever these activities are expected to reduce the risk of drivers blocking crosswalks, curb ramps, bike facilities, and/or critical sightlines.

For off-street stations, provide an off-street driveway and pullover space for pick-ups and drop-offs. If demand warrants, on-street stations may require reserving a length of curbside space for these activities. For both kinds of stations, pick-ups and drop-offs should be located to minimize interference with Flash BRT buses, pedestrians, and cyclists.

4.3.3. Determine locations for parking.

Some stations, such as end-of-line stations or transfer stations, may benefit from commuter parking (park-and-rides). Provide parking in a format that doesn't undermine the potential for TOD. Where practical, concentrate parking in garages to maximize station-adjacent land for development.

Again, locate parking entrances and exits to minimize interference with Flash BRT buses, pedestrians, and cyclists. Additionally, per ADA requirements, a certain proportion of parking spaces closest to the station will need to be accessible. Similarly, parking spaces close to the station can be reserved for carshare and electric vehicles (EVs).

Consider chamfering the sidewalk edges of parking structures to improve sightlines for pedestrians and exiting vehicles alike. Also consider raised crosswalks and, where bike facilities are present, protected corner islands at and around parking structures.

4.3.4. Size pick-up, drop-off, and parking facilities to accommodate ridership growth.

Review the station's projected passenger volumes and conduct station usage forecasts to project demand for pick-ups, drop-offs, and parking.

4.3.5. Develop shared parking strategies where applicable.

In lieu of providing dedicated station parking, it may be possible to coordinate parking needs with surrounding development. Analyze occupancy periods to determine if the parking needs of complementary activities can be efficiently shared in the same facility. An activity that requires overnight parking can share the same facility as an activity that requires daytime parking. Additionally, general-purpose parking facilities, such as municipal public parking garages, can allow stations and other nearby activities to shed their dedicated, redundant parking facilities.

Wherever possible, configure the parking around stations into “park once” districts so visitors arriving by car do not need to move their car every time they visit a different establishment.

4.3.6. Develop a coordinated curbside pick-up and drop-off strategy where applicable.

As discussed earlier, if there is demand for pick-ups and drop-offs at on-street stations lacking dedicated off-street space for these activities, they may require curbside space on nearby side streets instead. Develop a curbside management strategy that balances any need for station pick-ups and drop-offs with the curbside parking, pick-up, and drop-off needs for surrounding residents and businesses.

4.3.7. Develop a curbside truck delivery plan for on-street stations, if necessary.

Besides passenger pick-ups and drop-offs, trucks and other delivery vehicles serving nearby businesses may need to make curbside freight pick-ups and drop-offs, which should be managed to minimize interference with station operations. If the volume of truck deliveries warrants, work with area businesses to develop a curbside deliveries plan.

4.3.8. Determine locations for bus idling and layovers.

End-of-line stations and some transfer stations may require bus bays or other dedicated spaces for Flash BRT buses to idle and lay over, in addition to operator restrooms. Some stations also may benefit from dedicated spaces for service vehicles such as tow trucks, maintenance trucks and vans, and police cars. Locate any such spaces to minimize interference with Flash BRT buses, pedestrians, and cyclists.

4.3.9. Review roadway capacities to accommodate ridership growth.

Review the station's projected passenger volumes to determine potential congestion from vehicles traveling to and from the station. Develop a congestion plan to address any potential issues, with a particular focus on alternative travel modes such as cycling.

Figure 6.13: Photo by Google Street View.

5. Transfer Considerations

5.1. Description

Rider aversion to transfers can be countered with better transfer infrastructure. If MCDOT's Ride On Reimagined study recommends heavier use of transfers,[19] these would need to be accommodated by infrastructure such as crosswalks, shelters, and wayfinding. Transfers to/from Flash BRT stations may require additional attention.

This section provides guidelines for using streetscape elements to make transfers as quick and easy as possible. An easy, comfortable transfer experience—one that reduces walking distances, maximizes protection from the elements, and minimizes confusion—can reduce aversion to transfers. This section does *not* provide guidance for bus route scheduling, which also plays a role in making transfers easier and more comfortable.

5.2. Key Considerations

5.2.1. How much transfer activity is there (or will there be) at the station?

Transfer activity is driven by the number of connecting bus/rail routes at the station as well as the ridership on those connecting routes. End-of-line stations also have higher transfer activity.

5.2.2. Can riders walk quickly and safely between the station and its connecting bus/rail stops?

Missing or inadequate sidewalks and crosswalks can make riders averse to transferring at the station and pose safety hazards for any riders who are still attempting to transfer. Even if present and physically safe, long and indirect circulation routes also can discourage transfers. Finally, effective signal timing can make the difference between a pleasant transfer and a missed connection.

[19] *Ride On Reimagined.* Montgomery County Department of Transportation, 2022. https://www.montgomerycountymd.gov/DOT-Transit/reimagined/

5.2.3. Is the transfer experience comfortable?

Circulation routes that expose riders to the weather can discourage transfers. Riders are being asked to leave a comfortable, dry bus/train and tolerate the elements to get to the next comfortable, dry bus/train. If riders are protected from the elements as they walk, the transfer can feel less onerous.

Figure 6.14: Photo by the Metropolitan Transportation Authority

5.2.4. Is the transfer connection clear?

Vague and indirect circulation routes between the station and its connecting bus/rail stops can induce confusion and discourage transfers even if the connections are present and physically safe.

5.3. Guidelines

Figure 6.15: Station Access

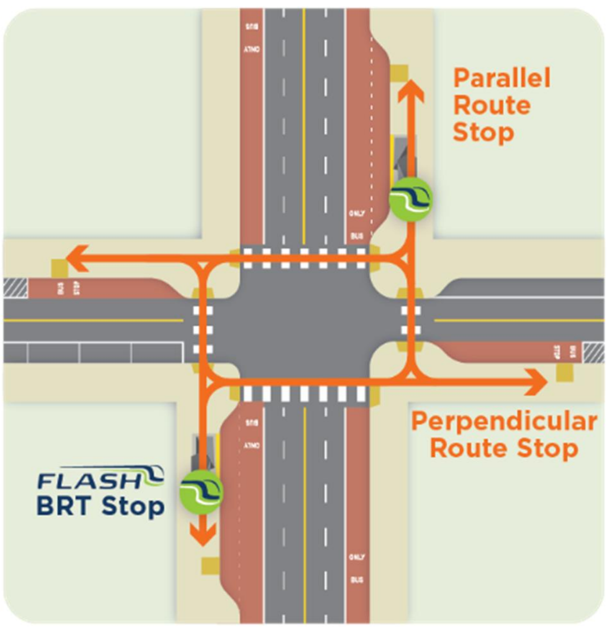
5.3.1. Determine the station's anticipated transfer activity.

