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Bus Rapid Transit Working Group

Bus Rapid Transit Service Design and Operations

Abstract: This recommended practice provides guidance on service design and operations for bus rapid transit (BRT) services.

Keywords: bus rapid transit, BRT, Basic BRT, Corridor Based BRT, Premium BRT, Fixed Guideway BRT, Express service, limited-stop service, frequency, service capacity, span of service

Summary: Bus rapid transit (BRT) service creates a premium rapid transit experience using rubber-tired vehicles. Service design is the key element underpinning BRT service and leads to key decisions around operations of BRT. However, planning BRT service requires several layers of strategic decisions to develop a plan that will be appropriate for the community context of each unique BRT corridor. This recommended practice provides guidance on BRT service design and operations for planners, transit agencies, local governments, developers and others interested in developing new, or enhancing existing, BRT systems.

This document is part of a suite of recommended practices covering the key elements that comprise BRT service. Because BRT elements perform best when working together as a system, this document may reference others in this series of recommended practices. Users of this document are advised to review all guidance documents to better understand how different BRT elements are interrelated in delivering a high impact transit project.

Scope and purpose: The recommended practice provides guidance on the design of BRT service and operations including such elements as defining the BRT corridor, relationship of the BRT to the agency's other services, service standards and service levels, frequency, capacity, station spacing, interaction with traffic and other transit services in the corridor, fleet requirements, and operations and training requirements.

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Introduction

This introduction is not part of APTA RP-004-10, Rev 1, "Bus Rapid Transit Service Design and Operations."

Bus rapid transit (BRT) consists of a suite of elements that create a high-quality rapid transit experience using rubber-tired vehicles. This experience often includes a high degree of performance (especially speed and reliability), ease of use, careful attention to aesthetics, and comprehensive planning that includes associated land uses. BRT seeks to meet or exceed these characteristics through the careful application of selected elements.

This recommended practice, *Bus Rapid Transit Service Design and Operations*, is intended to provide guidance for the design of a BRT service including such elements such as defining the BRT corridor, relationship of the BRT to the agency's other services, service standards and service levels, frequency, capacity, station spacing, interaction with traffic and other transit services in the corridor, fleet requirements, and operations and training requirements.

The recommended practice defines two broad categories of BRT service: Basic BRT and Premium BRT. These are the two "levels" of BRT systems that are discussed throughout this document. Users of this document should note that the U.S. Federal Transit Administration (FTA) has its own definitions of BRT service that establish whether the BRT is eligible for New Starts or Small Starts funding under the Capital Investment Grants (CIG) Program: Corridor-Based BRT and Fixed Guideway BRT. Users of this document are advised to be aware of the elements of BRT that are required to qualify for these two funding sources if they plan to apply for CIG funding.

APTA recommends the use of this document by:

- individuals or organizations that plan, design, build and/or operate bus rapid transit systems and those that are considering doing so;
- individuals or organizations that contract with others to plan, design, build and/or operate bus rapid transit systems; and
- individuals or organizations that influence how bus rapid transit systems are planned, designed, built and/or operated.

This recommended practice is one in a suite of BRT recommended practices published by APTA; the full list can be found under "Related APTA Standards".

Bus Rapid Transit Service Design and Operations

1. Goals for Bus Rapid Transit service

1.1 Project definition

When considering Bus Rapid Transit (BRT) during a transportation master planning or transit system development process, communities typically consider all their major travel demand generators and decide how best to connect them. Typical travel demand generators that can be effectively connected by rapid transit services include the following:

- central business district (downtown)
- colleges and universities
- regional shopping centers
- hospitals and other major medical facilities
- entertainment and sports complexes
- intercity transportation facilities (airports, rail stations, bus terminals)
- concentrations of high-density residential or commercial development

In some cases, the designation of a BRT service will arise from ongoing route planning and service management work and will not have been defined in a master planning process. The identification of a service as BRT can be a way to draw attention to the importance of a route in the transit network, either for customers as they navigate their way on the network or for decision-makers as they allocate capital and operating resources. A transit agency may decide to elevate a high-performing bus route to BRT by investing in new vehicles, transit priority measures, improved customer amenities at stops and increased service levels. Elevating a high-performing local route to BRT service can serve as an opportunity to optimize stop spacing, and an evaluation of current stop utilization should be included in this effort.

If the location of a BRT corridor has been selected in a master planning process, then it remains for the transit agency to decide the details of the way that transit service will be provided on the corridor. These considerations are outlined in the following sections.

1.2 Key BRT planning decisions

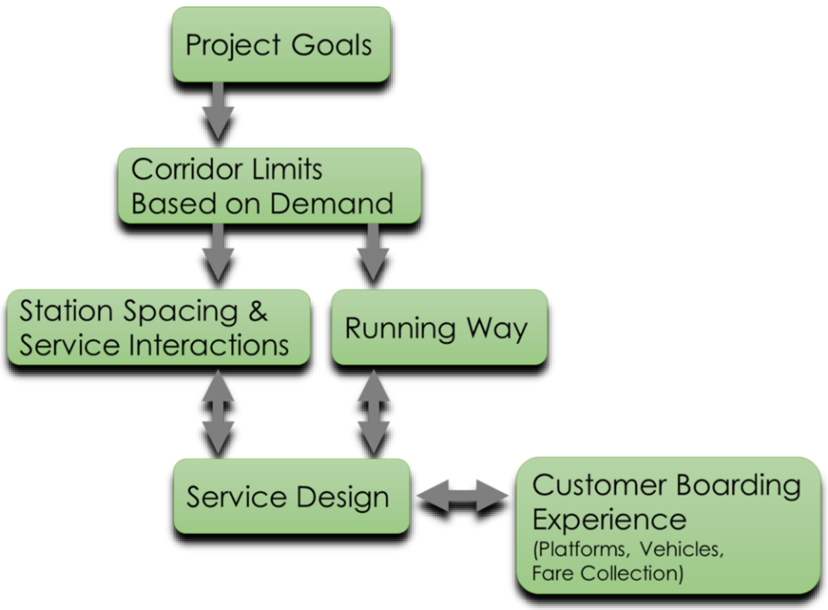
1.2.1 Project goals

Planning a BRT service requires several layers of strategic decisions to develop a plan that will be appropriate for the community context of each unique BRT corridor. Before pursuing BRT, a transit agency should have a clear understanding of the goals for the investment being made. For example, key goals could include:

- attracting new riders
- enhancing the experience for current riders
- supporting or advancing economic development
- providing more capacity to meet an increasing demand for service
- a combination of the goals above

These priorities will influence decisions throughout a BRT planning process. **Figure 1** shows the general flow of decisions that need to be made during a BRT project development process in order to develop a service plan and begin operations.

FIGURE 1
BRT Key Decisions



1.2.2 Corridor limits

After the goals have been established, the geographic extent of the BRT corridor must be defined. In some cases, an existing bus corridor will have exceptionally strong ridership and performance that serve as the basis for upgrading to BRT. In other cases, a network planning process may prioritize BRT corridors to play a role as a trunk line in the system or identify an opportunity to drive or leverage economic development. In either case, the limits of the corridor, including whether the corridor will operate as an open or closed system (see Section 4), should be established early on.

One of the key considerations for determining corridor limits is determining where the BRT terminal points will be. Oftentimes it is decided that an existing transit center will serve as a BRT terminal. If this is the case, then capital improvements may be necessary at the existing transit center to support the frequent BRT service. If there are not existing transit centers to serve terminals, then a new end-of-line facility should be included in the planning for the BRT corridor. Passenger transfers and vehicle layover space are important considerations when designing terminal locations.

A determination of whether routes will continue service beyond the BRT capital improvement corridor should also be made. While this is a common practice, it is important to note that extending routes beyond the BRT capital improvement corridor can result in reliability challenges for maintaining consistent BRT headways along the corridor.

These corridor limit decisions should be based on analysis of ridership demand patterns, major travel demand generators and key transit connections.

1.2.3 Station spacing, service interactions and running way

Having identified the corridor, issues related to its design and land use can be explored. Station spacing will depend on the density of existing and planned transit-supportive land uses. Station spacing will also depend on how the stations are meant to be served—for example, BRT may use longer station spacing if a local service is planned to serve the areas between stations (see Section 5). Similarly, the transit running way that is feasible will depend on the corridor's existing right-of-way, the nature of the corridor's frontage, current usage or existing infrastructure available, desired traffic operation, and project budget.

1.2.4 Service design

Next, the BRT service design can be developed, adhering to the corridor limits, running way and stopping pattern identified. The service plan will address bus frequency and span, as well as any interacting services. This will also determine the peak vehicle requirement that should be considered with vehicle selection.

Key Principles of BRT Service Design

There is no one "right" way to design and serve a BRT corridor. Service design decisions should guide the capital requirements. Define service plan early in the process. Embrace the flexibility, but don't sacrifice the priority!

1.2.5 Customer boarding experience

Finally, a package of decisions that establish the customer boarding experience will play a crucial role. This encompasses fare collection methods, boarding platforms and the vehicles themselves. The desired fare collection method will need to be accommodated on platforms or on buses. It is also important for bus floor height to be aligned with the height of the platform served for optimal boarding. These choices affect customer capacity and dwell times, which should be closely coordinated with service design.

1.2.6 Iterative planning process

Station spacing, service interactions, running way and the customer boarding experience are all intertwined. This section provides an overview of the general steps needed to define a BRT service plan, but it is important to understand that as the planning process progresses there may be decisions made about one of these characteristics that lead the transit agency to reevaluate and possibly modify the decisions about the other characteristics. For example, decisions could be made about fare collection that lead to a desire to only operate BRT service and no underlying local service, which could result in changes to the station spacing and vehicle requirements.

1.3 BRT service features

BRT should be viewed as a premium investment designed to maximize transit use in high-travel-demand corridors. As such, the implementation of the BRT service features (see sidebar) will help achieve these operational goals, ensuring that BRT operates as high-capacity transit service:

- consistent and reliable travel times
- faster travel times than typical bus service
- increased service frequencies
- reduced dwell times

These attributes, along with a high degree of connectivity with other transit modes, will enhance

Service Options That Differentiate BRT From Standard Bus Service

- Defined Stations with Amenities
- Station Signage
- Frequent Service
- Bidirectional Service
- Transit Signal Priority
- Increased Station Spacing
- Separate Branding
- Raised Platform Boarding
- Off-Board Fare Collection
- All-Door Boarding
- Dedicated/Managed Running Ways
- Unique Vehicles

the overall efficiency of all transit services by providing the end user with an elevated degree of flexibility in making a trip. Enhancing connectivity between BRT and fixed-route bus can improve the travel experience by reducing travel times and increasing overall accessibility to travel destinations.

1.4 Service level comparisons

Transit agencies offer a range of services, from local bus to commuter rail. Within bus service there are a variety of amenities and service levels that can be offered. BRT must offer features beyond that of typical bus service, but a BRT project can be a collection of services and elements that are determined to meet the needs of the BRT corridor and fulfill the overall project goals. No matter the level of BRT investment, the most important thing is to let riders know what to expect and how to ride the service.

Table 1 provides a summary of the typical features that are provided by BRT as compared with other transit modes. The Basic BRT features align with the U.S. Federal Transit Administration (FTA) definition for corridor-based BRT, and the Premium BRT features would qualify as an FTA fixed-guideway BRT project (see Section 1.4.1). This table provides a menu of options that an agency can select from but not every single feature is required in each BRT project for both basic and premium. The priority of a BRT project should be to push for as many of these features as possible to differentiate over local bus service.

TABLE 1
Summary of Potential BRT Features Compared with Other Transit Modes

	Local Bus Service	Commuter Express Bus Service	Basic BRT (FTA Definition: Corridor Based BRT)	Premium BRT (FTA Definition: Fixed Guideway BRT)	Light Rail Transit Service	Heavy Rail Transit Service
Defined Stations with Amenities	No	No	Yes	Yes	Yes	Yes
Station Signage	Limited	Limited	Yes	Yes	Yes	Yes
Bidirectional Service	Yes	Not typical	Yes	Yes	Yes	Yes
Frequent Service	Sometimes	Peak-only	Yes	Yes	Yes	Yes
Transit Signal Priority	Sometimes	Sometimes	Yes (as frequently as possible & alternative is	Yes, may include full preemption	Yes, may include full preemption	N/A, fully separate from traffic
Increased Station Spacing	No	Yes	Yes	Yes	Yes	Yes
Separate Branding	No	No	Yes	Yes	Yes	Yes
Raised Platform Boarding	No	No	Sometimes	Yes	Usually	Yes
Off-Board Fare Collection	Rarely	Rarely	Sometimes	Yes	Yes	Yes
All-Door Boarding	Rarely	Rarely	Sometimes	Yes	Yes	Yes
Dedicated/Managed Running Ways	No	Sometimes	Sometimes*	Yes*	Yes	Yes
Unique Vehicles	No	Sometimes	Yes (unique branding separate from local buses)	Yes (unique branding separate from local buses)	Yes	Yes

** A running way may be a combination of dedicated and mixed traffic running ways*

The U.S. Federal Transit Administration (FTA) has its own definitions of BRT service that establish whether the BRT is eligible for New Starts or Small Starts funding under the Capital Investment Grants Program: Corridor-Based BRT and Fixed Guideway BRT. Below is a brief overview of the FTA's definitions of BRT:

TABLE 2
U.S. Federal Transit Administration BRT Definition

FTA BRT Definition
Fixed Guideway BRT operates in majority separate right-of-way (ROW) during peak periods
Corridor based BRT operates in mixed traffic
Defined stations that are accessible, offer shelter, real-time information
Traffic signal priority for public transportation vehicles
Short bi-directional headways
Weekday for Corridor based BRT; Weekdays and weekends for Fixed Guideway BRT
Any other feature as the Secretary may determine are necessary to produce high quality public transit services.

Users of this document are advised to be aware of the elements of BRT that are required to qualify for these two funding sources if they plan to apply for Capital Investment Grants Program funding. For more information, review the FTA's Capital Investment Grants Program website: https://www.transit.dot.gov/funding/grant-programs/capital-investments/about-program.

2. Overall position of BRT within the transit system

2.1 The role of BRT within the family or suite of rapid transit services

The role BRT plays in a transit system may vary widely between agencies:

- BRT might be planned as the most premium service offering in a transit network where no rapid alternative exists; section 2.1.2 describes this example found in Kansas City, Missouri.
- BRT may be an application of a new type of rapid transit in a region where there is already a well-established rail rapid transit system, such as in Minneapolis, as described in Section 2.1.1.
- In some regions with multiple agencies, particularly those outside a metropolitan core, BRT service may be the primary transit service of an agency and serve as a feeder to an existing rapid transit system in the central municipality as is the case for Community Transit in Everett, Washington, as described in Section 2.1.3.

In each case, the transit agency should establish the role that BRT will play within its family of transit services and, if applicable, within the family of transit services in the metropolitan area. Defining this vision for the BRT service will help to guide strategic decisions about the appropriate levels of capital investment, service design principles and branding.

2.1.1 Kansas City Regional Transit (Kansas City, Missouri)

Kansas City Regional Transit is branded as RideKC and is the regional transit authority for the Kansas City area. BRT is the premium service offered by RideKC, and as such the agency has made a point to brand MAX service as a different mode than standard bus, as shown in **Figure 2**.

FIGURE 2
RideKC Suite of Services and Troost MAX BRT

2.1.2 Metro Transit (Minneapolis)

Metro Transit provides both light rail transit (LRT) and BRT rapid transit services in the Minneapolis–St. Paul region. The Metro Transit local bus network provides connections to the rapid lines. Metro Transit also has the Northstar Commuter Rail Line that provides peak period connections to the rapid transit network.

Metro Transit has been intentional in designating both BRT and LRT service offerings as the more rapid and premium modes of transit within the overall transit system. As shown in **Figure 3** both the BRT and LRT lines are called out with line designations and included together in maps with the tagline "Fast. Frequent. All day. All yours."

