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APTA BRT Operations Working Group

Operating a Bus Rapid Transit System

Abstract: This *Recommended Practice* provides guidance for operational considerations for bus rapid transit systems.

Keywords: bus rapid transit (BRT), operations

Summary: BRT is 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.

Scope and purpose: The purpose of this document is to provide guidance to planners, transit agencies, local governments, developers and others interested in operating a BRT systems or enhancing existing BRT systems. This *Recommended Practice* is part of a series of APTA documents covering the key elements that may comprise a BRT system. Because BRT elements perform best when working together as a system, each *Recommended Practice* may refer to other documents in the series. Agencies are advised to review all relevant guidance documents for their selected elements.

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The American Public Transportation Association greatly appreciates the contributions of the **BRT Operations Working Group**, who provided the primary effort in the drafting of this *Recommended Practice*.

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1.1 Sign-up

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.

1.1.1 Option 1: BRT shifts available for all to choose

Positives:

- Greater flexibility (operators on a split shift can work one part BRT and one part conventional).
- Only one shift selection process needed.
- May be preferred by union.
- No need for a second spareboard.

Negatives:

- 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.

1.1.2 Option 2: Separate roster for BRT operators

Positives:

- 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.

Negatives:

- Reduced flexibility in shift scheduling (particularly in systems with lower service levels).
- Need to run multiple shift selection processes.
- May be more difficult to work through with union (particularly if selection to the BRT pool is by means other than seniority).
- A separate spareboard is required, potentially reducing efficiencies.

1.2 Employee incentive considerations

Some transit providers may choose to pay a premium to those operators who work on BRT, particularly if the BRT operators are held to a higher standard of qualifications, customer service and appearance/uniform. However, this is not necessarily 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 may require additional training and/or qualifications for transit staff.

2. 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.

2.1 Service/performance goals

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 the system is being 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.

2.2 Signaling

2.2.1 Transit signal priority

Transit signal priority (TSP) is commonly used in BRT systems. While simple to use, there are several considerations that may require additional training:

- how TSP is actuated (bus positioning, upstream detection, etc.)
- what it can and cannot do (i.e., no absolute green priority)
- safety aspects (do not automatically assume the TSP will be actuated)

This training can be partly accomplished through classroom sessions, but many aspects can be most effectively taught using on-board instruction (where the BRT facilities are available for use).

2.2.2 Block signaling

Some BRT systems, such as EmX in Eugene, Oregon, use a form of block signaling in which entry into a single lane section of a BRT corridor is controlled by block signals, similar to those used on a rail transit system. This is quite different from anything most bus operators have likely experienced. A combination of classroom work, explaining the principles of block signaling (and the meaning of different signal indications if they are nonstandard) coupled with on-road training in their use, should be effective in training operators in the safe utilization of this system.

2.3 Queue jump lanes

The primary training considerations in the use of queue-jump lanes are the need to maneuver to merge back into general-purpose lanes after utilizing the queue-jump lane, and the need for operators to be alert for vehicles pulling into the queue-jump lane in an attempt to get a jump on traffic. On-road training would be the most effective method for operators to practice these items.

2.4 Narrow right-of-way

In some instances, it may be necessary to narrow a BRT right-of-way in order to fit the facility through a pinch point, such as on the LACMTA Orange Line. Operators should be made aware of any specific policies pertaining to these areas, trained to use additional caution in these areas, and should be given an opportunity to practice maneuvering a bus through these areas.

2.5 Turning radius for articulated vehicles

For many transit systems, introduction of BRT service may be the first time articulated transit buses have been put into service. An articulated bus may be more maneuverable than a typical 40-foot bus, with a tighter turning radius, because it is actually two smaller sections of bus joined by an articulated joint.

Once bus operators have had a chance to familiarize themselves with the articulated bus through some on-road training, they will typically find that the bus is no more difficult to operate than any other transit bus.

2.6 Technology

The introduction of BRT service and new intelligent transportation system (ITS) technologies can result in substantial new staff training and development requirements for service control staff. Typical needs include the following:

- **Infrastructure familiarization:** Whether the BRT service is part of a large BRT facility with a separate right-of-way and advanced stations or is a simpler approach operating on mixed flow or in bus lanes with enhanced shelters, there will be a significant number of items that service controllers will need to become familiar with. These include the expected operation of all of the systems and equipment on the stations and the vehicles (so the service controllers know what the systems should be doing and what to do or whom to contact if the systems aren't working) and the locations and turning options for all the access points.
- **Operation of new technologies:** BRT service introduction is often accompanied by the introduction of new ITS systems and technologies. Service controllers need to learn how to operate and make effective use of new communication systems, AVL, transit signal priority and other potential technologies.
- **Additional training for new roles:** If assigned to work on service control issues in a large busy transit station, service control staff may need to have additional training in customer service techniques. Use of AVL systems and the potential for anticipating service control requirements may necessitate training in decision making tools and systems. Training to recognize potential safety or security problems before they happen may also be appropriate for service control staff who are also overseeing closed-circuit monitoring systems.