Depending on its function within both the Flash BRT and overall transit networks, the station's transfer activity could vary widely. For example, a minor midline station may see less transfer activity than end-of-line stations or stations that cross major bus and rail lines. Review the station's ridership, then review the ridership for both the existing and proposed bus and rail lines connecting to the station to forecast the transfer activity between all lines.

5.3.2. Minimize circulation distances between the station and any connecting bus/rail stops.

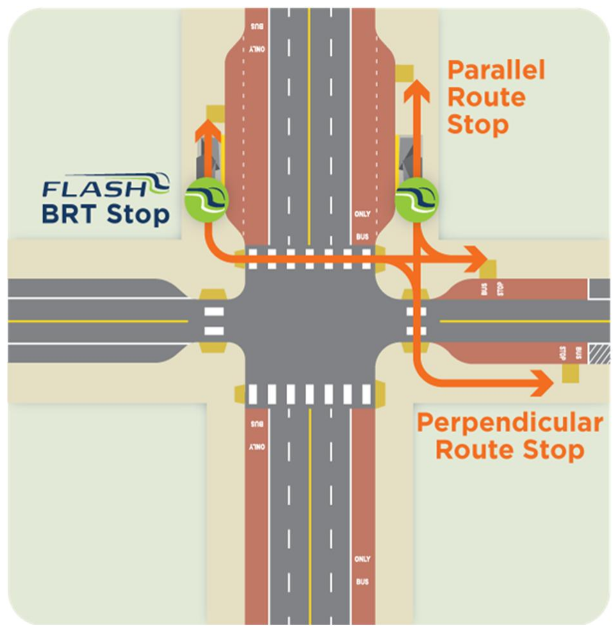
Position the stops for connecting bus/rail lines as close as possible to the station's platforms and provide circulation routes between them that are as short and direct as possible.

While the intersections around the station should provide crosswalks on all four sides to maximize access to nearby activities, it may still be possible to minimize the number of crosswalks that riders cumulatively need to use specifically for transferring:



As shown above, farside positions are typically recommended for Flash BRT stations, and they are often preferred for local bus stops as well; however, four farside stops (two Flash BRT stations and two intersecting local bus stops) would see cumulative transfer activity across all four crosswalks. If westbound or eastbound riders need to transfer to northbound or southbound stops (or vice versa), all four crosswalks will see cumulative transfer activity.

Figure 6.16: Station Access



Shifting one of the Flash BRT stations and one of the local bus stops to nearside reduces the number of crosswalks seeing cumulative transfer activity: the cumulative transfer activity from westbound or eastbound riders transferring to northbound or southbound stops (or vice versa) is distributed across only two crosswalks. While this shift impacts Flash BRT and local bus operations and may not be appropriate everywhere, it may be justified in locations with

Figure 6.17: Station Access

5.3.3. Protect transferring riders from the elements.

Provide shelters at all connecting bus/rail stops, and, to the greatest extent possible, provide canopies, lighting, and shade trees along the circulation routes between the station and its connecting bus/rail stops.

5.3.4. Provide wayfinding between the station and its connecting bus/rail stops.

While transfer signage should be present at both the station and its connecting bus/rail stops, explore additional wayfinding embedded into the pavement. Embedded markers can often highlight circulation routes more prominently than signage can.

6. Safety Considerations

6.1. Description

While the ADA prescribes various dimensional requirements for safe sidewalks, crosswalks, curb ramps, and other streetscape elements, creating a safe Flash BRT station environment goes well beyond complying with ADA requirements.

For example, even if a high-speed roadway adjacent to a station provides basic, by-the-book accommodations for pedestrians to cross the roadway to reach the station, the roadway could potentially undergo a more thorough and ambitious road diet or complete streets redesign to reduce the barrier it poses to pedestrians attempting to reach the station.

Figure 6.18: Photo by Google Street View.

This section provides guidelines for spatial needs, sightlines, conflict points, traffic calming and road diets, crash protection for vulnerable roadway users, lighting, and police/CCTV enforcement.

6.2. Key Considerations

6.2.1. How fast are vehicles traveling on the streets around the station, and can riders safely get to the station?

Even if the sidewalks and crosswalks between the station and its surroundings appear to be adequate, much more can potentially be done to protect pedestrians and cyclists traveling to/from the station. Each roadway around the station should be examined for its road diet and traffic calming potential, and crosswalks should be provided at all anticipated entrance and exit points to/from the station, as described in the Pedestrians section.

6.2.2. Are vulnerable roadway users protected from vehicles?

Sidewalks and bike facilities adjacent to fast, heavy traffic are not just unpleasant for pedestrians and cyclists, but potentially dangerous since they offer little or no protection from moving vehicles.

6.2.3. How do all the modes attempting to access the station interact with each other, and can they see each other at all the interaction points?

Pedestrians, cyclists, Flash BRT buses, other connecting buses, private and shared vehicles, and other modes will attempt to access the station at the same time, and there are multiple points at which these modes cross, interact, and potentially conflict with each other.

6.2.4. Who is responsible for lighting and policing around the station?

Lighting within the station will almost always be provided by MCDOT, but lighting on the streets and sidewalks connecting to the station may require coordinating between multiple parties.