2.1.3 Community Transit (Everett, Washington)

Community Transit is the county-wide provider of transit service in Snohomish County, Washington, and connects to the regional network in the metropolitan area of Seattle. Swift Bus Rapid Transit is Community Transit's highest capacity transit service. Swift incorporates key elements of BRT design, such as landmark stations; uniquely branded vehicles; off-board fare collection; real-time passenger signage; priority bus lanes; and fast, frequent and reliable service. **Figure 4** shows the future BRT network planned for Community Transit highlighting the integration with the larger regional light rail system.

FIGURE 3
Metro Transit Map Showing LRT and BRT

FIGURE 4
Community Transit Future BRT Network

3. BRT service standards

The operational attributes of BRT should define the service as distinct from conventional bus services. Service standards for BRT should align with standards for other rapid transit services. By having similar service frequencies, fare structures and hours of service, riders across the various premium services will have a more seamless travel experience.

In general, high standards of BRT will:

- establish BRT as a rapid transit service;
- allow for the implementation of BRT in a standardized manner across a system—benefitting planners, designers and public expectations for service; and
- reduce compromises made to dilute the efficiency, effectiveness and premium offerings of BRT.

This section provides a general overview and some guidance on considerations for developing BRT service standards. However, service standards are unique to each agency, as they are intended to ensure that the services provided operate in a manner that achieves the goals of each type of service. It is important that BRT standards be incorporated into the larger agency service standards to ensure that they are in alignment with overall agency policies and goals.

Key Principles of BRT Service Design

The operational attributes of BRT should define the service as distinct from conventional bus services. Service standards for BRT should align with standards for other rapid transit services.

3.1 BRT service design principles and standards

Agencies implementing a BRT system should focus the service design around the concepts of premium rapid transit service while adjusting to the unique needs of the corridor. Policies that affect service design may include the following:

- span of service
- frequency
- capacity and corresponding ridership demands
- degree of reliability (on-time performance and travel time)
- connections to other transit services
- community and economic development goals
- vehicle type and design
- station spacing (Section 5)
- station location (Section 5)
- open vs. closed system (Section 5)
- percent dedicated running way (Section 4)
- fare collection method (APTA BRT ITS-RP-005-10, *Implementing BRT Intelligent Transportation Systems*)
- system branding (APTA RP-BUS-BRT-001-10, *BRT Branding, Imaging and Marketing*)
- platform design/curb height (APTA RP-BTS-002-10, *Bus Rapid Transit Stations*)

Operational similarities to other modes of rapid transit, such as light or heavy rail, should also be emphasized to further distinguish BRT as a premium transit service as compared with existing fixed-route bus service. Utilizing similar service frequencies, all-door boarding and stations that borrow visual cues from rail stations can reinforce BRT as a premium service on the same level as rail transit service. This can be especially useful where LRT and BRT lines intersect, providing a more seamless transfer experience for riders and deemphasizing the differences between the modes. Wherever possible, BRT should be viewed by passengers and within the agency as part of the rapid transit system. Similar to Metro Transit in Minneapolis, both LA Metro and MBTA in Boston have also reinforced that BRT is part of the rapid transit network by including BRT lines on the same system map as the rail lines, as shown in **Figure 5** and **Figure 6**.

In instances when BRT is being added to an agency with existing rapid transit services, service standards for BRT should fit within the transit agency's existing standards in a way that makes the service expectations clear compared with existing modes. This will ensure that the new service complements rather than duplicates existing service. It will also ensure that the service is tailored to existing local conditions and needs. Performance targets should relate to the transit agency's existing performance measures and targets while reflecting the unique characteristics of BRT.

If BRT service is being added as the most premium level of transit service that an agency provides, new service standards should be developed to align with the goals for BRT service. These new standards may include longer spans of service and higher frequencies and could also include guidelines for performance such as headway adherence in addition to typical on-time performance criteria that are likely already established for other bus service.

FIGURE 5
LA Metro Rail and BRT Map

FIGURE 6
MBTA Rapid Transit Map Including the BRT Silver Line

3.2 Span of service

3.2.1 Principles

Span of service defines the extent of time over which service is provided. This includes both hours of service during the day and days of service in the week. The following principles of span of service are larger policy discussions that should occur to determine span of service for a new BRT service.

3.2.1.1 Replicate existing rapid transit

As with other aspects of service design (such as service frequency), the span of service offered should ideally replicate, as much as possible, any existing rapid transit in a system, such as subway, light rail and other higher-order transit modes. The objective for doing so is to instill in the mind of the rider or potential rider that BRT is within the family of premium services. Care should also be taken to consider the span of service for the rest of the transit system, especially feeder service, which could also benefit from increased span of service that results from a BRT investment. Here are two approaches:

- **Beginning service offering:** The most common approach has been to offer full service from the first day the BRT service is introduced (again, replicating rapid transit). A good ridership response has typically tended to support that approach.
- **Prioritized investments:** If all premium BRT amenities and infrastructure are not feasible in the beginning, an agency can still implement interim operational benefits to make up for a lack of infrastructure with the eventual goal of full, premium BRT service in mind. This will be a larger policy decision where the agency works with local governments and stakeholders to determine prioritized investments in the rapid transit service.

3.2.1.2 FTA guidance on span of service

FTA guidelines for a BRT project to qualify for New Starts funding state that the project "must provide short headway, bidirectional service for at least a *fourteen-hour span of service on weekdays and a ten-hour span of service on weekends*." FTA will consider projects that provide weekday-only service for Small Starts, including the same requirement for a minimum span of service of 14 hours for the weekdays.

3.2.2 Days of the week

In keeping with the above service design principles for BRT, the most common and preferred approach is to offer BRT service all seven days of the week, including holidays. Offering service only on weekdays, for example, might arguably create the impression that the service is more of a commuter-oriented service than true rapid transit.

The FTA requires service all seven days of the week for a project to qualify as fixed-guideway BRT. Corridor-based BRT projects should also operate seven days per week whenever possible, but the FTA will consider projects that provide weekday-only service for Small Starts.

3.2.3 Hours of the day

To meet the service design principles for BRT and to establish the impression that the service is true rapid transit, the most common and preferred approach for the span of service during the day is to offer BRT service approximately 18 to 21 hours per day. This helps to ensure that the span of service covers all or most times of potential service demand, including the following:

- start and finish times for shift workers (e.g., medical institutions, retail), especially those outside of traditional peak hours
- opening and closing times for retail
- classes at colleges and universities
- opening and closing times for institutions and community facilities (museums, libraries, etc.)
- times for the more popular entertainment or leisure activities (sporting events, theaters, etc.)
- intercity transportation services (airport, rail, bus)
- connections from other rapid transit corridors that operate with similar service hours.

In addition, there are a few rules of thumb that can be considered when determining the span of service for a new BRT system that will ensure that it operates as rapid transit:

- Span of service is usually consistent, or close to consistent, for all days of the week to provide a service that customers can rely on even if they are traveling at a different time than their typical commute.
- A slightly later start is common for Sunday service, and, in a few cases, on Saturdays.
- Evening finish times tend to be the same for all days, due to the desire for consistency and factors such as shift times, although a few systems end service earlier on Sundays or extend service later on Friday and Saturday nights particularly if serving a downtown entertainment district or University campus.
- Holiday service hours are usually the same as those for Sundays. To create a truly reliable system that passengers can count on, it is recommended that Sunday/holiday service be as comparable to Saturday service levels as possible to support the cultural shift away from significantly different work hours on Sundays.

Most U.S. BRT systems offer substantially more service than the minimum FTA span of service requirements for the reasons noted above. **Table 3** summarizes the hours of the day by day of the week that BRT service is provided on many of the more established and well-known BRT systems in North America as of 2019.

TABLE 3
Service Hours for Existing BRT Operations in the U.S. (2019)

BRT System	Weekdays	Saturday	Sunday
Metro Transit A-Line (Minneapolis)	4 a.m.–1:30 a.m.	4 a.m.–1 a.m.	4 a.m.–1 a.m.
MAX Troost (Kansas City, Missouri)	4 a.m.–1 a.m.	6 a.m.–12:30 a.m.	6 a.m.–12:30 a.m.
LA Metro Orange Line	24 hours	24 hours	24 hours
Cleveland HealthLine (Ohio)	24 hours	24 hours	24 hours
Community Transit Swift Blue Line (Everett, Washington)	4:15 a.m.–11 p.m.	6 a.m.–10 p.m.	7 a.m.–9 p.m.
Richmond Pulse (Richmond, Virginia)	5 a.m.–1 a.m.	6 a.m.–1 a.m.	6 a.m.–1 a.m.
Pace Suburban Bus Pulse Milwaukee Line	5 a.m.–12:21 a.m.	5:30 a.m.–12:23 a.m.	6 a.m.–12:21 a.m.
IndyGo Red Line (Indianapolis)	5 a.m.–1 a.m.	6 a.m.–1 a.m.	7 a.m.–10 p.m.
Lane Transit District EmX (Eugene, Oregon)	5:30 a.m.–midnight	7 a.m.–11 p.m.	8 a.m.–8:30 p.m.
MBTA Silver Line (Boston)	5:30 a.m.–1 a.m.	5:30 a.m.–1 a.m.	6 a.m.–1 a.m.
CTfastrak (Hartford, Connecticut)	4 a.m.–12:30 a.m.	5 a.m.–1 a.m.	6:30 a.m.–9 p.m.
RTD Flatiron Flyer (Denver to Boulder)	4 a.m.–1:30 a.m.	4 a.m.–2 a.m.	4 a.m.–1 a.m.
LA Metro Silver Line	4:30 a.m.–1 a.m.	5 a.m.–1 a.m.	5 a.m.–1 a.m.

3.3 Frequency

3.3.1 Policies to set service frequencies

Policies for BRT frequencies should be coordinated with the standards that are already in place for other rapid transit lines and for conventional transit services. The most common approach is to have one set of rules to fix a minimum frequency of service (which can vary, for instance by time of day or by direction) and a second set of rules to establish when and by how much the service should operate more frequently than the minimum (for instance, when ridership reaches a certain level). Typically, the frequencies for off-peak times are based on the minimum standards (although some midday frequencies are higher), while those during peak times most often exceed the minimum standards and are determined by ridership demand.

3.3.1.1 FTA guidance on service frequencies

FTA guidelines set the following minimum service parameters for a BRT project to qualify for New Starts or Small Starts funding:

- **Weekdays:** 15-minute or better headways through the day or 10-minute or better headways during the peak periods and 20-minute or better headways the rest of the day
- **Weekends:** 30-minute or better headways

3.3.2 Minimum service levels (policy frequencies)

Minimum service levels are intended to give a guaranteed level of convenience for customers, even at times when ridership is low. Because the BRT system is intended to be a higher-order service than local routes, it would normally have a minimum service level that is more frequent than the minimum for local routes.

The minimum service level can vary by time of day and by day of the week, if desired. It is typical for BRT systems to offer more frequent service during the weekday peak periods as warranted by higher ridership. A further consideration should be how the minimum service levels for the BRT service coordinate with parallel local routes, intersecting main routes and timed transfers. Also, if off-peak demands can justify significantly higher frequencies, there may be a good case for using higher-capacity vehicles, such as articulated buses.

Saturday frequencies are usually similar to those of weekday off-peak times, while Sunday frequencies typically range between Saturday and evening frequencies. Bringing Sunday frequencies closer to Saturdays is becoming more prevalent due to a greater tendency of retail and other activities to be open on Sundays.

Table 4 shows samples of minimum service levels for BRT service by different time periods. Note that the service levels are often more frequent than these minimum levels based on ridership demand, and it is common to have BRT systems operate with 5-minute or better headways during peak periods based on ridership, as described in the next section.

TABLE 4
Example Minimum Service Levels for BRT Systems (2019)

Minimum Service Levels	Cleveland HealthLine	Richmond Pulse	IndyGo Red Line	Seattle RapidRide
Early morning (before 6 a.m.)	15 minutes	15 minutes		
Weekdays (18 hours)	10 minutes	10–15 minutes	10 minutes	10 minutes
Saturdays (15 to 18 hours)	15 minutes	15 minutes	15 minutes	10–15 minutes
Sundays (15 to 18 hours)	15 minutes	30 minutes	20 minutes	10–15 minutes
Late night (after midnight)	30 minutes	30 minutes	15 minutes	

3.4 Service capacity standards

During peak periods in particular, service frequencies are usually better than the minimum standards and are driven by ridership demand. Service capacity standards can be developed to guide the frequency of service based on expected or observed ridership levels, usually at the peak load point on a route.

These standards can also be used to establish the starting frequency of service, and thus to help determine the initial fleet size when planning a new line. They can be used to predict and determine when ridership is increasing enough that service should be made more frequent and when service could be reduced, in times of ridership decline or budget reductions.

Some considerations when setting service capacity standards include the following:

- vehicle type
- vehicle configuration (number of seats, amount of standing space, number of wheelchair spaces)
- whether some customers will be required to stand
- anticipated length of time a passenger would be standing
- route length and speed (whether standees would be desired on long routes and/or operating at highway speeds)
- whether room should be allowed for ridership growth before the next scheduled or budgeted service increase and before the next acquisition of vehicles
- how wheelchairs and other mobility devices are handled onboard
- whether bicycles are carried inside buses
- whether standards should vary by time of day, day of the week and frequency offered

For more detailed information on setting load standards and service levels based on ridership, reference Transit Cooperative Research Program (TCRP) Report 165, “Transit Capacity and Quality of Service Manual”.

A decision could be taken to have service capacity standards lower on BRT than on conventional service, either to increase comfort or to ease the justification for service improvements. Or a decision could be taken to have service capacity standards higher on BRT than on conventional service, to account for a different vehicle type, higher ride quality or more frequency. Where service capacity standards are used to make decisions on service increases, lower standards for BRT may result in the need to add service more frequently and should be considered when developing anticipated BRT operating costs.

TABLE 5
Frequencies for Existing BRT Operations (data as of 2019)

BRT System	Weekday Peak	Weekday Midday	Weekend
Metro Transit A Line (Minneapolis)	10 minutes	10 minutes	10 minutes
MAX Troost (Kansas City, Missouri)	10 minutes	30 minutes	
LA Metro Orange Line	10-15 minutes	10-15 minutes	10-20 minutes
Cleveland HealthLine	10 minutes	10 minutes	15 minutes
Community Transit Swift Blue Line (Everett, Washington)	10 minutes	10 minutes	15-20 minutes
Richmond Pulse (Richmond, Virginia)	10 minutes	10 minutes	15 minutes
Pace Suburban Bus Pulse Milwaukee Line	10 minutes	15 minutes	15 minutes
IndyGo Red Line (Indianapolis)	10 minutes	10 minutes	15-20 minutes
Lane Transit District EmX (Eugene, Oregon)	10 minutes	10-15 minutes	15 minutes
MBTA Silver Line (Boston)	5-13 minutes	10-15 minute	8-15 minutes
CTfastrak (Hartford, Connecticut)	7-10 minutes	12-20 minutes	20 minutes
LA Metro Silver Line	10 minutes		20 minutes

3.5 Service standards productivity

Productivity standards are a typical part of service standards for all transit modes, BRT included. More information on performance measures for BRT service can be found in Section 8.1.

4. Policies affecting service quality

4.1 Percent dedicated running way

The factor with the single greatest influence on reduced travel times and increased reliability is dedicated running ways. A dedicated running way is what truly separates BRT from typical buses and most closely resembles rail services, which operate in their own running way. Selection of running way type should be in alignment with BRT service goals, financial budgets, anticipated ridership and infrastructure. Running way types may be used in any combination to provide maximum travel time savings within the limitations of the BRT project.