3. 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 are sufficiently different that they may require separate operating rules. This section highlights those cases.

3.1 Lane usage

> **NOTE:** This section is intended for those BRT operators who run their vehicles on mixed-use roadways. BRT operators who operate on a dedicated running way should refer to the APTA *Recommended Practice* "Designing Bus Rapid Transit Running Ways."

With traditional bus operations, vehicles typically spend most of their time traveling in the curb lane, with minimal lane changes. However, BRT introduces the potential for vehicles to travel in other lanes, and policies must be considered in this regard. Some operators may choose to be prescriptive in what lanes vehicles should travel in, while others may allow the bus operator to decide based on conditions.

3.1.1 Curb lanes

In situations where BRT stations are at the curb, the BRT vehicles will be required to make use of the curb lane, at the very least when servicing stations. In corridors with a mixture of BRT and conventional transit buses, the curb lane may become too slow for effective BRT operations due to the frequently stopping conventional services. Also, in mixed-traffic situations, the curb lane tends to be the slowest lane due to right-turning traffic. However, in situations where BRT is the only transit operating in a corridor, and is operating in a dedicated lane, the curb lane can be an effective option. It should be noted that in many cases, even with a dedicated transit curb lane, private vehicles are often permitted to enter that lane in order to make right turns at intersections.

3.1.2 Median lanes

The median lane can allow more efficient operations than the curb lane in some situations, as it allows the BRT vehicles to avoid right-turning traffic and conventional buses making frequent stops. However, if stations are located at the curb, then buses will be forced to make a right-hand merge to service the stations, which can be difficult in high-traffic situations. Operator familiarization training may be required for median lane usage, particularly if median lane running is not permitted in the transit system. Even with this familiarization training, there will be a period of adjustment while operators become accustomed to running in the median lane.

3.1.3 Shoulder lanes

Shoulder lanes are used in some BRT systems as a means of providing transit priority. These lanes are typically located at the right side of a highway and are normally narrower than standard travel lanes. However, some jurisdictions, such as Ottawa, provide shoulder lanes that are the same width as a standard travel lane. In some locations, their use by transit vehicles is limited and is subject to tight operating restrictions, while in other locations there are few restrictions on use.

In Minneapolis-St. Paul, use of the shoulder lanes is limited to transit buses, and then permissible only under the following conditions:

- Highway traffic must be moving at less than 35 mph.
- Maximum speed in the shoulder lane is 35 mph .
- Buses are required to re-enter the standard highway lanes if the shoulder is obstructed, and must yield to any vehicle entering the shoulder.

A shoulder lane can be a relatively inexpensive method of providing transit priority, as it typically only requires paving on an existing shoulder area. However, it is a nonstandard use of a highway shoulder in most jurisdictions, and in most cases will require buy-in from state or provincial highway authorities. There is also some public education required so that motorists are careful to check for oncoming buses before pulling over on the shoulder.

In Ottawa, shoulder lanes form significant sections of the Transitway. These shoulder lanes are used at all times by OC Transpo buses, and buses operate at full highway speeds in these lanes, regardless the speed of adjacent highway traffic.

Ottawa is currently studying the possibility of further improving the safety and effectiveness of these lanes. Measures under consideration include a painted buffer to increase separation between the transit lanes and general-purpose lanes, improved hazard protection and minor widenings of the asphalt surface at key locations.

3.1.4 Other lane types

The lane types described below are less commonly used in on-street BRT applications; however, some jurisdictions have found them to be suitable for their operational requirements given the site-specific opportunities and constraints within particular areas. These facility types will require varying degrees of additional training if they are not used in conventional transit services before the implementation of BRT.

High-occupancy vehicle lanes

High-occupancy vehicle (HOV) lanes are used in many areas as a means to encourage carpooling and transit use. These lanes can be beneficial to transit vehicles and should be used in most cases, especially when the lane is pre-existing. However, since these lanes are shared with other HOV vehicles, they tend to not provide the same priority to buses as designated transit lanes. As a result, HOV lanes should not be pursued in the initial design of a BRT system unless "pure" transit lanes are not an option.