6.3. Guidelines

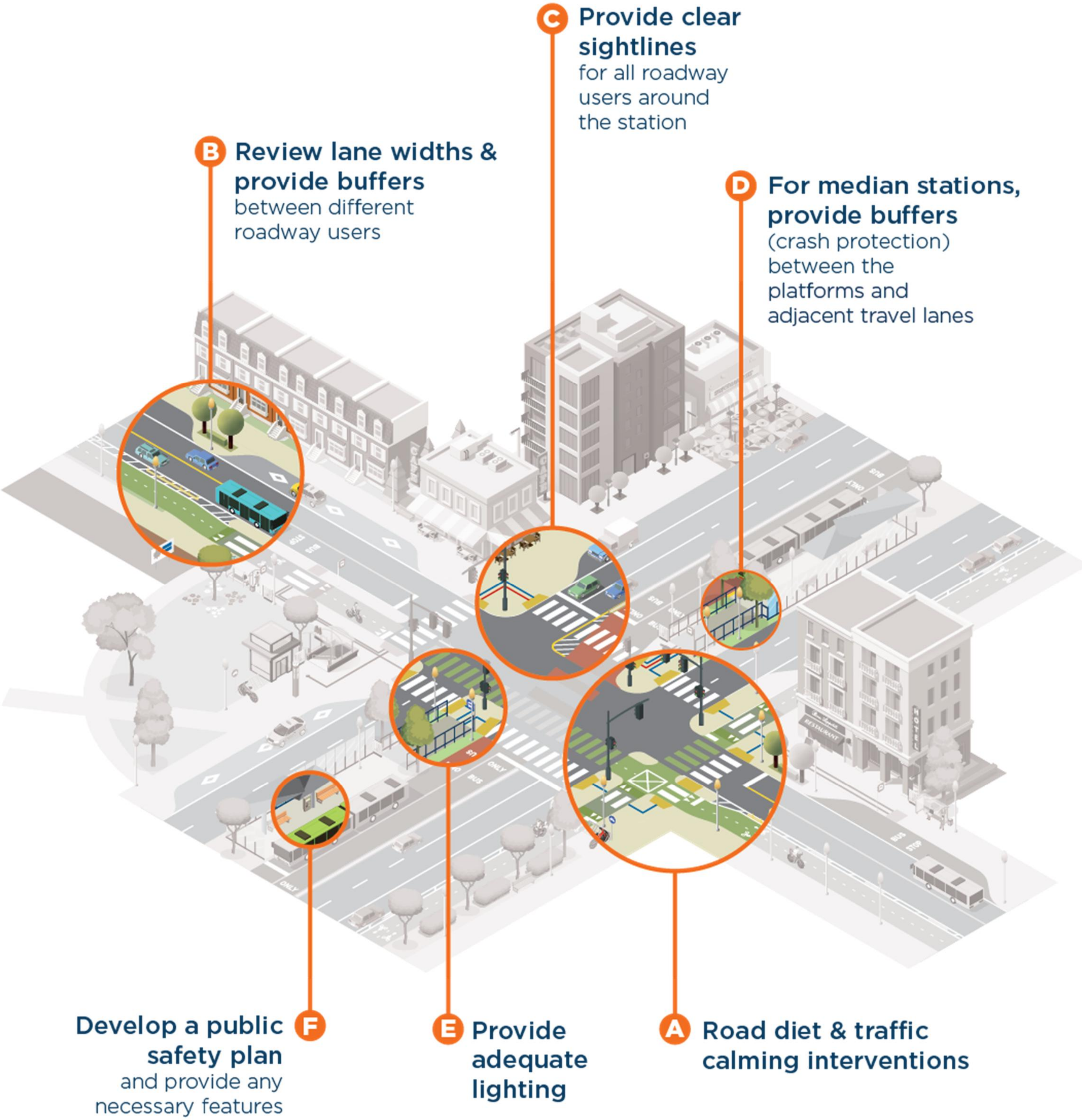


Figure 6.19: Station Access

6.3.1. Review the vehicular speeds and congestion levels on the roadways around the station to determine road diet and traffic calming interventions.

Even if a station-adjacent roadway already appears to have sidewalks and crosswalks at all necessary points, it may still benefit from a road diet and traffic calming interventions that reduce vehicular speeds and potentially even divert some throughput to other roadways.

As discussed in the Pedestrians and Bikes and Micromobility sections, refuge medians, raised intersections, sidewalk bulbouts at crosswalks, lane narrowing and reassignment (e.g., reassigning curbside vehicular travel lanes to curbside parking), and other road diet and traffic calming tools can make the roadway safer and more welcoming for pedestrians and cyclists. To determine which traffic calming tools may be most effective at which locations, review crash data for the streets around the station and focus on incidents between pedestrians, cyclists, and vehicles.

When adding bus lanes or busways, repurpose existing general traffic lanes for exclusive transit use before considering any roadway widening. While the latter allows the existing number of general traffic lanes to remain the same, the widening necessary to accommodate additional bus lanes or busways can increase traffic congestion since the wider roadway will require increased pedestrian crossing time. Additionally, the bus lanes or busway on a wider roadway with little vehicular congestion will not offer transit riders any time savings over driving, suppressing transit ridership.

In short, roadway widening introduces a significant disadvantage in that the increased number of general traffic and bus lanes reduces transit ridership and does not contribute to a walkable urban environment in which transit works best.

6.3.2. Review lane widths and provide buffers (crash protection) between different roadway users where needed.

See Section 4.4 in Montgomery County's Complete Streets Design Guide for dedicated transit, travel, and parking lane widths. It is important not to oversize travel lanes, which can induce speeding. In some locations, buffers—such as dividers between bike lanes and travel lanes, planters between sidewalks and travel lanes, and bollards at sidewalk bulbouts—can help protect pedestrians and cyclists from high-speed and turning vehicles.

6.3.3. Provide clear sightlines for all roadway users around the station and minimize conflict points.

Ensure that all roadway users can see each other at all interaction points around the station (e.g., intersections and crosswalks) and position driveways, intersections, and other interaction points carefully to minimize conflicts. As an alternative to crosswalks, some locations may benefit from "shared spaces" where interaction points are defined less as points and more as larger zones within which multiple modes are forced to move slowly as they interact. However, special consideration must be given to how people with disabilities navigate these zones.

6.3.4. For median stations, provide buffers (crash protection) between the platforms and adjacent travel lanes.

Ensure that riders waiting on a median station's platforms are protected from adjacent traffic via railings, fences, or other barriers. These barriers also discourage pedestrian crossings at arbitrary locations across the roadway by channeling crossings to the station's designated entrances. Note that platform shelter windscreens are not adequate barriers by themselves and need to be supplemented with the more substantial barriers above.

6.3.5. Work with localities, utility companies, and landowners to provide adequate lighting around the station.

While lighting within the station is provided by MCDOT, work with the locality, the Maryland Department of Transportation State Highway Administration (MDOT SHA), the utility company, and/or adjacent landowners to provide and maintain adequate lighting on the station-adjacent streets, sidewalks, and bike lanes.

6.3.6. Develop a public safety plan for the station and provide any necessary security features.

Coordinate policing responsibilities at and around the station with the Montgomery County Department of Police. Determine locations for CCTV cameras and place bike storage in highly visible areas.

7.Transit-Oriented Development

7.1. Description

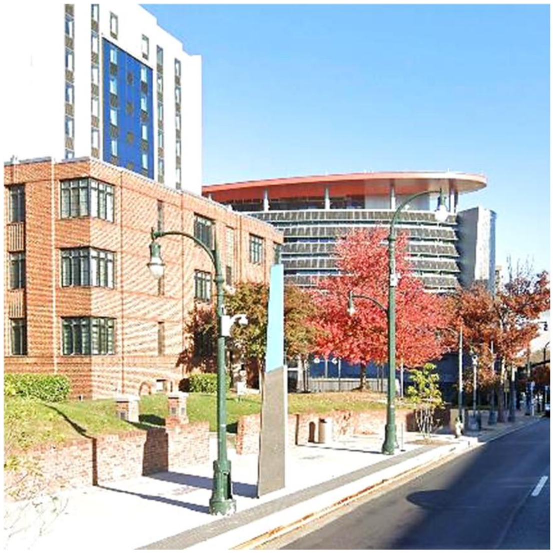


Figure 6.20: Photo by Google Street View.