A dedicated running way allows BRT service to operate with minimal impacts from traffic and congestion. While it is understandable that dedicated running way may not be feasible throughout the entirety of a BRT corridor, there are a few principles to consider when planning the amount and portions of the alignment that will be in a dedicated running way.

Key Principles of BRT Service Design

The most congested section of an alignment should be prioritized for dedicated running way to maximize the travel time savings and reliability of the BRT service.

Per FTA definitions and requirements for New Starts funding, over 50 percent of a fixed-guideway BRT route must operate in a separated right-of-way dedicated for transit use during the peak periods. This provides flexibility in designing the alignment and allows for exceptions where there is no available right-of-way or where it is cost-prohibitive or physically infeasible. However, when planning which portions of the running way should be dedicated or mixed with local traffic, impact to the overall alignment travel time should be considered. The most congested section of an alignment should be prioritized for dedicated running way to maximize the travel time savings and reliability of the BRT service. Portions of an alignment that are not congested may not even require a dedicated lane for competitive travel times. Note that projects with less than 50 percent dedicated running way are eligible for Small Starts as a corridor-based BRT project.

Congested portions of alignments may also be where the most issues and constraints arise regarding potential availability of a dedicated running way. This is where collaboration with local communities and roadway owners is critical to successful delivery of a project that can truly provide reliable BRT service. One of the key decisions that needs to be made early is if the dedicated running way is physically separated from other traffic lanes with barriers and dedicated entry points or if the running way is achieved through striping. A physically separated right of way provides the most benefit in terms of providing reliable travel times. Striped running ways require more active enforcement to ensure that they are free of other vehicles to avoid delays to BRT. Frequently, striped lanes permit vehicular travel to access business driveways and intersections. This is known as a Business Access Transit (BAT) Lane. FTA regulations permit BAT lanes to be considered toward the 50% dedicated running way requirement for New Starts funding. **Figure 7** shows a BAT lane utilizing striping to differentiate the lane from other traffic.

FIGURE 7
BAT Lane with Striping

For more in-depth discussion of considerations around running way design, see APTA BTS-BRT-RP-003-10, *Designing Bus Rapid Transit Running Ways*.

4.2 Routing implications on service reliability

As a rapid transit service, it is especially important that BRT service be reliable and that the system meet its schedule as often as possible. The service standard for schedule adherence is often higher for BRT than for conventional bus service. There are several routing factors to consider that can affect the reliability of the service:

- proportion of the route that is in mixed traffic, especially congested streets in the central business district and other high-activity centers
- effectiveness of transit priority measures, including transit signal priority
- route length
- number and spacing of stations
- travel speeds within a corridor
- number and types of routes within the fixed guideway
- headway-based schedule and management

The proportion of a route that operates in mixed traffic has the largest single impact on route reliability. The impacts of traffic congestion can be mitigated substantially with transit priority measures, such as signal priority and exclusive intersection "queue jump" lanes at major intersections and congestion points.

It is important that transit priority measures be considered early in the planning process, as some require substantial infrastructure changes and considerable time to design and implement. BRT planners should also coordinate with local public works departments, local traffic engineers, and state departments of transportation.

A case that requires special attention is the service through the downtown core, where there is usually significant traffic congestion and fewer opportunities for dedicated BRT facilities. Aggressive implementation of transit priority measures may be needed in such cases. The National Association of City Transportation Officials (NACTO) has worked with many cities to implement transit priority measures that help facilitate transit operations in congested downtown areas. The NACTO "Transit Street Design Guide" provides guidance on the design and engineering of options to prioritize transit on city streets and can be consulted for additional detail on incorporating transit facilities into street design.

Key Principles of BRT Service Design

A key goal of any BRT project should be to incorporate as many measures as possible that reduce dwell time variability and facilitate faster boarding.

If it is not feasible to include transit priority measures that meet the goals for BRT service in a downtown area, another option to consider is terminating the BRT service near major trip generators or local connecting service in downtown rather than running all the way through downtown, if this reduces the amount of time BRT vehicles spend navigating congested streets.

The number of stations along a route can also affect the reliability of service. Dwell time at stations is one of the most significant variables in creating reliable service, especially in a limited-stop service such as BRT. While fairly regular ridership patterns can emerge at stops along a route, it is still hard to predict how many people will get on or off a bus at any given stop on any given run. On a route with a high number of stops, such variations can add up quickly and result in vehicles struggling to stay on schedule. As such, a key goal of any BRT project should be to incorporate as many measures as possible that reduce dwell time variability and facilitate faster boarding (e.g., off-board fare payment, level boarding and inside bicycle racks).

4.2.1 Route length

Route length is a service characteristic that can contribute to challenges with maintaining a reliable schedule and travel time, especially for corridor-based BRT projects that do not operate with the majority of the route in a dedicated running way. Service delays can be compounded on long routes, making it very difficult to remain on schedule or to keep consistent headways over the entire length of the corridor. Part of the planning process should be an evaluation of the route characteristics and major ridership generators to determine if splitting the corridor into more than one route makes sense.

Sound Transit's I-405 freeway based BRT project is scheduled to open in 2024 and was originally intended to be a 40-mile-long corridor, but an early decision was made to plan and implement the project as two service lines, with both routes ending in Bellevue. Ridership analysis was conducted to determine that very few riders would travel the entire length of the corridor, and the major destination for the corridor is Bellevue in the center, as is shown in **Figure 8**. By splitting the corridor into two operating lines, the reliability will be much improved, and since Bellevue will be a terminal location, the service will deviate from the freeway to serve the downtown directly.

FIGURE 8
Sound Transit I-405 BRT Project

4.3 Creating reliable schedules

The goal of BRT is to provide service levels and reliability consistent with other rapid transit modes, which results in a higher expectation for reliability than on conventional bus routes. As such, service reliability needs to be a major consideration when developing BRT schedules. Usually, recovery time is built into the routes to maintain reliable service, which results in at least some increase in both capital costs (more vehicles) and operating costs (more service hours). Because of the cost impacts, it is important to have an achievable schedule—but not one with excessive time built in to it, which can result in slower service or having several buses sitting idle at a terminal. ITS technology can also allow tighter schedules to be built by using the technology to track vehicle locations and manage headways, resulting in both lower costs and faster service. Recovery time should be scheduled at endpoint terminals rather than at midroute stations.

It is also imperative to test the schedules thoroughly prior to opening the system to the public. While modeling and historical data can provide insights into how a schedule might run, there is no substitute for real-world testing. Before Community Transit opened the Swift Green Line in March 2019, it conducted time trials including over 400 trips of the corridor. This means an operator drove the corridor from end to end over the course of a full month, getting travel times by segment, by time of day, and by day of week. Timings were done both before construction started and prior to service startup. This helped Community Transit refine initial estimates, and it also helped confirm the benefit of its new BRT infrastructure. Now that the service is running, Community Transit is refining the schedules based on real-world bus travel times.

4.3.1 Standby vehicles

Planning for BRT service should include standby vehicles as part of the typical daily scheduled service for BRT. Similar to rail operations, it is important to have standby vehicles available to fill in service gaps that may occur in the event of an unexpected operational incident or vehicle failure. This is an important tool to maintain the reliable service expected from rapid transit. Standby vehicles are most often needed during peak periods, and consideration for accommodating these buses along the route or at terminals should be considered as part of the planning process.

4.3.2 Active headway management

Because BRT lines are based upon high-frequency service, it is quite important for BRT operations to maintain consistent service headways. If buses are bunched or have large gaps, customers may not experience the frequent service that is intended. To preserve the intended level of frequency, some BRT operations use techniques known as active headway management.

Active headway management consists of various interventions by bus dispatchers, managers or supervisors to ensure consistent service headways. This is made possible by real-time information about headways that can be monitored through CAD/AVL systems.

First, sharing headway adherence information with bus operators can allow operators to adjust their operations somewhat. For example, if an operator's console shows they are getting too close to the bus ahead of them, they can slow down to maintain desirable spacing. However, operators should be given clear policies about how to use headway adherence information, especially if it may conflict with typical schedule-based practices.[1]

At terminal points, an agency may have bus dispatchers, managers or supervisors actively control departures. Under this approach, each bus is inserted into service at the time that will keep headways most consistent (rather than following a static schedule). This method is effective for maintaining trip spacing at the start of a route. However, it can also make bus layover times more variable, which operators may view negatively. [2] (In this situation, an agency may consider using operator fallbacks, in which a bus switches operator at its terminal. This allows the bus to have an efficient layover while allowing the operator to take a longer break.) It also requires additional effort and/or staffing from transit supervisors.

An agency may also establish "hold points" along a route, where bus dispatchers can direct operators to wait for a short time if they are getting too close to the bus ahead of them. This policy prioritizes the spacing of buses midway along a route. However, it will increase travel time for passengers riding through the "hold point" on the affected trips. [3] It also requires additional effort and/or staffing from transit supervisors.

Unfortunately, active headway management and other strategies to improve reliability often involve a trade-off between speed and reliability. An excessive focus on consistent headways can lead to a situation in which the slowest bus on a route forces all of its following buses to slow down to maintain consistent headways. An excessive focus on speed or efficiency can lead to schedules that drivers are unable to operate reliably. Agencies must strike an appropriate balance between speed and reliability.

Other approaches to headway management may be used in extreme situations but are generally discouraged. Buses that are falling too far behind their lead bus may be able to catch up if they are directed to skip stops or turn around before the end of the route (an unscheduled "short-turn"). However, these practices are quite disruptive for customers whose stops would be skipped. Another drastic way to address reliability issues is to

[1] Giesen, R. (2017). Avoiding bus bunching: From theory to practice. Transportation Research and Education Center at Portland State University.
[2] Murphy, D. (2018). Active headway management for Swift BRT operations. TRB 6th National Bus Rapid Transit Conference.
3 Ibid.

have standby operators and buses that can be added to a route if a large service gap develops. This adds significant operating cost without addressing underlying issues.[4]

The remainder of this section discusses various operational policies that can impact service scheduling, travel times and reliability. It should be noted that various intelligent transportation systems (ITS) choices can also impact travel times. Implementing transit signal priority (TSP) effectively can reduce overall travel times and improve reliability. Lane guidance and collision avoidance systems not only help improve safety, but they also reduce delays that can result from crashes and near crashes. Station docking systems and effective fare collection technologies can reduce dwell times at stations and speed up service. See APTA BRT ITS-RP-005-10, *Implementing BRT Intelligent Transportation Systems* for more information about these options.

4.4 Compulsory stop vs. stop-on-request only

Whether vehicles will make every stop along the route or whether they will stop only upon request are two different approaches to BRT design and operation, each of which has its advantages. Most customers familiar with rail rapid transit systems will expect vehicles to make every stop and for all doors to open every time, which makes this an appropriate choice if it is important that the BRT service replicate rail rapid transit (although some light rail systems do not make all stops automatically). Compulsory stop operation may also be less intimidating and easier to use for new riders, as it does not require learning how to request a stop. If priorities are for faster travel times and there is an expectation that customers using the system will be familiar with it, then stopping and opening doors only on request would be an appropriate choice.

Some considerations for whether stops are compulsory or on-request include the following:

- If boarding or alighting activity is occurring regularly at most stations throughout the full service period.
- If stops appear to customers as rapid transit stations or as upgraded bus stops.
- If customer stop request features (stop request buttons and display) available on the vehicle.
- If boarding is permitted and encouraged at all doors or only at the front door.
- If a rail rapid transit service already part of the transit system.
- If deceleration and acceleration at stops where no customers are boarding or alighting adds an acceptable length to travel times (there may be a need to slow down at stations for safety reasons).
- Whether the system is trying to manage spacing between coaches.
- Whether customers with visual disabilities know whether the vehicle is stopping.
- Whether the station names being announced and/or displayed prior to arrival at the station.
- If hot or cold climates make it important to keep cool or warm air inside the vehicle.

These decisions may have an impact on vehicle specifications, as additional equipment may be required if a demand responsive approach is taken. The additional vehicle equipment could include stop request buttons/strips/cords, stop request signage, and customer door activation on the interior and exterior of the vehicle. Also, a marketing campaign and customer information should be considered if the practice is a unique situation for the system.

Selecting either stopping policy will not have a significant impact on scheduling. While flag stop operations may save time when certain stations are skipped, schedules should still be designed to accommodate all stations in case they are requested. In addition, flag stop operations can cause drivers to drive more slowly as they “troll the curb” looking for passengers, thus counteracting any time savings.

[4] Urgo, J. (2018). Headway-based scheduling opportunities. Alameda-Contra Costa Transit District.

4.5 On-board versus off-board fare collection

While some BRT systems maintain the conventional transit norm of having fareboxes on the vehicles and requiring fare payment at the front door, several systems have off-board prepayment, just as is done on subways and other high-capacity transit systems. This typically requires the purchase and installation of ticketing and ticket validation equipment at stations and terminals instead of fare boxes on the vehicles. It also requires a comprehensive public education campaign if this type of fare collection is new to the transit system.

The primary advantage of off-board fare payment is faster travel times with reduced dwell times (and related cost savings due to lower requirements for vehicles and service hours). This is achieved primarily from allowing boarding at all doors, along with eliminating delays from fare or transfer disputes or when passengers ask questions about fares (which in turn lessens the distractions for drivers). The benefits of off-board payment may be less if a high percentage of riders use prepaid fare media such as passes or stored-value cards (smart cards) and the vehicles are equipped with fare validators at all doors.

The main disadvantage of off-board fare payment is the need to have fare inspectors and the costs associated with them, although an offsetting advantage of this can be heightened security if the inspectors are also able to deal with other incidents or if their presence creates disincentives for disruptive behavior. Even with inspectors, some revenue loss due to fare evasion should be expected with off-board payment (approximately 4 to 5 percent). The cost of ticketing equipment is also a factor, although this is mostly offset by not having to purchase fare boxes.

A full off-board fare payment option may be cost-prohibitive for BRT dedicated guideway systems that include routes that extend beyond the BRT guideway for large portions of their routes, as it may be difficult to justify purchasing and installing ticketing machines at stops along local routes outside the BRT guideway. Ticketing equipment could still be installed on the BRT corridor, but the vehicles that extend beyond the BRT corridor would still need onboard fare collection equipment including fare boxes, thus adding to the cost; inspectors would still be needed; and there would be a greater likelihood for public confusion from mixing two different fare collection procedures.

4.6 Transit signal priority (TSP)

Transit signal priority (TSP) is the process of altering traffic signal timing at intersections to give a priority to transit operations. TSP can be triggered by BRT vehicles operating in dedicated busways, bus lanes or mixed-use lanes, and is often used in locations with significant traffic congestion and resulting bus delays. The use of TSP in BRT operations can reduce travel times and improve service reliability.

TSP can be used to improve travel times and reliability by facilitating queue jumps and providing bus bypasses at freeway ramp meters. This is achieved by providing a separate signal green phase that allows buses to pass before adjacent traffic. There are two types of priority that can be provided by TSP: unconditional priority, where BRT vehicles always receive signal priority, or conditional priority, where BRT vehicles receive priority only during certain operating conditions. TSP systems can be manually implemented by the transit operator or activated automatically using onboard technology. Automatic activation (provided through GPS/radio emitter, video detection or in-pavement loops) is preferred because it eliminates the need for operators to be involved in making the TSP call. Manually requested TSP requests should be considered only in unusual circumstances such as a near-side stop with variable dwell times, which would benefit from the operator making the request after serving the station.

For mainline TSP to be most effective, bus stops should be located on the far side of signalized intersections so that a bus activates the priority call prior to traveling through the intersection and arriving at the stop. For queue-jump treatments, it is preferred to have the transit stop on the near side of the intersection, so the queue-jump call is made as the bus begins to reenter traffic after serving the stop.