While some Flash BRT stations may draw ridership from park-and-ride commuters, most stations draw their ridership from the development around each station. The built form that this development takes determines the modes that potential riders use to access the station, and whether potential riders even attempt to take transit at all.

For example, if the residential development around a station comes in the form of low-density single-family houses (in which each house has its own driveway and garage), those residents are more likely to avoid transit altogether and simply drive to their destinations, while higher-density apartment buildings are more likely to generate pedestrians and cyclists that will use the station.

This section provides guidelines for creating and supporting TOD around stations.

7.2. Key Considerations

7.2.1. Is the station well connected to the existing development immediately around the station?

Can riders easily walk or bike from the station to adjacent parks and recreational facilities, shopping centers, retail corridors, office buildings, and neighborhoods? A continuous sidewalk network along surrounding streets and blocks is essential, and some of these activities may benefit from direct connections to the station.

7.2.2. Is there any proposed or in-progress development immediately around the station, and does it come in a transit-supportive format?

If any development is forthcoming around the station, it is worth examining and potentially revising site plans before ground is broken. It may be possible to work with developers to improve the connections to the station.

7.2.3. Is there infill development potential on any undeveloped or underdeveloped land immediately around the station?

Even before any developers take interest, explore the zoning for undeveloped or underdeveloped parcels immediately around the station to see if they can support TOD. Building forms also should support walkability—transit-*oriented* development can easily become mere transit-*adjacent* development if vehicular access is designed to be more important and convenient than pedestrian and transit access.

7.3. Guidelines

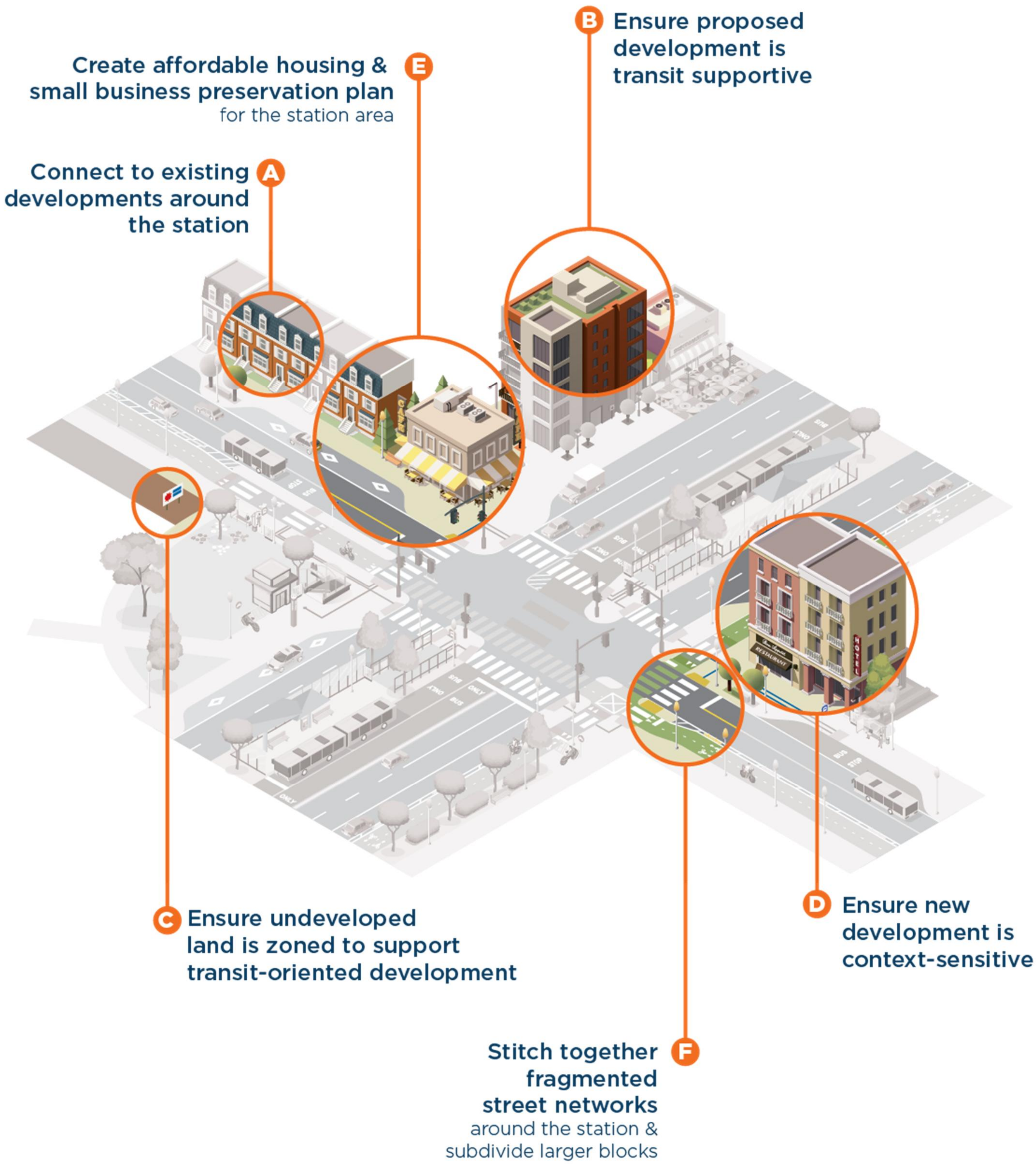


Figure 6.21: Station Access

7.3.1. Connect to the existing developments, neighborhoods, and points of interest immediately around the station.

As discussed in the Pedestrians section, connect the station's walking, cycling, and micromobility facilities to the existing developments and neighborhoods immediately around the station. Connect to common transit trip generators such as shopping centers and retail corridors, apartment complexes, office buildings and office complexes, schools and libraries, hospitals, parks and recreational facilities, and other large activity centers.

7.3.2. Ensure any proposed development immediately around the station is transit supportive.

Check to see if there are any proposed or in-progress developments around the station. Check developers' site plans to see if their built forms are in a transit-supportive format (mixed uses, higher densities, smaller blocks, interconnected street grids with sidewalks) and work with developers to improve any shortcomings to the greatest extent possible.

Additionally, ensure that the public and commercial spaces in any proposed developments are oriented to the station or to the streets and sidewalks connecting to the station. For example, an insular plaza or courtyard offers fewer spillover benefits for the entire neighborhood than one that is seamlessly connected to the sidewalk. Similarly, commercial spaces that are easily accessible and visible from the street may generate more patronage from and convenience for the entire neighborhood than commercial spaces hidden inside a building.

7.3.3. If there is undeveloped or underdeveloped land adjacent to the station, ensure it is zoned to support TOD.

Undeveloped or underdeveloped (lower-density) land adjacent to a station provides the opportunity to create denser, mixed-use, transit-supportive neighborhoods—if the local zoning permits it. Check the zoning for the undeveloped and underdeveloped parcels around the station and see if they can support denser, mixed-use infill development. If not, work with the Montgomery County Planning Department and/or the applicable municipal planning departments to upzone or rezone these parcels.

7.3.4. Ensure new development immediately around the station is context sensitive.

While a development's built form will largely be dictated by zoning, additional considerations for context-sensitivity include building materials, architectural design, and other features that should be thoughtfully designed to complement rather than clash with existing development.

7.3.5. Create an affordable housing and small business preservation plan for the station area.

Existing residents and businesses in the station area may worry about displacement or gentrification, and it may be possible to mitigate or minimize both through policy interventions. For example, affordable housing mandates can be used to retain, introduce, or increase a certain proportion of affordable housing in the station area.

7.3.6. Stitch together any fragmented street networks around the station and subdivide larger blocks.

An ongoing, long-term guideline for the station area is to work with localities and developers to (re)connect streets and subdivide blocks as opportunities arise.

8.Wayfinding and Placemaking

8.1. Description

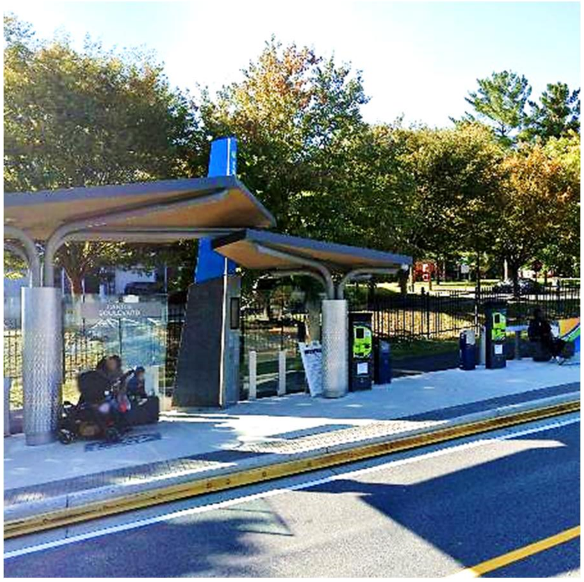


Figure 6.22: Photo by Google Street View.

"Wayfinding" is commonly assumed to refer to signage in and between transit facilities, but good wayfinding includes more fundamental elements to orient Flash BRT riders. This section explores using accessible circulation routes, thoughtful focal and congregational points, directional markers integrated into circulation surfaces, and other accessible design elements to orient riders beyond merely providing signage.

Some wayfinding elements overlap into the realm of placemaking, which is the art of creating pleasant public spaces in which all people—not just transit riders—want to spend time. This section explores methods to seamlessly connect stations to surrounding neighborhoods, to provide public spaces that inspire a sense of ownership among both transit riders and nearby residents, to employ sustainable design in the station area, and to collaborate on public artwork.

Note that this section focuses primarily on wayfinding and placemaking for the areas *between* the station and its surrounding streets and blocks, while wayfinding and placemaking guidelines for the station itself are discussed in more detail in Chapter 2.

8.2. Key Considerations

8.2.1. Are the circulation routes to the station easy to understand even without signage?

Excessive signage can sometimes hamper—rather than aid in—wayfinding, so the most fundamental step in establishing good wayfinding is to ensure circulation routes are short, clear, and direct.

8.2.2. Where might riders traveling to the station need clarification on their route?

Even if circulation routes to the station are as short, clear, and direct as possible, there will inevitably be points at which riders seek clarification for continuing their travel to the station.

8.2.3. Is the station integrated into the surrounding neighborhood?

Not only should the station's public spaces be integrated into those of the surrounding neighborhood, but so too should the station take note of the surrounding neighborhood's architecture, character, and culture to inform its design and reinforce a sense of place.

8.2.4. Are there opportunities for providing public art around the station?

A station can serve as a focal point for its community by integrating artwork from artists in surrounding neighborhoods. Its public spaces also can host community fairs, festivals, and other activities.