5. Service interactions and station spacing

Before a service plan can be developed for a BRT project, it is important to understand the operational goals and characteristics of the project. One of the most fundamental questions is whether the project is the development of a BRT service/route or a BRT guideway that is served by multiple routes. Making a determination to either introduce a single BRT route or to construct a BRT guideway that can accommodate several different transit services is a key early decision that needs to be made to provide the foundation for further routing and service design decisions.

Additionally, it is important to define early in the project development process whether the BRT system will be a closed system in that only BRT service will use the corridor and stations (could be one or multiple BRT routes) or if it will be an open system that will have other buses using the BRT corridor and stations. The following questions are important considerations to think through in the early stages of a project, as they are foundational to developing the service plan and defining the capital improvements:

- Will the BRT corridor be an open system (allowing other bus routes) or a closed system?
- Is the project a single route that goes from Point A to Point B? Or is the project the investment in capital improvements in a corridor that will be served by multiple routes?
- Will the routes continue beyond the limits of the capital improvements?
- If multiple routes will share the corridor, will they all be branded as BRT, or will just one route be branded as BRT?
- If other routes will operate on the BRT corridor, will they share the BRT stations, or will they stop more frequently?

This section provides examples of different BRT service designs that are in service for existing U.S. BRT systems. One of the many benefits of a BRT project is that the service design can be tailored to meet the unique needs of the corridor. Cleveland RTA describes BRT as “rail-like convenience with the flexibility of the bus.” The decisions that are made to define the service plan are where the true benefits of the flexibility of the bus should be considered and utilized.

5.1 BRT service project

Many of the BRT projects in the U.S. have been developed as a BRT service, which is typically a single route serving stations along a defined corridor. This type of routing operates like a typical rail transit service, running over the full length of a busway or BRT corridor and stopping at each station to serve passengers. It can also include short-turns (selected trips terminating at a midpoint where demand drops off significantly) or branches, either within or beyond a BRT corridor. These types of BRT corridors do not usually include express or limited stop routes.

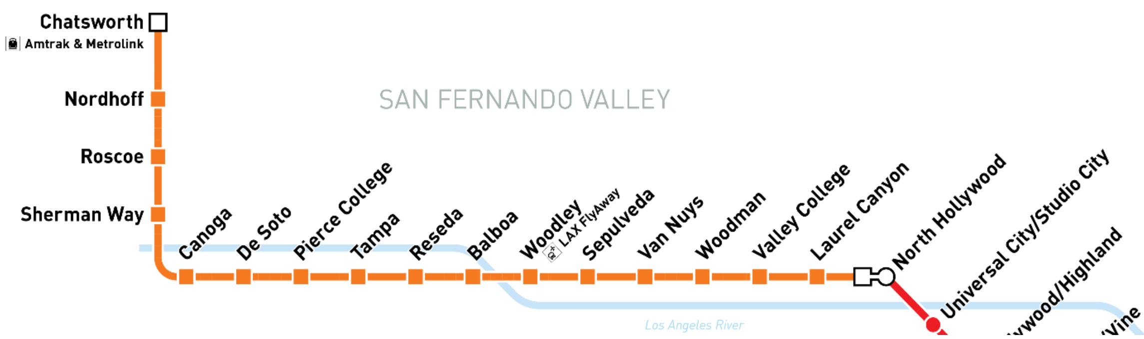
The all-stops route service frequency will usually be high during most time periods (e.g., every 5 to 10 minutes or better during peak periods and 10 to 15 minutes during the midday). The type of route often requires even higher-frequency service along busier sections close to major travel demand generators and may require the use of high-capacity vehicles such as articulated buses.

Examples of this type of BRT service are the following:

- Cleveland RTA's HealthLine
- Lane Transit District's EmX Eugene and Gateway Lines (Eugene, Oregon)
- MBTA's Silver Lines (Boston)
- Community Transit Swift Blue and Green Lines (Everett, Washington)
- LA Metro's Orange Line
- Transfort's MAX (Fort Collins, Colorado)
- GRTC's Pulse (Richmond, Virginia)
- King County Metro's RapidRide Lines (Seattle)

These routes can operate in mixed traffic with use of bus lanes and transit signal priority or on a separate guideway in a roadway median or unique corridor. **Figure 9** shows the LA Metro Orange Line map, which is representative of the simple route maps for these types of systems. The map shows that there is one line that serves every station along the alignment.

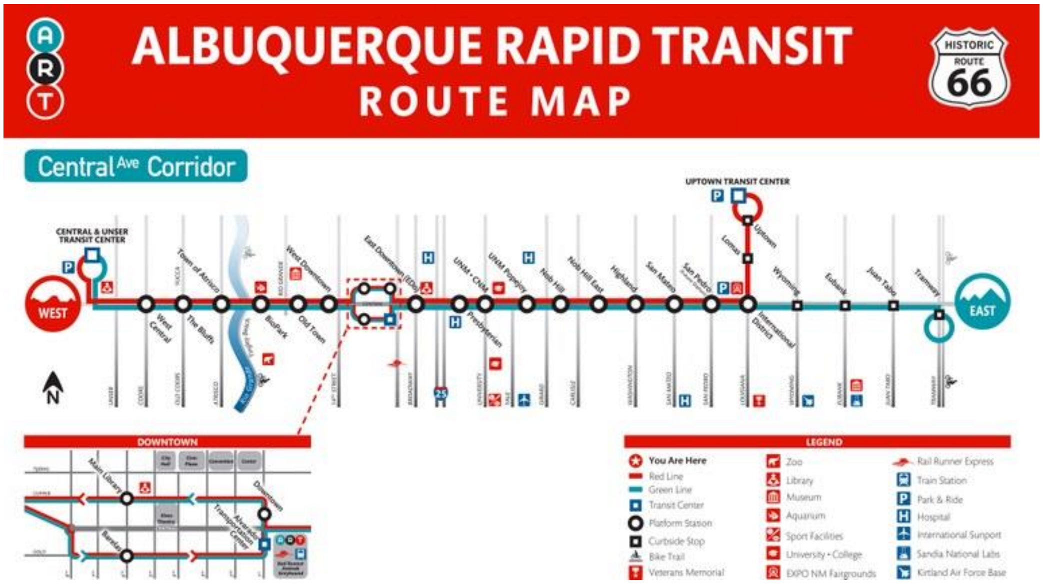
FIGURE 9
Los Angles Orange Line Route Map



5.1.1 Branching

BRT service corridors can also include routes with branches. Branching allows for more frequent service to be provided in the section of the corridor with the highest demand and includes the added benefit of serving more destinations. **Figure 10** shows the Albuquerque ART route map, which includes the Blue and Green lines. For the majority of the corridor, both routes serve all stations, resulting in higher frequencies for the shared section and the branches, diverge on the eastern end of the corridor.

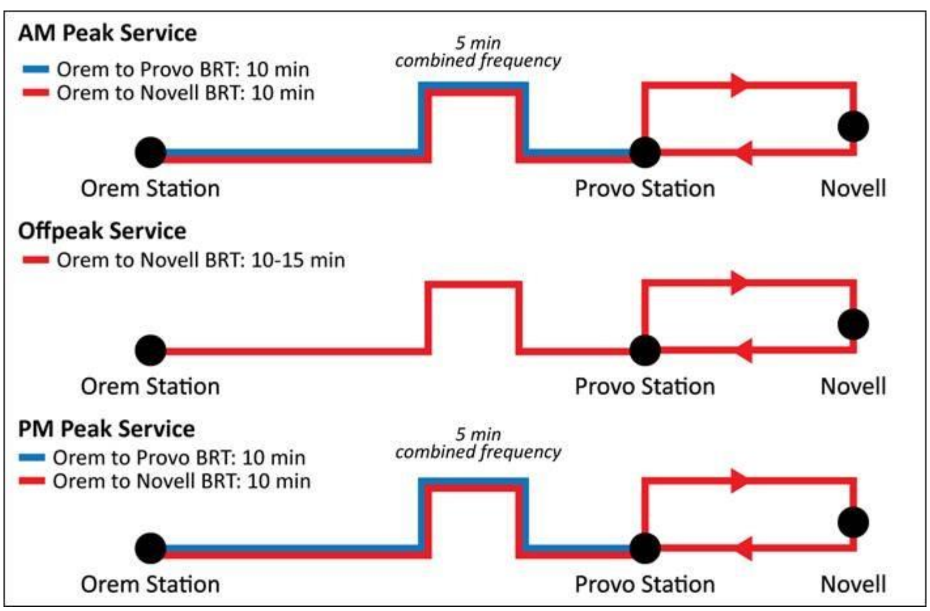
FIGURE 10
Albuquerque ART Route Map



5.1.2 Short-turns

A second approach to providing more frequent service on the highest-demand portion of the corridor is to operate short turn service, as is shown in **Figure 11**, which is the service plan that was developed for the UVX BRT project between Provo and Orem in Utah.

FIGURE 11
Service Plan Concept for the Provo-to-Orem BRT



5.1.3 Relationship with parallel local service

Many BRT service routes are implemented in corridors with established, well-utilized conventional or local bus service. When a new BRT service is implemented, transit agencies must decide on the respective roles of BRT and local service and how to modify existing services, if at all. The usual options include the following:

- **Removal of the existing local service:** Entire length or partial length of the new BRT corridor
- **Reduction in the existing local service:** Operate the local route less frequently or modify the routing
- **No changes to existing local service**

Key Principles of BRT Service Design

The BRT project should include an assessment of the pedestrian sidewalk infrastructure to determine if passengers who previously had access to a local bus stop can safely walk to a BRT station.

In deciding on these options, there are several factors to be considered:

- ridership and potential for new ridership in the corridor
- segment loads along the route and performance during peak and off-peak hours
- average trip length for the existing route to replace or complement BRT route
- station/stop spacing, including condition of the pedestrian infrastructure between stops
- physical attributes of the route
- transfer convenience/demand
- congestion on parallel streets and highways
- transit system operating budget
- public and community support for the BRT project

The following sections provides additional information to consider when determining if parallel service should be removed or modified.

5.1.3.1 Removal of parallel service

If all parallel service is to be removed, then service levels on the new BRT system must be able to handle the passenger volumes currently carried by the conventional service, as well as any increases in ridership expected as a result of the new, more attractive BRT service.

In this case, stations would normally be spaced closely enough (approximately ⅓ mile) so that passengers located between stations, who likely had a local bus stop nearby, can easily walk to the nearest BRT station. The BRT project should include an assessment of the pedestrian sidewalk infrastructure to determine if passengers who previously had access to a local bus stop can safely walk to a BRT station. If station spacing results in unacceptable walking distances or conditions, it may be desirable to retain at least some parallel conventional service or add additional stations to the BRT project. Ideally, an operational analysis could be completed to determine whether additional stations or operating on the same corridor as a local bus route would be more impactful to the travel time and reliability goals of the BRT project.

5.1.3.2 Reduction of parallel service

If it is determined that the goals of the BRT project are best achieved by retaining local bus service on the BRT corridor, then the local service should be evaluated to determine whether it would be beneficial to reduce the parallel service in either of these ways:

- reducing the local route service frequency
- shortening the length of the local route by keeping only a portion of the route to be parallel to proposed BRT route

Maintaining some local service on the corridor does allow for longer station spacing to be considered for the BRT service, as the local bus stops will still provide opportunities for passengers to gain transit access to the corridor in between stations. However, if the frequency offered on the local service is too low, many riders will make the choice to walk farther to access the BRT route that runs more frequently. This could result in lower ridership on the local route, making it more difficult to justify the operating expense of providing that route.

Agencies should consider all options for investing operating dollars on the corridor in the way that will serve the most riders, and some agencies have found that it is better to put the operational dollars into the BRT route to either operate even more frequently or to serve a few more stations rather than continuing to operate an infrequent local service that may struggle to meet the agency's desired service standards.

Key Principles of BRT Service Design

A key decision that agencies will need to make for these types of guideway-based BRT systems is whether all the routes that use the corridor or just the mainline route will be branded as BRT service.

5.2 BRT dedicated guideway project

A BRT dedicated guideway project consists of purpose-built infrastructure intended to be used by multiple routes. The infrastructure is usually a separate busway and can be fully grade separated or can accommodate at-grade intersections.

Examples of BRT dedicated guideways in the U.S. include the following:

- Pittsburgh East Busway
- South Miami-Dade Busway
- CTfastrak (Hartford, Connecticut)
- U.S. 36 corridor with Flatiron Flyer service (Denver)

BRT dedicated guideway projects often have routing patterns and operating plans that are more complicated than the BRT service–based projects, as these running ways often accommodate feeder routes and can include express or limited-stop services. Some of these systems do operate with an underlying all-stop or mainline BRT route, similar to the routes described as part of the BRT system operation, and then additional routes are added to the corridor.

When implementing routes that overlap the main trunk route, especially for routes with lower frequencies, efforts should be made to integrate the schedules of both routes where possible to create an evenly spaced headway and increase the overall corridor service frequency. This can usually be done quite easily for routes with identical service frequencies but may be more challenging when dealing with routes with different service frequencies.

Express or limited-stop services combined with feeder/line haul services provide a high degree of flexibility, which gives this type of BRT the ability to offer a high-frequency, no-transfer service to a higher proportion of trips than is usually the case for rapid transit in suburban corridors.

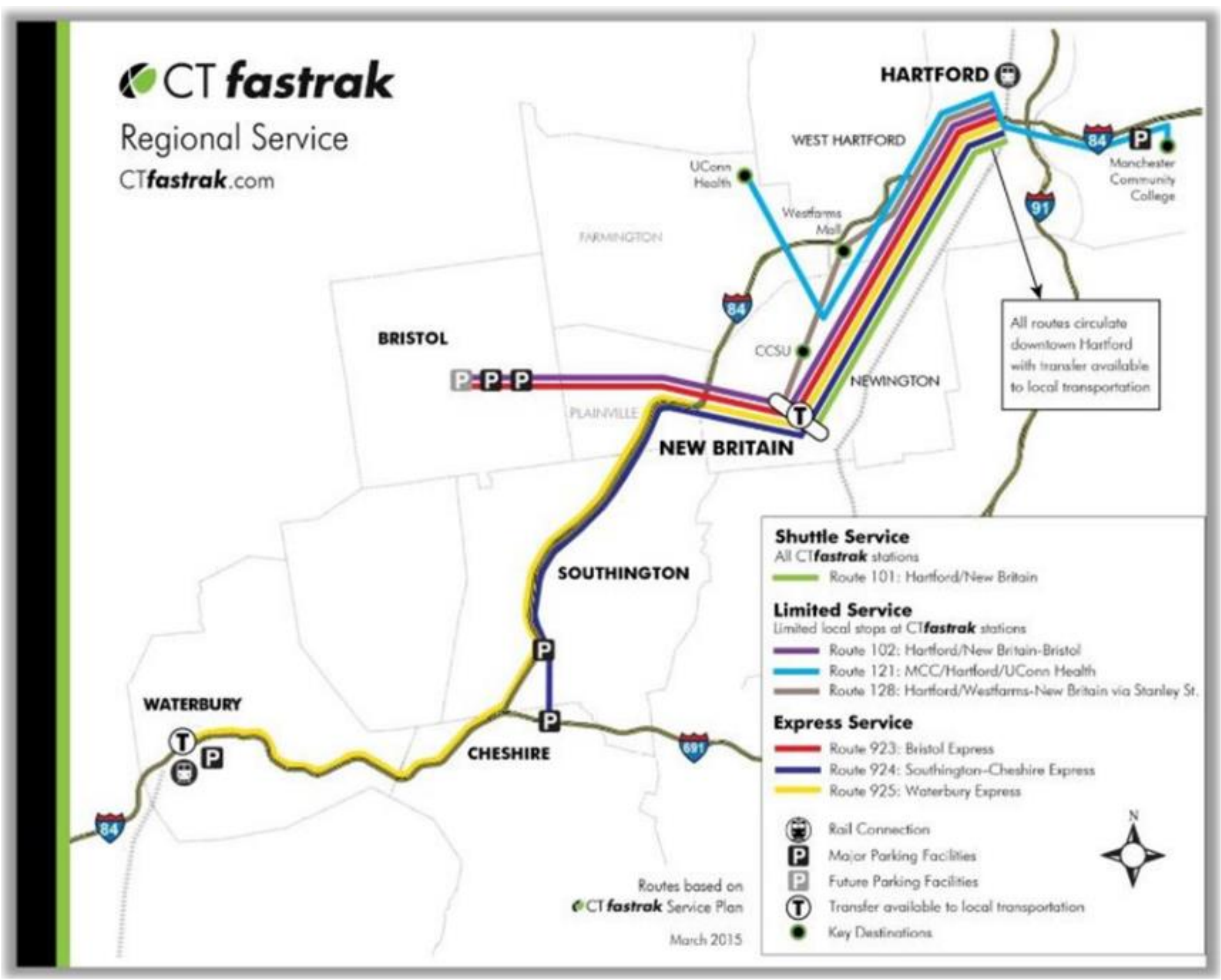
A key decision that agencies will need to make for these guideway-based BRT systems is whether all the routes that use the corridor or just the mainline route will be branded as BRT service.