8.3. Guidelines

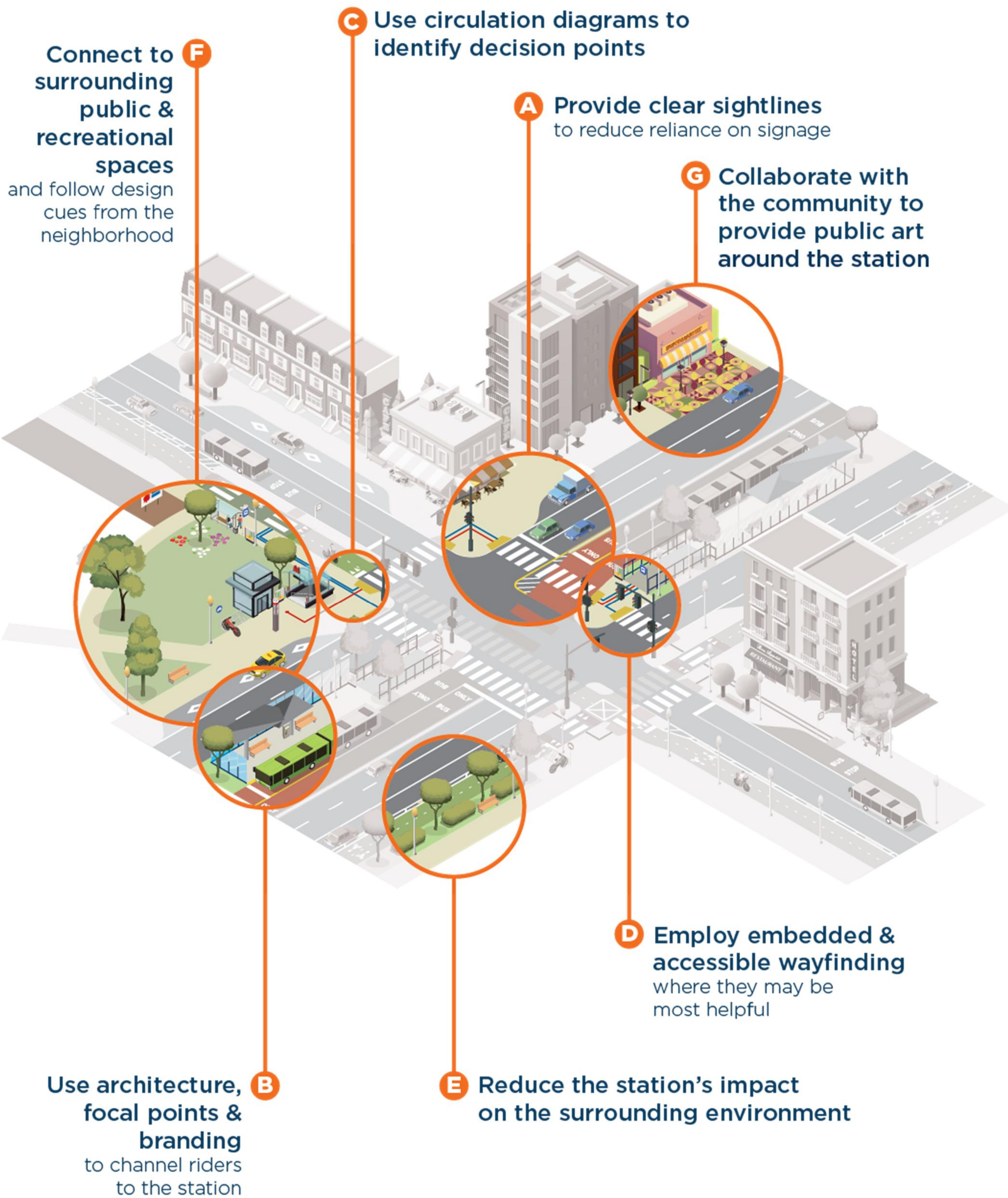


Figure 6.23: Station Access

8.3.1. When planning the circulation routes in the Pedestrians, Bikes and Micromobility, and Vehicles sections, provide clear sightlines to reduce reliance on signage.

While each station's context will present unique circulation challenges, lay out circulation routes to minimize reliance on signage. Short, direct, highly visible routes will require less signage than longer routes with turns, bends, and other visual obstructions. If the station is clearly visible from as many surrounding streets and sidewalks as possible, then less signage will be necessary to direct riders to it.

8.3.2. Use focal points, prominent architecture, and consistent branding to channel riders to the station.

Since the station is the desired destination, lay out circulation routes and spaces to naturally channel riders to it. For example, plazas and other public places should be placed along the circulation routes connecting to the station's platforms, rather than in perfunctory, out-of-the-way, leftover areas.

Additionally, the station's architecture (platform canopies and other structures) should be visible from as many circulation routes and spaces as possible. In this way, the station functions as a focal point—a landmark to which the eye is naturally drawn and to which people instinctively travel. Prominent pylons can supplement the station's architecture—especially if they are lighted at night—to reinforce its function as a focal point. Pylons also can serve as confirmation points—they communicate "yes, a station is in this direction" at points farther away from the station where it might not yet be visible. Ensure that station architecture and pylon design are both consistent with MCDOT and Flash BRT branding guidelines.

8.3.3. Using the circulation diagrams from the Pedestrians, Bikes and Micromobility, and Vehicles sections, determine the points at which each mode will seek clarification for circulation decisions.

Only after clear circulation routes, prominent focal points, and consistent branding have been established should signage be used to supplement the other wayfinding. Use signage at decision points where the various modes seek clarity on how to access the station. For example, a fork in a walking path is a decision point for pedestrians; a driveway entrance is a decision point for vehicles looking to drop off, pick up, or park at the station; and an intersection is a decision point for pedestrians, cyclists, and vehicles alike. In addition to complying with ADA requirements for text size, color contrast, reflectivity, and posting height, ensure all signs are consistent with MCDOT and Flash BRT branding guidelines. Per ADA requirements, some signage may also require Braille. Additionally, since most people with vision impairments cannot read Braille, raised text should accompany any Braille.

Tactile walking surface indicators should be considered as well; see MCDOT's Planning and Designing Streets to be Safer and More Accessible for People with Vision Disabilities for more information.

8.3.4. Employ embedded and accessible wayfinding where they may be most helpful.

As discussed in the Transfer Considerations section, explore embedding wayfinding directly into the pavement to clarify the circulation routes between transfer points. The aforementioned embedded tactile wayfinding also can direct riders with vision impairments from surrounding sidewalks to the station's platforms.

8.3.5. Reduce the station's impact on the surrounding environment.

While sustainable landscaping is covered in more detail in Chapter 2, localized stormwater management should still be integrated into the streets, sidewalks, and public spaces around the station—bioswales, rain gardens, and porous pavement can reduce runoff and beautify these spaces.

8.3.6. Connect to surrounding public and recreational spaces and follow the design and context cues in the surrounding neighborhood.

The station's circulation routes and public spaces should be seamlessly integrated into the surrounding neighborhood's public spaces so that the station functions as a cohesive, integral part of the neighborhood. The station and its public spaces should reinforce the surrounding neighborhood's sense of place by referencing the neighborhood's architecture, character, and culture.

8.3.7. Collaborate with the surrounding community to provide and maintain public art around the station.

Develop a public art and events plan for the station to solicit artwork from artists in the surrounding community, to determine maintenance needs for any artwork, and to program the station's public spaces for community events. Murals, sculptures, and interactive art can all reinforce the station's function as a community focal point.

Appendix: MCDOT BRT Glossary of Terms

MCDOT BRT Glossary of Terms

Intent:

This glossary is intended to unify language throughout the guidelines, so all sections are referring to the same elements of the corridor, in the same manner, to create clear and consistent guidelines.

Glossary

Item No.	Term	Definition
1.	Accessible boarding area	The place where passengers get on and off the bus at the front door, directly adjacent to the bus stop sign. This also is where the bus operators deploy the ramp for passengers using mobility devices. The area is a firm and stable surface and shall provide a clear length of 96 inches (8 feet), measured perpendicular to the curb or vehicle roadway edge, and a clear with of 60 inches (5 feet) minimum, measured parallel to the vehicle roadway, as stated in 810 Transportation Facilities chapter of the 2010 ADA Standards for Accessible Design.
2.	Across from	Bus stop at a T-intersection (3-leg). Can be near side or far side.
3.	Active TSP	Provides adjustments to the signal timing to provide preference to the BRT by detecting the presence of the BRT as it arrives at the signal.
4.	Americans with Disabilities Act (ADA)	Federal legislation that sets accessibility standards for many aspects of the built environment, including transportation facilities.
5.	Alight	To get off or out of a transportation vehicle.
6.	All-door boarding	A system by which riders can board transit vehicles at any available door instead of just at the front door. Typically requires fare card validators at each door.
7.	Advanced Traffic Management System (ATMS)	A category group encompassing sophisticated systems and technologies employed to improve traffic flow and safety via advanced traffic monitoring and control as well as communications methodologies.

8.	American Public Transportation Association (APTA)	APTA is a nonprofit organization that represents and advocates for public transit systems across the US. It sets industry standards, promotes research and information sharing, and supports the development of bus, rail, and other public transportation services.
9.	Articulated bus	A type of longer bus that is comprised of two or more rigid sections linked by a pivoting joint. Articulated buses allow for higher passenger capacity and are typically 60 feet long.
10.	Automated bus lane enforcement system (ABLE)	A technology solution leveraging detection mechanisms such as cameras, sensors, and license plate recognition to monitor and enforce bus lane usage, potentially issuing penalties for violations.
11.	Battery-electric bus (BEB)	A bus that uses battery electric technology for propulsion rather than an internal combustion engine.
12.	Board	To get on or into a transportation vehicle.
13.	Buffer	A designated space separating BRT traffic from other types of traffic. This can be raised of designated by pavement markings.
14.	Bump-out/curb extension	A curb bump-out is a strategy to improve safety for all road users by extending the curb at a corner and narrowing the roadway width at intersections.
15.	Bus bunching	An irregularity in public transit operation where buses (on the same route) intended to be spaced apart run close together or simultaneously, usually due to delays or scheduling issues.
16.	Business intelligence (BI)	A suite of strategies, techniques, and tools used to transform raw business data into meaningful insights, aiding decision-making processes.
17.	Bus pullouts	Bus pullouts are insets within the curb past the normal curb line that give the bus enough space to get out of the main guideway.
18.	Bus stop	A location marked with site-specific signs indicating where buses will stop.
19.	Bus stop bike lane mixing zone	A bike-bus stop zone is a design where the bike lane is at street level, the bike lane overlaps with the bus stop merging zone, and bikes do not interact with transit passengers.
20.	Bus yard	A designated area where buses are parked, maintained, and serviced when not in operation, ensuring their readiness for the next duty cycle.

21.	Computer-aided dispatch/automatic vehicle location (CAD/AVL)	A technology solution that automates vehicle dispatch and tracking procedures, usually leveraging GPS for precise location information.
22.	Canopy	A single component of a weather shelter. Depending on station design, multiple canopies can be combined to form a weather shelter.
23.	Center running	A runningway with the BRT lanes running both directions in the center of the roadway with median on either.
24.	Clear zone	The clear zone, behind the curb, is where transit riders wait, queue, board, and alight the bus. The clear zone is 6 feet, Dept. minimum, and includes the bus stop sign, accessible boarding area, space for a bus shelter, and other streetscape amenities.
25.	Connected and autonomous vehicle	A category of vehicles equipped with advanced technology for automated operation, reducing or eliminating the need for human intervention.
26.	Control center	The operational hub of a transit agency where real-time monitoring, dispatch, and management of transit services take place, ensuring seamless and efficient operations.
27.	Contra-flow	BRT vehicles operate in the opposite direction of mixed traffic in the adjoining lanes.
28.	Couplet operations	A two, one-way BRT pair runningway operation. One BRT lane is mixed traffic, and the other lane is a dedicated guideway depending on peak travel times. Can be reversible depending on configuration.
29.	Curbside running	A runningway type in which the BRT lanes run along the curb with a bike or parking lane on the other side separating it from the automobile traffic.
30.	Data Security Standard (PCI-DSS)	An industry-standard set of security measures aimed at ensuring the secure handling of credit card information across various stages including acceptance, processing, storage, and transmission.
31.	Degree of segregation	The level of protection of cyclists and pedestrians; the bike and pedestrian lanes can be along the corridor or separated by striping, a parking lane, or physical median.
32.	Dwell zone	The space in the street, needed for a transit vehicle to stop at the curb or edge of roadway, and perform dwell functions: rider boarding and alighting, fare collection, etc.

33.	Exclusive guideway	A guideway that is used only for BRT traffic to allow for uninterrupted trips.
34.	Exclusive lanes	Exclusive lanes provide BRT vehicles with a runningway generally clear of other vehicle types, particularly in a center- or median-running configuration. In side- or curb-running configurations, general traffic will be directed to stay out of the exclusive BRT lanes through guide signage, overhead signalization, and in some cases physical delineation such as bollards, raised button markers, or barrier.
35.	Exclusive roadways	Exclusive roadways can either be grade separated from general traffic and pedestrian crossings or be placed alongside parallel public roadway facilities at the same grade with physical separation. Exclusive roadways also can be on a unique alignment not adjacent to or parallel with public roadways.
36.	Far-side bus stops	Bus stops located immediately after an intersection, allowing the vehicle to pass through the intersection before stopping for passenger loading and unloading.
37.	Federal Transit Administration (FTA)	A U.S. federal agency tasked with providing financial aid, technical assistance, and policy oversight to local public transit systems, fostering their development and smooth operation.
38.	Floating bus stop	A floating bus stop is situated between the BRT lane and a protected cycle track to ensure BRT passengers are not deboarding the bus into a cycle track. This creates an island configuration for the bus stop.
39.	Fuel cell electric bus (FCEB)	A type of bus that uses a hydron-filled fuel cell for propulsion rather than an internal combustion engine.
40.	Green street	Green streets and landscaping elements are designed and implemented to help mitigate the pollutants and treat the runoff off roadways.
41.	Guidelines	Guidelines are different than standards; guidelines should be used as an outline while referencing any pertinent standards during design.
42.	GTFS/GTFS-RT	General Transit Feed Specification (and its real-time extension) are open data standards facilitating transit data exchange and real-time updates. Used widely by transit agencies and app developers for disseminating transit information.