5.2.1 Feeder route system

The CTfastrak corridor that connects Hartford to New Britain in central Connecticut is an example of a BRT dedicated guideway that includes multiple feeder routes. **Figure 12** provides a map of the CTfastrak service that includes a mainline BRT route as well as additional routes that serve multiple different destinations beyond the BRT guideway.

In these types of systems, it is common for the mainline BRT route to use higher-capacity vehicles while the feeder service can use the lower-capacity vehicles. Multiple vehicle lengths may impact the station designs, so a definition of the service plan and understanding of the vehicles that will use the stations should be made early in the project development phase. The agency should plan the feeder service and BRT service together for appropriate sizing of the station lengths and capacity, and to determine where passing lanes are required.

FIGURE 12
CTfastrak System with Trunk and Feeder Services Using the BRT Corridor



5.2.2 Express or limited-stop service

A BRT guideway-based system can also include an overlay express or semi-express service as a supplement to the all-stop mainline service. This can provide a quicker service for longer-distance trips but is usually justified only when the passenger demand is high enough to support both types of service operating at rapid transit frequencies. When express or limited stop services are offered, the BRT guideway needs to be designed to accommodate passing so express routes are not held up at stations that they are intending to bypass.

Figure 13 and **Figure 14** show route- and service-level information for the seven routes that comprise the Flatiron Flyer BRT service in Colorado between Denver and Boulder. The FF1 provides the consistent all-day, all-stop mainline service, while the other routes provide express or limited-stop service to provide faster travel times during the peak periods.

FIGURE 13
Flatiron Flyer Freeway BRT Routes

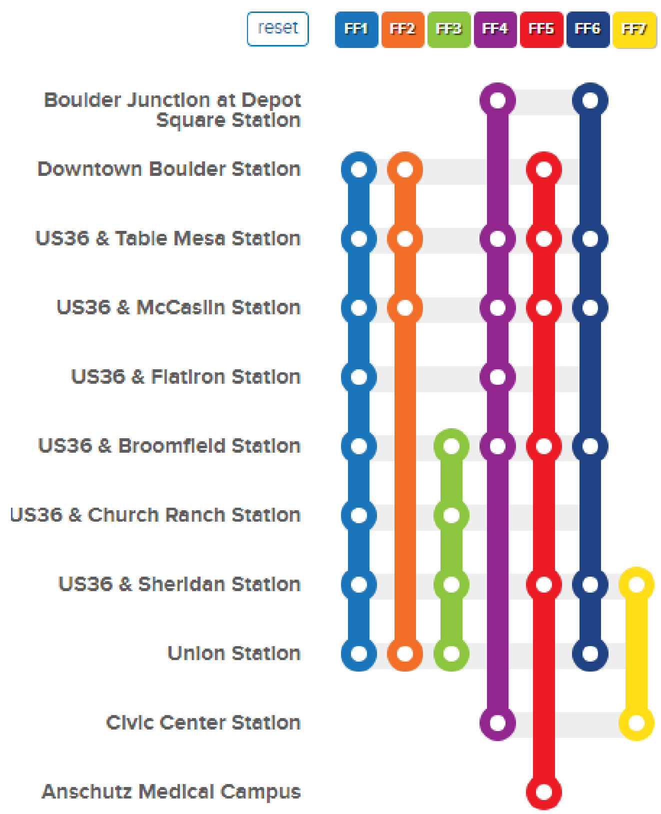


FIGURE 14
Flatiron Flyer Route Headways by Time of Day and Direction

Bus Rapid Transit Route		Eastbound to Denver			Westbound to Boulder		
		AM Peak	Midday	PM Peak	AM Peak	Midday	PM Peak
FF1	Union Station and Downtown Boulder Station	15 min	15 min	15 min	15 min	15 min	15 min
FF2	Express Union Station and Downtown Boulder Station	10 min	--	10 min	10 min	--	10 min
FF3	Union Station and US 36 & Broomfield Station	15 min	--	--	--	--	15 min
FF4	Boulder Junction at Depot Square and Civic Center Station	15 min	--	15 min	15 min	--	15 min
FF5	Downtown Boulder Station and Anschutz Medical Campus	30 min	--	3 trips	3 trips	--	30 min
FF6	Boulder Junction at Depot Square Station and Union Station	--	--	3 trips	3 trips	--	--
FF7	US 36 & Sheridan Station and Civic Center Station	20 min	--	--	--	--	20 min

5.2.3 BRT facilities for multiple routes in a congested area

In addition to a dedicated running way for specific BRT corridors, a segment of dedicated running way with the purpose of serving multiple routes in a congested area can also be beneficial. In this case, a segment would be identified for having a dedicated running way, and station spacing would be set to accommodate multiple routes.

Local bus and BRT services could all access this dedicated running way segment and stations. This can facilitate and improve mobility in high-density areas and allow riders to board multiple routes to different destinations from a single station. This type of project requires its own planning study to identify potential routes that can take advantage of a dedicated running way segment. **Figure 15** shows a map of the Providence, Rhode Island Downtown Transit Connector project scheduled to open in 2020, which is an example of this type of dedicated running way segment. The Downtown Transit Connector will have service at least every 5 minutes during the weekday periods between the two endpoints (Providence Train Station and Hospital District), but this service level is not provided by a single route branded as BRT but by a combination of seven different routes that each extend beyond the corridor either to the north or the south.

FIGURE 15
Planned BRT Guideway Serving Multiple Routes in Providence, Rhode Island

5.3 Station location and spacing considerations

For station locations, the following are the major factors to consider:

- location of major origins, destinations and activity nodes
- location of major cross streets and transfer points
- density and land-use patterns in the corridor
- economic redevelopment
- available right-of-way or infrastructure

As much as possible, stations should be located at major origins and destinations, as well as major transit transfer points. Often, these are the same location, such as a transfer terminal location at a retail development or a downtown transfer terminal.

Other factors for both station spacing and location may include the following:

- availability and quality of the pedestrian sidewalk infrastructure
- quality of pedestrian environment (trees, block spacing, storefronts, street furniture)
- width of streets
- stops shared with or separate from conventional service
- near-side vs. far-side stops (further aligned with availability of TSP)
- topography
- weather
- customer demographics (e.g., seniors)
- typical spacing for non-BRT service (bus and rail) in the region
- local conditions and expectations
- urban design opportunities (see the APTA Sustainability and Urban Design Standards)
- traffic operations
- maximum acceptable and desirable walking distances
- whether or not a parallel local service is available
- speed and service objectives for the BRT service
- adjacent land uses

Consideration can also be given to varying the spacing of stations to allow for more frequent stops, or more stations in higher-density portions of the route, while allowing for greater spacing between the stations in less-dense portions of the route. In a typical grid system, locating stations at intersect points with local bus routes should result in spacing consistent with acceptable walking distances, assuming that similar standards have been used to determine the spacing of the crossing bus routes.

Long station spacing (significantly beyond desirable walking distances) may require the retention of parallel conventional services. If there is an initial decision to retain parallel conventional services, then spacing BRT stations beyond normal walking distances will speed up the service and may be the most efficient way to operate the system. Longer station spacing may also be appropriate if the main objective of the BRT service is simply to connect major activity centers (e.g., transit hubs or park-and-ride facilities) or if the alignment has inconsistent development patterns including long stretches of low-density development that is not supportive of transit ridership.

Walking distances between stations will vary based on local public expectations and transit agency service standards. The distance people are willing to walk to transit varies but is typically on the order of 0.25 to 0.33 miles (0.4 to 0.5 km), typically a 5- to 10-minute walk. Note that when thinking about walking distance to transit, the entire trip length from an activity center or residence should be considered, not just distance along the corridor. The pedestrian network and proximity to other high-capacity transit determine the walkshed served and the total walking time to access stations. In higher-density or high-activity areas, it is common to have more frequent stop spacing given the number of people able to access each station.

Many people are willing to walk farther to access a higher-order service such as BRT compared with conventional transit, although there is still a limit on how far people will walk before the trip is no longer attractive. Customers also prefer not to walk too far in the opposite direction of their desired path of travel to access public transit facilities.

For BRT operating within an arterial corridor with at-grade signalized intersections, stops or stations are generally preferred on the far side of the intersection, especially to maximize the effectiveness of transit signal priority. At a far-side stop, the bus can make its call for TSP on approach to the intersection, proceed through the intersection in a relatively predictable manner, and then make its stop after clearing the intersection. With a near-side stop, an approaching vehicle can make a request for TSP when approaching the intersection, but the time required for boarding and alighting passengers is hard to predict, and the extended signal time may be lost if the actual dwell time varies. More information on station location can be found in APTA RP-BTS-002-10, *Bus Rapid Transit Stations*.

5.4 Connections with local routes and other services

Local arterial and feeder bus services operate in conjunction with BRT services to extend the benefits of BRT and to integrate BRT into the overall transit network. To take maximum advantage of BRT, these routes may need to be modified to reflect the presence of BRT. These modifications could include the following:

- Route diversions or stop relocations to ensure that each route intersects the BRT in at least one location where passengers can transfer conveniently at a station.
- Route diversions where the arterial route may use a section of busway or BRT corridor for a portion of its route. (Points to consider here: Vehicle types for both routes need to be compatible. Consider fare collection method and policy for all-door boarding for both routes or only BRT route. If the headways are very different, bunching may occur, and hence a passing lane may be needed.)
- Route extensions along a busway section or BRT corridor to take advantage of the faster operating speed and to connect passengers on feeder and arterial routes to more transfer opportunities.
- The elimination of route sections where bus service can be replaced by walk-in access to a BRT station.
- Timing changes to provide a timed transfer or pulse operation at major transfer locations (particularly late at night when service frequencies may be low).

How the BRT services and regular transit services connect will depend on the overall objectives and principles of the BRT system and the preferred service design structure. Such attributes as passenger demand and station location may also be influencing factors. Bus stop proximity will also need to be considered if the BRT stations are exclusive to the BRT service.

Where the route structure places a high reliance on transfers, travel from low-frequency services to high-frequency services will be more convenient than travel from high-frequency services to low-frequency services. This is most evident when the service frequencies of the BRT line are much more frequent than those of the local connecting services.

In cases where frequencies of the BRT routes and local connecting services are more closely matched, there may be a case for timed transfers. Generally, less frequent service benefits from timed connections to minimize passenger transfer waiting times. In cases where both the BRT routes and local connecting routes are operating with frequent service (typically 10 minutes or better), timed transfers are usually not required.

The local services connecting with the BRT systems may require time allowances for connections. This may be required to ensure that connecting passengers have sufficient time to transfer from one service to another and is generally used when service frequencies are moderate to low. Decisions regarding timing at stations or major transit transfer points can also be affected by other factors, such as local weather conditions, topography, and connecting pedestrian infrastructure.

BRT systems also provide opportunities to interface with other transit services, including other rapid transit, regional commuter operations, and intercity motorcoach services. There is a growing focus of connecting micro-transit options to BRT systems, which include services like bike, scooter and ridesharing that provide multiple options for passengers to connect to the rapid transit network.

5.4.1 Shared station considerations

When BRT and local services share a running way, BRT stops can either be co-located with local stops or separate from local stops. If the stop is sufficiently large so that the BRT vehicle can service the stop without interference from a conventional bus also using the stop, then this is the preferred practice since it will ease transfers between modes.

However, if there is insufficient space to accommodate both, then stops should be separated. Also, from a service branding perspective, it may be desirable to separate the stops, especially if the BRT service is being marketed as a totally separate system from the conventional service. There are two different approaches that can be considered for shared stations.

Shared boarding platform: BRT service can share the boarding platform with the other buses serving the corridor. If this is the preferred option, the number of buses should be evaluated to determine if a single-length platform will be acceptable. If the service is frequent enough that there will be bus bunching, a double-length platform should be considered to allow two buses to serve the station at the same time. Bus bunching is likely to occur and double-length platforms should be considered when the combined service level results in service more frequent than every 7 to 8 minutes. This should be considered as a general rule of thumb, but the length of routes and operating characteristics including running way could result in bunching occurring with less-frequent service or conversely with the system able to handle more service without bunching.

If the boarding platform is shared, then a double length platform does not necessarily result in the ability for the buses to pass each other but may require the stations to function as first-in/first-out. If this is the case, as shown in **Figure 16**, all buses using the station should operate similar to BRT at that location with all-door boarding at a minimum. If it is not possible to have local routes operate similar to BRT at the shared station, then an option that allows the BRT service to pass the local service should be built instead.

In addition to providing the most convenient transfer between services, the shared station option often results in the need for less right-of-way and infrastructure. This also allows local bus passengers to benefit from many of the enhancements of BRT, including station amenities and faster boarding times.

FIGURE 16
Shared Boarding Platform Concept

Adjacent local bus stop: If it is not feasible to have local buses operate with BRT-type all-door boarding and reduced dwell times, then local bus stops should be designed with separate boarding areas from the BRT and in a configuration that does not impede the BRT service. **Figure 17** and **Figure 18** show two concepts for locating local bus stops in a manner that they are close enough to provide convenient transfers but also allow for the BRT to maintain priority and avoid delays along the corridor.

Figure 17 illustrates the concept of building a pull-out for the local bus stop so the BRT can remain in the bus lane even when the local route is serving a station. The local bus pull-out could also be located in front of the BRT station, and the configuration that works best will likely be on the available right-of-way. This configuration allows the services to generally share a boarding location but also provides an opportunity to brand the BRT boarding platform separately. Additionally, riders will know which position the BRT will stop at.

FIGURE 17
Local Bus Stop Pull-Out at a BRT Station

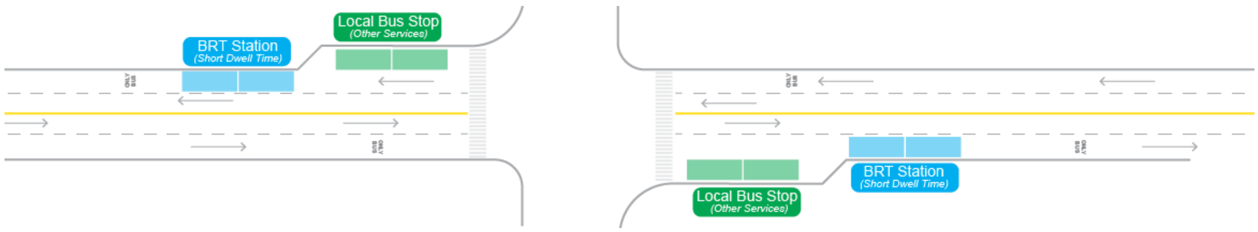
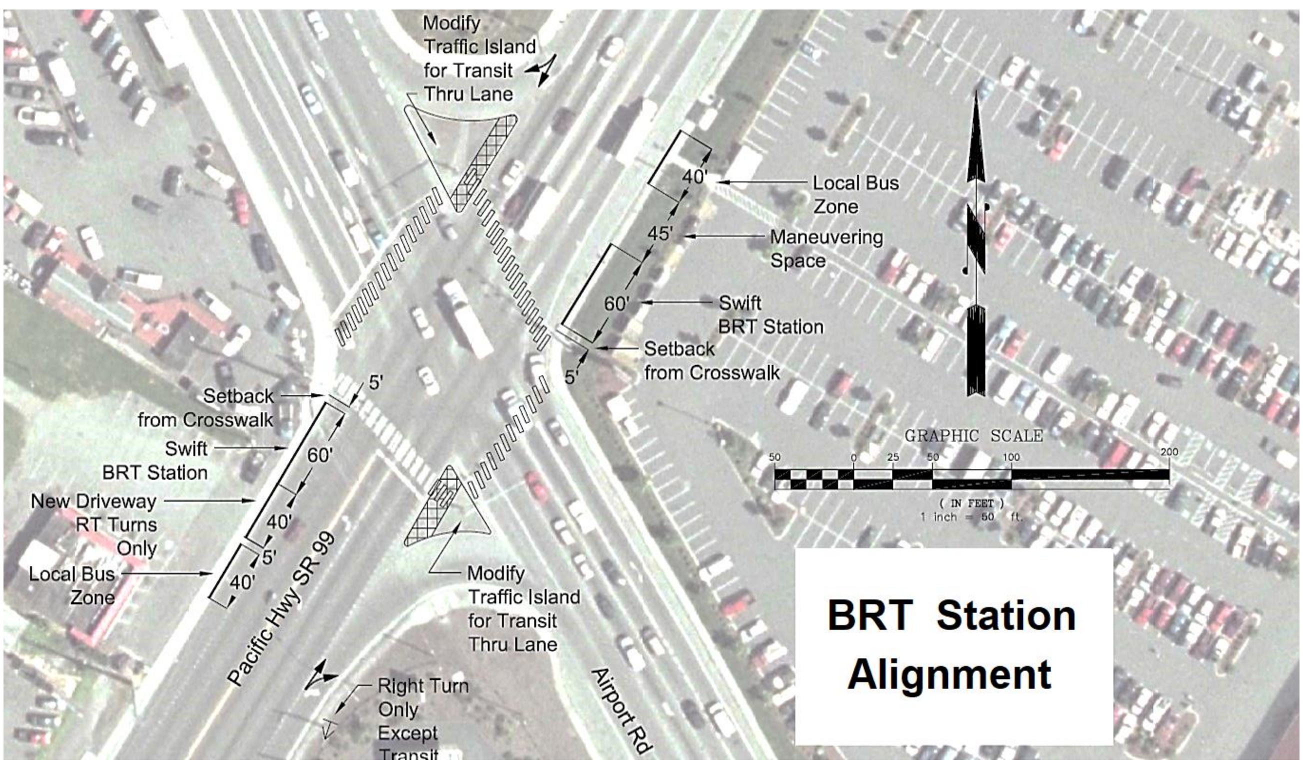


Figure 18 illustrates an alternative concept that can be considered if there is another travel lane available to the BRT bus to get around a local bus serving a bus stop in the bus lane. This configuration shows the BRT station located closest to the intersection and the local bus stop 80 to 100 ft farther from the intersection in front of the BRT station. The distance between the stations allows the BRT bus to leave the station even if there is a bus serving the local stop. This design requires less right-of-way than adding a local bus pull-out, but the traffic conditions should be considered to make sure the adjacent travel lane is generally uncongested so the BRT bus is able to use it to pass a stopped local bus.

FIGURE 18
Local Bus Stop Located in Front of the BRT Station with an Adjacent Travel Lane



5.4.2 BRT route deviations

Given the goal for BRT to provide fast and reliable service, route deviations from the BRT running way and major corridor should be avoided to the extent possible. Route deviations from the BRT running way should be carefully evaluated for the impact to travel time compared with the anticipated ridership gain from the deviation. Deviations should be accompanied with transit priority measures to the maximum extent possible to avoid additional delays from the deviation. Reasons that a deviation could be considered:

- To directly serve a major ridership generator (downtown, college campus, hospital, etc.).
- To provide a direct connection to another rapid transit service or major transfer point.

If a deviation is included in the BRT project, it is best if it occurs at the end of the route so as to avoid delays to passengers traveling through that portion of the route. Unless it is the end of a route, BRT service should generally avoid traveling into transit centers that require buses to circulate through a large bus loop and experience delays getting into and out of the facility. However, connections to other services are important, so options to connect the BRT stations to the transit center without requiring the BRT bus to deviate should be considered and evaluated with the costs of adding connecting pedestrian infrastructure compared with the ongoing increased operating cost of adding travel time to the BRT route to directly serve a transit center.

6. Fleet requirements

6.1 Fleet size based on cycle time

To provide the efficient and reliable service necessary for a successful BRT system, a firm understanding of the variables that impact travel time is essential. At its foundation, BRT travel times are influenced by the same two factors as traditional bus routes: running time and dwell times. The primary focus of BRT design is to implement strategies that reduce the amount of time spent between and at stops; this is often achieved by providing dedicated busways, reducing the number of stops, implementing traffic signal priority, and designing buses and stops with features that accelerate the boarding process. The benefits of these strategies, as well as common approaches to implementation, are outlined in this section.

Layovers play a critical role in BRT reliability, providing opportunities to recover lost time. For typical BRT operations, a layover time of 10 – 20 percent of the running time should be provided at the head and tail of the route. The layover time and requirements should also be verified to ensure conformance with any collective bargaining agreements that are in place for the operating agency.

6.2 Vehicle features

The design of BRT vehicles not only contributes to the operational performance of the system but can also bring attention to the service, inviting higher ridership. For this reason, selection of bus features should consider functionality (size, technology, propulsion), as well as passenger appeal and comfort (branding, ADA accommodations, passenger amenities). The following sections outline considerations for bus features related to service and operations.

6.2.1 Vehicle size and seating

BRT is best served along corridors with high ridership, often requiring the use of standard 40 and 60 ft articulated buses. While 60 ft articulated buses are often recommended for optimal service performance, the exact configuration of various bus sizes should be determined once the BRT service plan and ridership projections have been refined. **Figure 19** shows the 60 ft articulated bus that is used for the mainline, all-stop CTfastrak route.

In addition to ridership, the goals for the BRT service should be considered to make a final vehicle selection. There are often decisions that are made to increase amenity spaces for things like bikes and luggage onboard the bus that result in fewer seats. One of the most important factors for BRT systems is short dwell times, so ensuring that the bus seating and door configuration allows for easy circulation and minimal delays for boarding and alighting passengers is important.

All goals should be considered, including the unique operating characteristics of each corridor. For example, freeway-based BRT systems travel long distances between stations at high speeds, so the most important consideration for that type of corridor may be providing comfortable seating for as many passengers as possible, which could result in a different vehicle type than what is thought of as a typical BRT vehicle for arterial corridors that are typically selected based on the primary goal of reducing dwell times.

FIGURE 19
CTfastrak 60 ft BRT bus

6.2.2 Door configuration

The door configuration of BRT vehicles can significantly impact the amount of time required for boarding and alighting. BRT vehicle designs should consider the quantity, location and width of doors to accelerate entry and exiting of the vehicle. To support passengers with mobility limitations and to facilitate passengers being able to board and alight at the same time, doors that open to the outside of the bus and create a larger opening should be considered. This door opening configuration is shown on a Minneapolis A Line bus in **Figure 20**. Some 40 ft BRT vehicles now come equipped with three doors, significantly increasing passenger handling capabilities.

It is recommended that BRT systems with median arterial busways consider deploying vehicles with passenger doors on both sides, allowing stations to be shared by buses traveling in opposite directions similar to a rail center platform operation. The decision to include doors on both sides of the bus should be considered early in the planning process to influence the station design. Doors on both sides of the bus will reduce the amount of space onboard the vehicle for seating and/or bicycle and luggage storage. As such, this decision should be considered by evaluating all the goals of the BRT, taking into consideration of both construction and ongoing maintenance costs including the cost of having a truly dedicated BRT fleet for one corridor.

FIGURE 20
Maximizing Doorway Width for Passenger Flow (Minneapolis A Line bus)

6.2.3 Passenger amenities

As the agency's flagship bus service, BRT should provide a larger array of passenger amenities than other vehicles in the fleet. Possible amenities to consider that could enhance the rider experience may include the following:

- passenger information, including digital signs and/or maps with information specific to the BRT corridor
- visual and audible next-stop notifications, including connections to other transit services and major destinations
- air conditioning
- comfortable seating
- Wi-Fi
- power outlets/USB ports
- bike racks
- rear-facing wheelchair securement

6.2.4 Accessibility

Full accessibility to customers using wheelchairs or other mobility devices is a requirement for all new transit projects. Accommodating mobility devices can, however, have the effect of slowing the service, such as when a wheelchair ramp is deployed. This delay can be reduced considerably through level boarding and vehicle guidance systems at stations (as discussed in detail in APTA RP-BTS-002-10, *Bus Rapid Transit Stations*, and APTA BTS-BRT-RP-003-10, *Designing Bus Rapid Transit Running Ways*.

Additional delays can result from having to attach securement belts in forward-facing wheelchair positions. Several BRT systems across the U.S. have successfully used rear-facing positions, where securement is not needed, thus lessening this delay factor.

Recently, several U.S. agencies have also begun to introduce these passive restraint systems on BRT systems, including in Cleveland, Ohio; Eugene, Oregon; and Everett, Washington. TCRP Synthesis 50, *Use of Rear-Facing Position for Common Wheelchairs on Transit Buses* provides more information on experiences with and the benefits of the passive restraint wheelchair position.

The passive restraint system provides a padded head and back panel facing the rear of the coach at the front end of the wheelchair space, as shown in **Figure 21**. The primary feature of this system is to have the back panel absorb the forces of deceleration. Upon boarding, the wheelchair passenger positions the back of the wheelchair as close as possible to the padded panel and applies the chair brakes. The benefits of this system include the following:

- significantly decreased dwell times
- increased reliability of service
- faster boarding and alighting for the customer
- independent use of the transit system for the customer
- ability to accommodate nonstandard mobility devices
- ability to accommodate passengers with large objects, such as parcels or strollers
- less damage to mobility devices from the securement system
- reduced need for operators to leave their seats
- reduced maintenance cost of securement system

FIGURE 21
Passive Wheelchair Restraint (Swift bus in Everett, Washington)

Americans with Disabilities Act (ADA) regulations do not prohibit passive restraint systems. However, it should be noted that the current requirement for two wheelchair positions in each coach states “one of which must be forward facing.” The requirements also state the need for ADA-compliant securement systems at every location for those customers who request it.

6.2.5 Bicycle accommodation

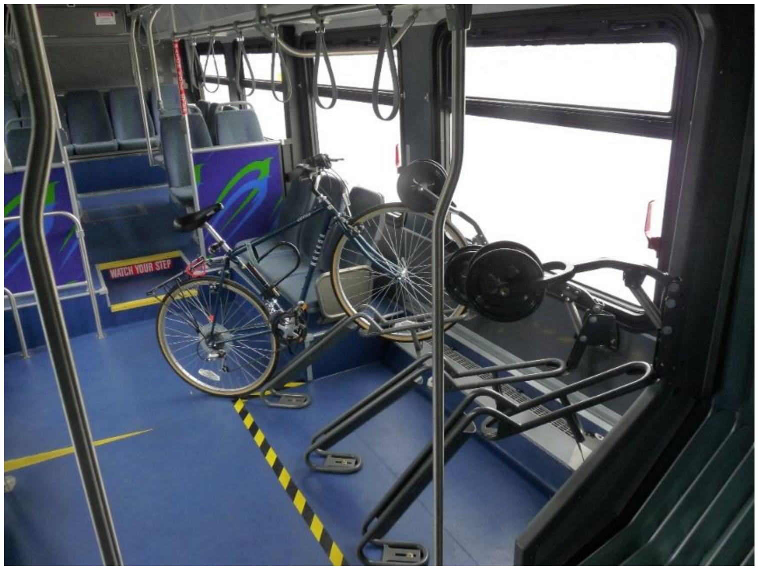
Accommodating bicycles on BRT can be a feature in attracting ridership but can also add delays to travel time. This is especially the case for exterior bike racks, where the cyclist must lower or extend the rack, put the bike on the rack and properly secure it before boarding the bus. However, depending on ridership and bicycle demand, it may be the best option for the corridor to include racks on the front of the bus, as is shown in **Figure 22**.

FIGURE 22
Bicycle Rack on the Front of a Bus (The Pulse BRT in Richmond, Virginia)

Eugene's EmX and Community Transit's Swift are examples of BRT systems that have installed interior bike racks, which, along with having near-level boarding, have helped minimize dwell times at the stations. The main disadvantage of interior racks, however, is the loss of vehicle capacity and the inconvenience to other passengers, especially during peak times and high vehicle occupancy, when trying to maneuver the bike on or off the vehicle.

Figure 23 shows the interior bike racks onboard a Community Transit Swift bus. Community Transit has found the accommodation of bicycles inside the bus to be a feature that passengers appreciate, as the racks have been heavily used since their inception. Community Transit has found that about 8 to 9 percent of Swift riders bring their bikes with them to complete their transit trips compared with 2 to 3 percent of riders on conventional Community Transit fixed routes, which have bicycle racks on the front of the bus.

FIGURE 23
Interior Bicycle Racks (Community Transit Swift Bus)



If both increasing dwell times and reducing passenger space inside the bus are major concerns, an agency could decide not to accommodate bicycles on the BRT service. This option should be carefully contemplated, paying special attention to how passengers will access the corridor. This option should also be coordinated with an effort to provide ample bike racks and lockers at stations. Off-board bicycle storage can raise security concerns regarding bicycle theft, which can be lessened with properly designed lockers or if the station or terminal has a full-time staff or security presence.

Secure bicycle storage at major BRT stations is something that should be considered and implemented even if bicycles are accommodated on the bus. If secure storage is provided, more riders will feel comfortable leaving their bicycles when they need them for only one end of the trip. Reducing the number of bicycles onboard will minimize the impact to travel times.

For an in-depth review of integrating bicycles into transit, including further discussion around bicycle accommodation on buses, see APTA Recommended Practice APTA SUDS-UD-RP-009-18, *Bicycle and Transit Integration.*

6.3 Operations and maintenance cost considerations

Estimates of O&M costs associated with BRT operations are highly variable depending on the extent of the service, the technologies deployed and infrastructural modifications. With each of these factors, an increase in O&M costs in one area may be counterbalanced by a decrease in another. For instance, most BRT operations entail frequent headways, which require additional vehicles, infrastructure, fuel and operators. Each of these cost variables, however, may be supplemented by fuel and maintenance savings resulting from operational improvements from congestion avoidance, decreased recovery time and less frequent stops. Similar logic can be applied to technologies used to enhance BRT operations, such as transit signal priority, off-board fare collection and intelligent transportation systems. Though there may be increased costs with component repair and replacement (e.g., TSP optical emitters), operations cost may be lowered as a result of reduced travel and dwell times.

6.4 Spare ratio

The FTA provides guidance of overall bus fleet spare ratios in FTA Circular 9030.1C, "Urbanized Area Formula Program: Grant Application Instructions." The circular indicates that the bus spare ratio for agencies with more than 50 buses should not exceed 20 percent, as calculated on the annual maximum service requirement for the whole system. BRT systems are typically operated with a separate subfleet that is unique to the BRT routes and the buses. It is common for subfleets to have a higher than 20 percent spare ratio depending on the total number of buses in the subfleet. If the subfleet is small and a ratio of only 20 percent is used, then it may be necessary to operate standard buses on the BRT route in situations when multiple BRT buses are out of rotation. This could be perceived negatively and cause confusion for riders and should not be something that occurs regularly.