43.	Internet of Things (IoT)	A network of interconnected physical devices, capable of exchanging data and interacting via the internet, supporting various applications across numerous fields, including transportation.
44.	In-lane stop	Bus stop located in a travel lane, allowing the bus to serve the stop and continue the route without having to merge out and then back into the travel lane.
45.	IP55/IP65 Standards	International standards denoting the levels of dust and water resistance offered by electronic devices; crucial for equipment operating in challenging outdoor conditions.
46.	Land Mobile Radio (LMR), Digital Mobile Radio (DMR), and Voice over Internet Protocol (VoIP) System	Diverse communication systems used in transportation and transit operations. LMR operates on dedicated radio frequencies and is known for its robustness, DMR is a digital upgrade of LMR that converts analog audio signals into digital data before sending it over the radio frequencies, while VoIP leverages internet connectivity for versatile and potentially cost-saving communication options.
47.	Median	Raised space located often in the center of a roadway dividing opposing traffic lanes. Medians can be landscaped and can include left-turn lanes.
48.	Median running	A runningway with the BRT lanes running opposite directions on either side of a center median.
49.	Merge zone	The merge zone is the space, in the street, needed to maneuver into and out of a curb lane at a pull-out stop, often denoted by the no parking sign.
50.	Mid-block bus stops	Bus stops located between intersections.
51.	Mixed flow	This is describing the type of traffic within the runningway—in this case, it would involve multiple modes including BRT, local bus, automobiles, cyclists, and pedestrians.
52.	Mixing zone	An area or lane in which general traffic vehicles turning left or right may cross through the BRT lane to access the appropriate turn lane.
53.	Mobile gateway router (MGR)	A device installed on buses to provide internet connectivity for on-board systems and passengers, enabling a range of connected services.

54.	National ITS Architecture	The National ITS Architecture is a joint project of the U.S. Department of Transportation's Federal Highway Administration (FHWA) and Federal Transit Administration (FTA). The architecture provides a framework for planning, defining, and integrating intelligent transportation systems to encourage interoperability and efficient resource utilization.
55.	Near-side bus stops	Bus stops located immediately before an intersection, allowing for passenger unloading and loading while the vehicle is stopped at a red light, preventing double-stopping.
56.	Offset stations	Stations located at opposite sides of the block so the stations for both directions are not directly across from each other.
57.	On-board equipment	Various devices and technologies installed on buses, serving operational, safety, and passenger convenience purposes.
58.	Passive TSP	Provides preference to BRT movements through the intersection by implementing signal timing in a corridor with high transit use with timing that favors average bus speeds/rhythms.
59.	Platform	Also known as station platform. The area immediately adjacent to where buses stop to pick up and drop off passengers. Generally, includes amenities like benches and weather shelters.
60.	Platform as a Service (PaaS)	A cloud computing model in which a service provider offers a platform including hardware and software tools over the internet, facilitating application development and deployment.
61.	Power over Ethernet (POE)	A technology that enables electrical power to be carried by network cables along with data, simplifying the powering of devices connected to the network.
62.	Public Right-of-Way Accessibility Guidelines (PROWAG)	Guidelines that expand upon ADA to provide additional and improved guidance for accessibility in the built environment, including at transportation facilities.
63.	Pull-out stop	A type of bus stop where buses exit the flow of traffic to serve a stop along the shoulder or curb of the road.
64.	P25 Radio	A standardized digital radio communication platform designed for use by public safety organizations, supporting clear and reliable communication during routine and emergency situations.

65.	Queue jump	Queue jump lanes combine short, dedicated transit facilities with either a leading bus interval or active signal priority to allow buses to easily enter traffic flow in a priority position.
66.	Ramp meter	A traffic control device that regulates the frequency of vehicles entering a freeway, improving the safety and efficiency of merging traffic and reducing congestion.
67.	Reversible runningway	Reversible lanes carry BRT vehicles in a single direction at any given time, often to accommodate peak direction travel only, reversed for AM and PM peak periods.
68.	Right-of-way	The legal right, established by usage or grant, to pass along a specific route through grounds or property belonging to another.
69.	Roadside ITS elements	Various devices and equipment installed along roadsides as part of Intelligent Transportation Systems.
70.	Runningway	The type of corridor in which the BRT system runs in with varying differences in the following characteristics including right-of-way, lane widths, striping, signage, curb, gutter, relation to median, intersection geometry, driveway access, bicycle/pedestrian facilities, degree of segregation, and other physical configurations.
71.	Securement area	An area onboard transit vehicles that is designated for individuals that use mobility devices (such as wheelchairs) that require additional equipment to secure inside the bus.
72.	Semi-exclusive lanes	A semi-exclusive BRT lane subjects the BRT to all intersection signal controls but allows the BRT to run on its own dedicated lane under certain circumstances or subject to an operating schedule.
73.	Shared guideway	A shared guideway is a corridor that is not exclusive to BRT traffic but shared with general traffic.
74.	Shared platform stop	A shared platform stop is a stop that houses passengers for both BRT and local bus services.
75.	Side running	A side-running bus way has an exclusive BRT lane located to the right or outside of general-purpose lanes and may have either a bike or parking lane between the BRT lane and the curb.
76.	Software as a Service (SaaS)	A cloud computing model where software applications are provided over the internet on a subscription basis, eliminating the need for local installation and maintenance.

77.	Staggered stations	Stations that are far and near off the intersection evaluated.
78.	Station	Includes the station platform as well as additional components adjacent to the platform such as pathways to/from the platform and amenities such as bicycle racks. The larger physical size and greater number of amenities typically distinguishes stations from standard bus stops.
79.	Station ITS elements	Intelligent transportation system (ITS) components installed within transit stations to facilitate passenger information dissemination, enhance safety, and improve overall passenger experience.
80.	Ticket vending machine (TVM)	A physical device that is used at stations to sell transit tickets and load transit fares on to fare cards.
81.	Transit signal priority (TSP)	Components that modify traffic signal timing or phasing when transit vehicles are present to improve service reliability and travel times.
82.	United States Access Board 2010 ADA Standards for Accessible Design	The US Access Board is a federal agency that promotes equality and inclusion of people with disabilities by creating accessibility guidelines and standards for the built environment, transit vehicles, telecommunications equipment, medical diagnostic equipment, and information technology. The most recent federal standard is the 2010 ADA Standards for Accessible Design, which sets the minimum requirements—both scoping and technical for newly designed and constructed or altered State and local government facilities, public accommodations, and commercial facilities to be readily accessible to and usable by individuals with disabilities.
83.	USDOT	The United States Department of Transportation, the federal agency responsible for implementing and managing the nation's transportation infrastructure and policies.
84.	V2V/V2I/V2X communication	Acronyms denoting Vehicle-to-Vehicle (V2V), Vehicle-to-Infrastructure (V2I), and Vehicle-to-Everything (V2X) communication, defining the exchange of information between connected vehicles and various elements of the transportation ecosystem.
85.	With-flow	BRT vehicles operate in the same direction of mixed traffic in the adjoining lanes.

Flash Bus Rapid Transit (BRT) Guidelines

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