It is recommended that, to the extent possible, agencies with more than one BRT corridor or route procure a consistent fleet or at least consistent branding among the lines to most efficiently utilize the vehicles and reduce the total number of spare buses required for service. More information about spare ratio and total fleet requirements can be found in the TCRP Synthesis 109, "System-Specific Spare Bus Ratios Update".

7. Operations and training requirements

Most BRT projects are developed for transit agencies that are already operating bus service, and the typical practice is to incorporate the operation of the BRT routes into the overall bus operation. The BRT routes will usually include unique operating procedures that should be incorporated in the overall operator training materials/handbooks if all operators are eligible to operate BRT service or provided as a supplemental handbook if only a subset of operators will operate BRT routes. The BRT training materials should provide guidance on any procedures that are unique and may include items such as the following:

- passenger boarding (all-door, wheelchair location)
- fare payment
- stop requests
- headway management
- bicycle loading
- platform docking
- running environment including rules for the busways or unique transit signals

The key to any successful transit operation is to ensure that the service is accessible and understandable for all passengers so it is convenient for existing transit riders, easy for new riders to understand and welcoming to potential riders. Therefore, it is critical that the differences between BRT and standard bus service are also communicated to passengers.

This section provides more detail regarding BRT operational considerations for both operators and passengers. It includes an overview of the process to transition BRT service from completion of construction into operation.

7.1 Operator work rules and collective agreement

Some transit providers may choose to pay a premium to operators when driving BRT routes, particularly if the BRT operators are held to a higher standard of qualifications, customer service and appearance/uniform. However, this is not a requirement for effective BRT operations. There may be elements of a BRT service, such as running ways, technologies, vehicles, and vehicle/platform interface, that require additional training and/or qualifications for transit staff.

In cases where BRT operations are staffed by in-house employees, there are two options for signing up bus operators. The first option is to allow all bus operators to choose shifts that include BRT. The second is to have a pool of dedicated BRT operators who would then pick shifts within the BRT service. There are positives and negatives associated with either option, and in many systems, the choice will be largely made based on the current collective agreement with the bus operators union and/or discussions with the union. The positives and negatives with each option are summarized below.

Whether the selection is a separate roster or all operators are certified/eligible, the degree of change between BRT and regular service should be carefully considered when creating run cuts. Some agencies have found that an operator doing both types of service in a single pick (i.e., BRT one day and regular service the next) causes confusion and stress if the operating rules are significantly different.

TABLE 6
Choosing BRT Operator Work Rules

	Positives	Negatives
Option 1: BRT shifts available for all operators	• Greater flexibility (operators can choose if they want BRT or standard bus) • Only one shift selection process needed • May be preferred by union • No need for a second spareboard • Provides flexibility in runcutting for operator shift scheduling that includes BRT and non-BRT duties	• Need to train all bus operators on BRT • No ability to have distinctive uniforms for BRT operators • No ability to select appropriate operators for BRT through qualification and testing procedures • Operators who sign up for BRT work but have not worked BRT for a long time since their initial BRT training might need refresher training • Spareboard operators who draw BRT work might not be able to provide the highest-quality service for BRT (e.g., on-time performance)
Option 2: Separate roster for BRT operators	• Need to provide specialized training only to a smaller pool of operators (reduced cost) • Greater ability to select appropriate operators • Can issue distinctive uniforms to BRT staff	• Reduced flexibility in shift scheduling (particularly in systems with lower service levels) • Need to maintain list of operators who are qualified to drive BRT service and to potentially run a separate shift selection process • May be more difficult to work through with union (particularly if selection to the BRT pool is by means other than seniority) and could restrict use of part-time operators on BRT • A separate spareboard is required, potentially reducing efficiencies

7.2 Operating rules

While transit providers who are contemplating BRT are likely to have a set of operating rules that govern their existing bus operation functions, there are several aspects of BRT that may be sufficiently different that they would require separate operating rules. Examples of BRT elements that could require new or separate operating rules are as follows:

- running ways and block signals
- technology

- station approach and docking
- mandatory stops
- boarding passengers with bicycle, stroller, mobility device
- headway spacing
- fare collection
- unique operations within transit centers

7.3 Operator training and development

While the basics of training a person to operate a transit bus are common between BRT and standard bus transit, there may be several areas that are unique to BRT. This section identifies training that may be required above standard training practices. While the goals of any transit employee should include excellent service delivery and customer service, this is even more important in a BRT system, especially if it is branded as a premium service.

Operators should be made aware of any service/performance goals particular to the BRT system if applicable. Where possible, operators should receive additional training pertaining to these goals and other training as applicable.

Operators should also be trained on items such as unique BRT vehicle characteristics/features, special signals and stopping positions. **Table 7** is a summary of Eugene EmX's instructor checklist for its three-day BRT training curriculum that is provided as an addition to its standard operator training.

Operators should be recertified periodically (e.g., every six months) to operate BRT buses, possibly on an in-service bus. Special nonrevenue (e.g., nighttime) training might be offered to operators new to BRT service. If all extra-board or vacation relief operators are eligible per the collective bargaining agreement to operate BRT, then it will be important to ensure that they are all recertified on BRT.

TABLE 7
EmX Checklist for Three-Day BRT Operator Training

Day 1	Day 2	Day 3
Pre-trip • Starting sequence (control panel) • Ramps • Door sensors • Bike rack/bike button • Wheelchair area (tip bar) • Trolley bell • Inside/outside PA • Emergency exits (door override) • GPS light **Reference points** • Docking (tape/clock tower) • Driving through corridor **Hazards** • SS • Gateway 102 • Q St inbound • International way roundabout • Centennial sign • Kruse way 101 **Alternate stops** • See list	**Pre-trip** • Wheelchair area (two rear-facing bays) • Traffic priority • When to call • Mixed traffic light timing (maximum boarding time) • Routing • In/out of corridor • Alternate stops • Parking behind loops • Troubleshooting • Pulling onto loop • Door switch **Ramp** • Sequencing **Eugene station** • Bay U light • Checkout loop Bay T • Routing	**Putting it all together** • Work on everything from previous days • Work on efficiency/speed

7.4 End-of-line facility (terminus point) operations

An important consideration when making decisions regarding BRT routes is the end of line and layover needs. Oftentimes BRT projects are planned with endpoints at existing transit centers. An evaluation of the existing transit centers should be conducted to determine what improvements are needed to support both the active station area and layover needs of the new BRT service. If the BRT service will utilize existing transit centers as terminus points, then the project should be defined to include more than just a station at the new terminus.

7.4.1 Boarding platform

It is recommended that a dedicated platform or loading zone be provided for BRT routes within a transit center that is served by other buses. The BRT branding should be incorporated in the BRT loading zone so it is clear for passengers where they board the BRT route. Depending on how layover is accommodated at the facility, there may be multiple BRT buses at the loading zone, and it should be clear to passengers which bus to board that will be departing next. Consideration should also be given as to avoid any passenger confusion and avoid passengers boarding buses that are going to layover and not into service.

The BRT loading zone should have fare collection equipment near the BRT boarding area and not only rely on fare equipment that may be located in a more central location within the transit center.

If there is more than one BRT route that serves the transit center, it should be clear for passengers to understand where to board each route.

7.4.2 Layover considerations

Layover needs for a BRT route should be based on an evaluation of layover requirements, including the union contract for the operating agency in addition to considering extra layover for additional standby buses. Terminal points should also include any amenities that are required for operator layover and relief, which will include at least one operator restroom. Shift changes may occur at the end of line which may require accommodation of parking for operator cars or trucks. Maintenance vehicle parking and accommodation should also be considered in the design of terminus points.

7.5 Operations and maintenance startup

7.5.1 Operations and Maintenance Plan

The first step in transitioning a BRT project from construction into operation is to develop an Operations and Maintenance Plan, which typically includes the following information:

1. General project description (project map, number of stations, capital improvements, BRT alignment, stations, vehicles, running way, signals, fare collection terminals)
2. Description of the operating agency (service area, current fleet, current ridership, governance and funding structures, operating model [direct or contract], etc.)
3. Service description (hours, frequencies, travel times, etc.)
4. Concept operating schedules and staffing levels (e.g., number of operators required)
5. Forecast ridership and service standards
6. Changes to existing transit service, transfer connections
7. Fleet needs (vehicle type, number of vehicles based on anticipated ridership)
8. Dispatch and central control operation (note any differences if using headway-based operations)
9. Fare collection and enforcement, revenue projections
10. Vehicle storage and facilities requirements
11. Vehicle maintenance requirements (preventive maintenance plans, etc.)
12. Station and running way maintenance responsibilities and requirements (note any locations where other jurisdictions are responsible for maintenance)
13. System security, safety and operator training plans, emergency response and evacuation
14. Special events
15. Coordination with other agencies
16. Staffing needs (number of operators, new maintenance staff, security staff)
17. Operations and maintenance cost forecasts and budget
18. Technology such as signal priority, docking
19. Operator training plan and draft SOPs
20. Side letter agreements with union (if needed)
21. Pre-revenue operations

7.5.2 Unique startup and maintenance requirements

From a transit system operations perspective, one of the biggest differences between a BRT system and standard bus service is the amount of infrastructure included in a BRT project. BRT projects include stations with not only more physical infrastructure but also much more complicated technology systems than a standard bus stop.

The transit agency should ensure that there is adequate budget and staffing resources to support the BRT maintenance plan. This plan should address all items with requirements that differ from standard bus stops and may include, but not be limited to, the following matters:

- more frequent servicing of the stations with defined maintenance periods to avoid peak service time (to preserve the high-quality of service that has been established for BRT comparable to rail stations)
- service requirements for ticket vending machines including cash collection
- snow removal depending on climate (oftentimes local jurisdictions handle snow removal at regular sidewalk bus stops and the additional investment in stations requires transit agencies to take on this responsibility)
- IT support for the electronic elements including passenger information and fare collection systems (additional systems may be included at stations, onboard buses or both)
- maintenance agreements with local municipalities for any shared responsibilities
- maintenance requirements for the running way

7.5.3 Timeframe for startup

The following timeline gives guidelines for key milestones prior to commencement of BRT service:

- 2 Weeks prior – complete operator training
- 6 Weeks prior
  - Complete operator run pick
  - Operator field training
- 8 weeks prior – Mechanic training on vehicle (if new vehicle)
- 12 weeks prior – Delivery of BRT vehicles
- 9 months prior – identify and negotiate any required Collective Bargain Agreement changes
- 12 months prior – finalize operational polices required to support BRT

7.6 Safety certification

In addition to unique maintenance requirements, the additional infrastructure constructed to support BRT also requires a more detailed safety certification process than is typically done for a standard bus operation.

A Safety and Security Management Plan (SSMP) implements a Safety and Security Policy and guides integration of safety and security into each phase of the BRT project development process. This will ensure that the design, construction, installation and testing of all system elements identified as safety- and security-critical meet or exceed identified requirements. This SSMP applies to all project development activities for a BRT project through preliminary engineering, final design, construction, integrated testing, demonstration, and initiation of revenue service.

An SSMP's organization can include the following items:

- Safety and Security Policy statement.
- Integration of safety and security into project development process (responsibility matrix).
- Safety and security risk analysis and assessment (e.g., likelihood and severity, scenarios).
- Safety and security in project design.
- Process for ensuring qualified operations and maintenance personnel.
- Safety and security verification process (including final safety and security certification).
- Agency coordination.

7.7 Passenger education

Depending on the type of BRT service operated, the transit agency may need to educate its riders and the community about the BRT operations and rider requirements that may differ from other bus or rail services offered. The following are issues that may need to be addressed by the transit agency:

- **Station locations:** How to connect to other transit services from BRT stations.
- **Passengers using rear doors:** If the BRT service allows rear-door boarding.
- **Fare box, fare vending and/or payment requirements:** The service may require payment prior to boarding via use of a ticket vending machine or other prepayment method. The transit agency should also communicate to the public that the same fare used on bus and other modes are valid without a transfer or that a day pass is honored on multiple modes without an additional fare required (if applicable).
- **Role and authority of fare inspectors:** Education on ramifications of fare evasion (fines, trespassing, etc.).
- **Motorist education:** Education of the automobile driving population may be needed to advise them of BRT signalization, queue jumps, lane changes, etc.
- **Passenger information:** Make clear to the public the basis of dynamic message signs (i.e., is next-bus information real-time or based on an established schedule?).

7.7.1 On vehicles and at stations

It is most important to ensure that passengers understand how to ride BRT when they are on the system. Stations and vehicles should be designed in an intuitive and user-friendly manner so it is clear to passengers how they complete their whole trip, including the following:

- where to board (including for riders with bikes or using mobility devices)
- how frequently the service operates and how long before the next bus
- how to pay a fare
- clear designation of the route and stops and if passengers need to do anything to signal for a stop or if the bus will always stop at all stations

Ensuring that the passenger information is accessible to all users is important, and all ADA requirements should be met at a minimum. It is important to think through how important rider information can be communicated visually as well as auditorily. At a minimum, the vehicles should include audio stop announcements, including connections to other rapid transit services.

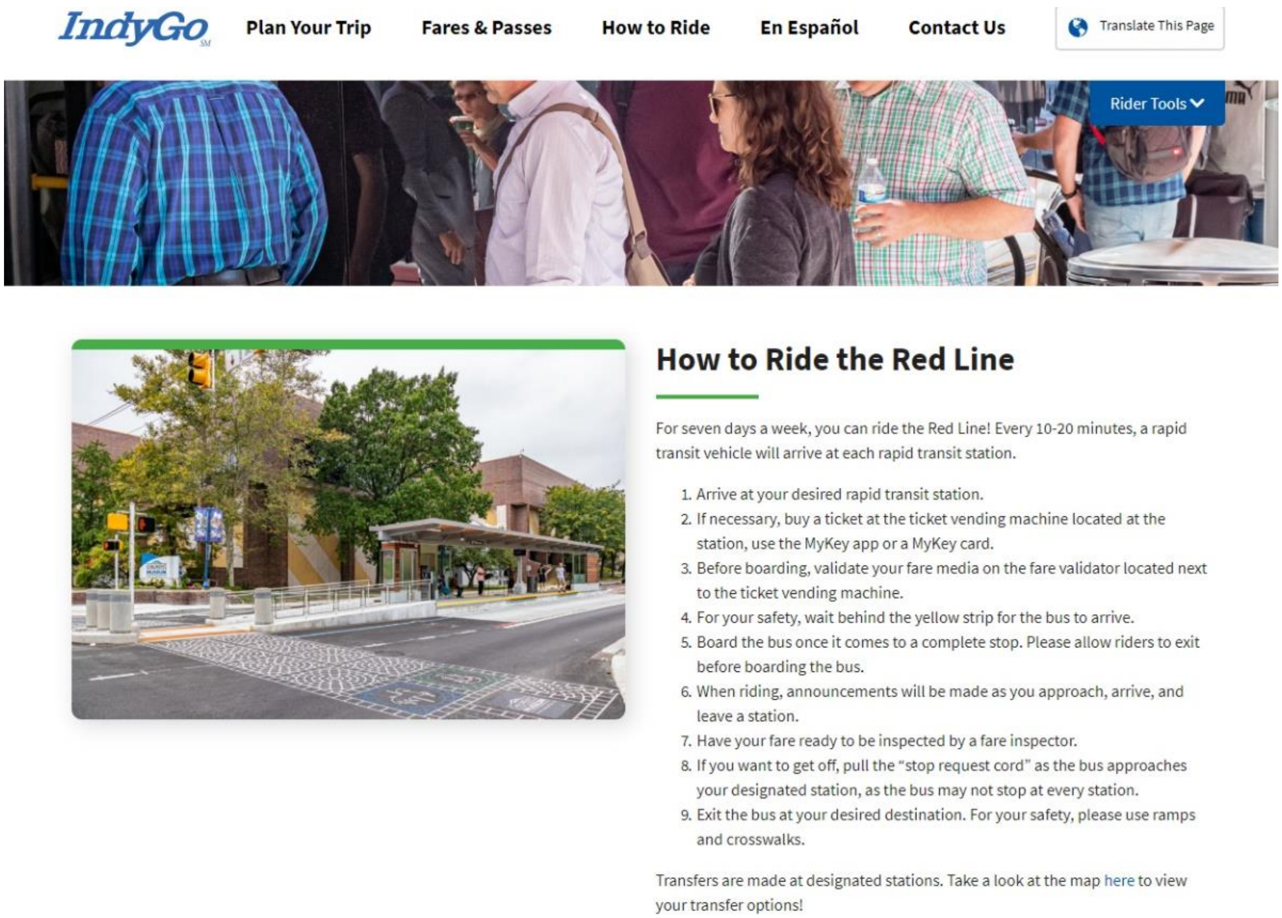
The buses should include holders for schedules that passengers can take with them. The BRT schedules should also include information about how to ride BRT, including fare payment and all-door boarding. As more people transition away from paper, it is important for passengers to be clear on where they can go online to get information about the BRT service; this should be done with displays on the bus or at the stations. If advertising is provided on the bus or at stations, it should not detract from passengers being able to find and comprehend information about how to complete their BRT trip.

7.7.2 Online resources

In addition to providing clear information on the system, it is important for agencies to provide information on their websites about how to ride BRT service and how it is different from other transit services. This is important for helping first-time riders understand what to expect on the system and know how to complete a trip before trying the service.

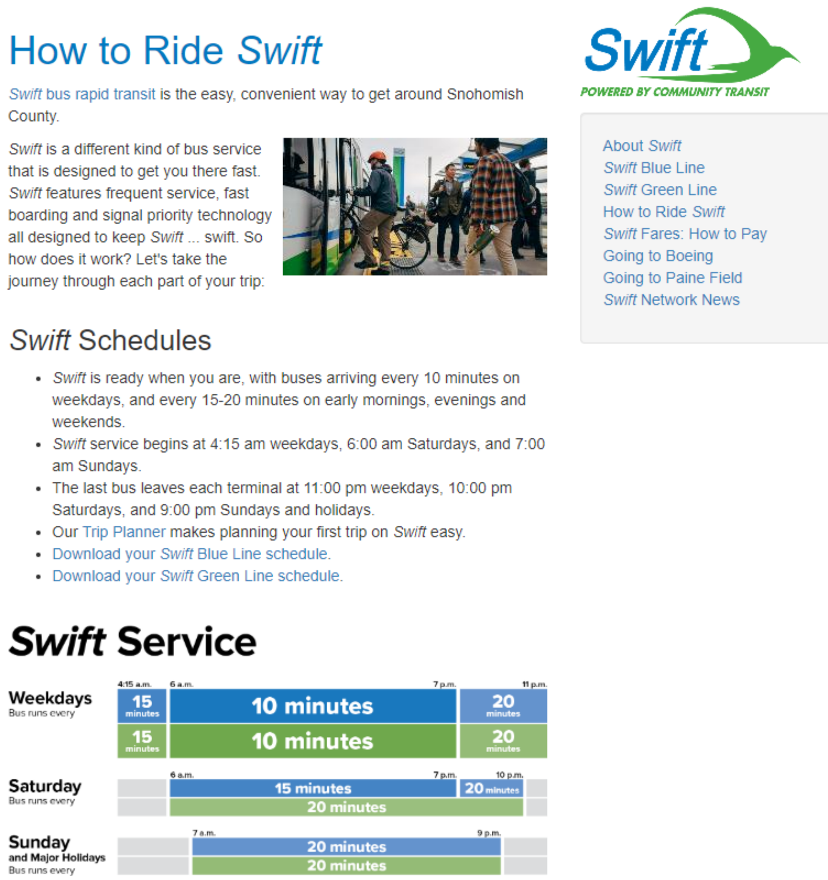
Figure 24 is a very simple example from the IndyGo Red Line website that outlines the basic steps to ride BRT.

FIGURE 24
How to Ride the Red Line Information from IndyGo



It is also common to include information about the service span, frequencies, fare payment, bike policy and route maps on the "How to Ride BRT" pages. Alternatively, that detailed information could be provided on other sections of the web page combined with information for all routes. **Figure 24** is the initial screenshot from the "How to Ride Swift" page from the Community Transit web page and includes links to pages that provide information about using Swift to connect to key destinations or other services.

FIGURE 25
How to Ride Swift Information from the Community Transit Web Page



7.7.3 Motorist education

Given that very few BRT systems in the U.S. are completely separated from automobile traffic, it is important that the launch of a new BRT project include education for motorists so they can safely navigate around the BRT corridor. The following are some examples of the types of items that should be included in motorist education:

- vehicle restrictions in BRT guideways
- guideway crossings
- changes to traffic signalization
- pedestrian access and new crossing locations

Motorist education is especially important for BRT projects on existing arterials that include significant changes to roadway geometry, driver patterns including access, and traffic control. The BRT corridor should be intuitive for drivers to understand with appropriate signage and striping. However, new BRT corridors may be the first time that bus priority treatments are implemented in a region, so the signage and striping may be new to motorists, supporting the need for supplemental information. **Figure 26** provides an example of the type of information that the City of Albuquerque provided to educate motorists about how to safely navigate the changes to Central Avenue with the addition of BRT.

FIGURE 26
Driver Education Information for the BRT Corridor in Albuquerque

Driving on Central Avenue

Stay in Your Lane, to Keep Everyone Safe

Driving on Central Avenue

ART runs in the middle of Central Avenue between Coors and Louisiana.

- Make left turns and U-Turns, only at traffic lights.
- Buys only means stay in your lane.
- Crossing double lines means fines.
- Only buses, emergency and ART maintenance vehicles are permitted in the ART lane.

HAWK Signals

High-intensity Activated crossWalK beacon (HAWK) is a traffic control device used to stop road traffic and allow pedestrians to cross safely.

- These crosswalk lights are similar to regular stoplights:
  - Yellow = slow down
  - Red = stop.
- If the crosswalk lights aren't on, continue driving through.

Bus Signals

- Bus signals are mounted on traffic signals in front of the bus lanes.
- These signals are black and white and consist of a horizontal line, a triangle and a vertical line.
- These signals only direct transit vehicles. Drivers should ignore them.

Pace Suburban Bus outside of Chicago uses an innovative approach to educate drivers on its freeway Express Bus service that operates on the shoulder to avoid congestion. As shown in **Figure 27**, the markings on the outside of the Pace Express buses includes language that the bus is "authorized to use the shoulder." This is an easy-to-understand approach to alerting drivers to the fact that the bus is allowed to use the shoulder and that the shoulder treatment is for the bus and not for general autos.

FIGURE 27
Paint Scheme That Includes Driver Education Information (Pace Express Bus, Chicago metro area)

8. Service monitoring and refinement

8.1 Performance measures

Performance measurement and monitoring is a critical element of all service design and needs to be considered from the outset of BRT planning and included in the project design and budget (both capital and operating). Policy objectives of the BRT project should guide the selection of performance guidelines and indicators, with consideration also given to data and resource needs for ongoing monitoring and analysis.

8.1.1 Productivity

Productivity objectives are perhaps the most valuable to service design, as they serve as the basis for reallocating or adjusting service levels. Numerous productivity standards are possible; however, two are of particular value: boardings per service hour and load factor (or utilization rate).

Boardings per service hour (or per mile) is an industry standard indicator for assessing productivity. This provides a means of comparing similar routes (those using the same fleet type), which makes it useful for many BRT systems. However, boardings per hour is an insufficient measure for comparisons between different types of routes (e.g., those with high turnover vs. those with long single-seat rides) or transit services with different vehicle types and capacities.

A preferred means of equitably measuring productivity of transit services is load factor or utilization rate. Load factor is a measure of the demand compared with the available capacity, which in BRT applications translates best into a ratio of passenger miles to seat miles. This can guide operational adjustments to better match supply with demand (such as introducing short-turns or different sized vehicles).

For illustrative purposes, **Table 8** is a sample of minimum efficiency guidelines for bus services in Vancouver, British Columbia, showing the differing productivity guidelines for B-Line (low-cost BRT) and other bus services. Figures are average percentage of seats occupied over the entire route in the peak direction, measured as passenger-miles divided by seat-miles.

TABLE 8
Minimum Efficiency Guidelines for Vancouver BRT

Service Brand	Weekday Peak Periods	Weekday Midday	Evening	Weekend Daytime
B-Line	50%	40%	30%	30%
Express coach	50%	40%	20%	30%
Bus	30%	25%	15%	20%
Community shuttle	25%	15%	10%	15%

Source: TransLink Transit Service Guidelines (2004)

8.1.2 Reliability

Service reliability is an important measure of both system performance and customer experience. Two key indicators are schedule adherence and headway adherence. Schedule adherence is the traditional approach to measuring service reliability. However, on BRT services with high frequencies and without published schedules, headway adherence is a much more relevant measure. It can be measured both at the route level as well as at the individual trip level or at the stop level. Analysis of this sort requires extensive data, reasonably available only through automated collection (e.g., AVL).

If schedule adherence is not being monitored, then an indicator of speed (or delay) should supplement headway adherence measures.

The following example is from San Francisco (SFMTA), which is used for all transit modes and should be applicable for BRT:

- **On-time performance target: 85 percent.** At least 85 percent of vehicles must run on time, with "on time" defined as 1 minute early to 4 minutes late.
- **Headway adherence target: 85 percent.** Actual headways must be within the lesser of 30 percent or 10 minutes of the scheduled headway.
- **Service delivery target: 98.5 percent.** 98.5 percent of scheduled service hours must be delivered and must begin service at the scheduled time.

Examples of on-time performance definitions for various modes are as follows:

- **SFMTA (San Francisco):** 1 minute early to 4 minutes late
- **NYMTA (New York):** 5 minutes early to 5 minutes late
- **CTA (Chicago):** 1 minute early to 5 minutes late
- **LACMTA (Los Angeles):** 1 minute early to 5 minutes late
- **WMATA (Washington) Bus:** 2 minutes early to 7 minutes late (all time points)

Examples of headway adherence definitions for various modes are as follows:

- **WMATA (Washington) Rail:** Less than 2 minutes deviation for peak trips; less than 50 percent deviation the rest of the day
- **SFMTA (San Francisco):** Within the lesser of 30 percent or 10 minutes of scheduled headway

8.2 Data collection and analysis

Extensive data collection will be necessary to support the measurement of these indicators. Traditional manual data collection methods of ride checks and point checks are increasingly being supplemented by automated data sources. The two primary sources of automated data are automated passenger counter (APC) and automatic vehicle location (AVL) systems. In some cases, these can be further supplemented by fare box data.

8.2.1 Automated passenger counters

APC systems enable the collection of a high volume of highly detailed passenger data. The systems are composed of both hardware and software to produce passenger boarding and alighting counts. The count records include time clock, GPS/odometer and other information (e.g., wheelchair ramp deployment).

A wide array of passenger and operational information can be derived from this data, including the following:

- boardings, alightings and load at any given location and place in the system
- arrival and departure times at stops and timing points
- travel speed and travel time between stops
- dwell time at stops

Deployment of APC units over 10 to 15 percent of the entire fleet is considered an industry minimum to reliably gather sufficient data for meaningful analysis. In many systems, there is a move toward a much higher degree of APC deployment on dedicated BRT subfleets, with many agencies opting for full (100 percent) APC coverage.

8.2.2 Automated vehicle location

AVL systems are complementary to APC data in providing operational data to support service analysis. Detailed operational data that AVL systems can provide include the following:

- constant data stream with the location of all vehicles in real time
- automatically or manually recorded events (stop, door opening, lift deployment, etc.) associated with a trip, time and location
- speed (actual, average, variance)
- headways (actual, average, variance)

As most AVL systems have been designed primarily for real-time applications, they do not necessarily capture and/or archive data that would be valuable for off-line analysis. Those wishing to maintain and analyze AVL data should procure systems with the ability to do so.

Overall, automated systems can provide a far greater amount and detail of information, and with a shorter turnaround time than is possible with manual data collection. The result is the possibility of almost instant extensive data for all trips and time conditions, which is highly reliable and easily accessible to a broad range of users. The challenge is that these applications require a lot of data processing to produce high-quality, reliable data. The data produced by automated systems (particularly APC) needs to be interpreted and transformed to eliminate data error or bias. Of particular concern to BRT systems is the high degree of counting error generated by many APC systems in heavy load situations. Realistically, at least some amount of manual data collection may remain essential to calibrate or supplement the APC results.

Related APTA standards

APTA Sustainability and Urban Design standards
APTA-BTS-BRT-RP-001-10, Rev. 1, "BRT Branding, Imaging and Marketing"
APTA-BTS-BRT-RP-002-10, Rev. 1, "Bus Rapid Transit Stations"
APTA-BTS-BRT-RP-003-10, Rev. 1, "Bus Rapid Transit Running Ways"
APTA-BTS-BRT-RP-005-10, "Implementing BRT Intelligent Transportation Systems"
APTA SUDS-UD-RP-009-18, "Bicycle and Transit Integration"

References

National Association of City Transportation Officials (NACTO) "Transit Street Design Guide, https://nacto.org/publication/transit-street-design-guide/

TCRP Report 165, "Transit Capacity and Quality of Service Manual, http://www.trb.org/Main/Blurbs/169437.aspx

TCRP Synthesis 50, Use of Rear-Facing Position for Common Wheelchairs on Transit Buses, http://www.trb.org/Publications/Blurbs/153576.aspx

TCRP Synthesis 109, "System-Specific Spare Bus Ratios Update, http://www.trb.org/Main/Blurbs/170537.aspx

Definitions

dwell time: The time a transit vehicle spends at a stop to discharge and take on passengers, including opening and closing doors.

headway: The time interval between the passing of successive transit buses or trains moving along the same route in the same direction, usually expressed in minutes. Also be referred to as "service frequency."

intelligent transportations systems (ITS): An umbrella term used to describe the variety of technologies, treatments and strategies that allow improvements to the flow of transit systems.

Abbreviations and acronyms

ADA	Americans with Disabilities Act
APC	automatic passenger counter
AVL	automatic vehicle locator
BAT	Business Access Transit
BRT	bus rapid transit
CAD	computer aided dispatch
CIG	Capital Investment Grants
CNG	compressed natural gas
CTA	Chicago Transit Authority
FCEB	fuel cell electric bus
FTA	U.S. Federal Transit Administration
ITS	intelligent transportation system
LACMTA	Los Angeles County Metropolitan Transportation Authority
LRT	light rail transit
NACTO	National Association of City Transportation Officials
NATSA	North American Transportation Services Association

NYCTA New York City Transit Authority
O&M operations and maintenance
PID passenger information display
ROW right-of-way
RTPI real-time passenger information
SFMTA San Francisco Municipal Transportation Agency
SSMP Safety and Security Management Plan
TCRP Transit Cooperative Research Program
TSP transit signal priority
WMATA Washington Metropolitan Area Transit Authority

Summary of document changes

- Document combined two previously separate recommended practices: APTA BTS-BRT-RP-004-10, "Bus Rapid Transit Service Design" and APTA BTS-BRT-RP-007-10,"Bus Rapid Transit Operations"
- More clearly defined BRT service as "Basic BRT" or "Premium BRT"
- Updated document overall to reflect more current experiences on BRT systems
- Removed outdated BRT system references and images
- Updated BRT examples cited and pictures of BRT systems

Document history

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