One-way reversible/bi-directional lanes

This facility type can take two forms. One is a lane that changes direction based on time of day, normally following the direction of peak traffic volumes. In most jurisdictions, these lanes are marked with green arrows or red X's, indicating the allowable direction of travel. These can be beneficial in situations where there is only sufficient right-of-way available for one transit lane, which can now be use in either peak direction. Typically, these lanes are located in the center of the street or near the median, so there can be issues in using these lanes when buses are required to make curbside stops along their route.

The second form is that seen in Eugene, where there are single-lane sections used by EmX vehicles in both directions. In this case, both ends of the single lane sections are controlled by signals, similar to a rail transit block signaling system. This system prevents more than one bus from entering the block at any given time, preventing collisions, and allowing the lane to be used in both directions. This can become a significant impediment to increasing service levels, as higher service frequencies will increase congestion and delays at these choke points. As a result, this option should only be used where there is insufficient right-of-way available for dual lanes.

Contra-flow lanes

Contra-flow lanes are lanes that travel against the flow of traffic. One typical application is on a one-way street, where the right-hand curb lane in the direction opposite the flow of traffic will be designated for opposing transit use. Another application is to have a pair of transit contra-flow lanes in the center of a two-way street, with transit vehicles traveling opposite the flow of traffic for the side of the road they are on. These lanes have been used in several jurisdictions, including Pittsburgh and Los Angeles. Although they are not prevalent in the transit industry, some properties have found them to be quite beneficial.

These lanes are often politically difficult to implement and operate, as there is often a perception that they are unsafe due to transit vehicles traveling opposite the flow of general traffic, and a general unawareness by motorists and pedestrians of the contra-flow lanes. They frequently cause conflict with other motorists attempting to make left turns across the contra-flow lanes.

There are measures that can be taken to improve the safety of contra-flow lanes and therefore their chances of political/public acceptance. If there is sufficient road right-of-way available, a physically barrier, such as a jersey barrier or guardrail, can be effective in reducing the risk of head-on collisions. Ensuring that adequate signage is in place can also serve to inform other motorists of the contra-flow lanes and what precautions they should take. Also, the provision of fully protected left turns at signalized intersections can reduce the potential of conflict between left-turning vehicles and transit vehicles, although the impact of this on the potential signal delay to transit vehicles moving through the intersection should be carefully considered.

An example of a location where contra-flow lanes have been found to be useful is in Pittsburgh, where the Port Authority operates buses on three contra-flow lanes: on Smithfield Street and a portion of Wood Street in downtown Pittsburgh and on Fifth Avenue in the Oakland area (the location of Pittsburgh's major educational and medical institutions, as well as several cultural attractions). The contra-flow lanes are found to work well to maintain continuous movement through heavily congested streets. However, due to safety concerns with the many students in Oakland, there is a 15 mph speed restriction, and pedestrian barriers have been erected to ensure that people don't casually step out into the bus lane.

The contra-flow lanes are also somewhat self-enforcing when placed on one-way streets, which limits the number of unauthorized vehicles on the lanes.

Mixed BRT and LRT operations

In order to reduce BRT right-of-way costs, an operator may opt to utilize an existing transit right-of-way such as a light rail transit (LRT) line. Port Authority of Allegheny County's South Busway utilizes a segment of its LRT system between the Dawn stop and Station Square Station. While bus and rail vehicles have separate platforms at the stations, they share a common 1.5-mile right-of-way, which includes a 3,600-foot tunnel. The guideway is comprised of rails embedded in concrete. Separate wayside signals control rail and bus operations. During a weekday morning peak hour, 26 buses and 16 light-rapid vehicles pass through the combined LRT and BRT section. The combined bus and rail operations have worked successfully since the South Busway opened in 1977.

3.1.5 Operator choice

The most flexible lane choice option is to permit the vehicle operator to decide based on conditions. In an example where a system's stations are located at the curb, an operator will likely prefer to stay in the curb lane. However, if that lane should slow considerably, the operator would have the option to pull out into the median lane as he or she sees fit. This also allows the operator to pull out into the median lane to pass another bus that may be stopped at a local transit stop. Like median-lane running, this may require additional operator training, as most operators are likely instructed to stay in one lane as much as possible.

It should be noted that there is the potential for confusion with this option as to which vehicles are allowed to change lanes under what circumstances. For example, a BRT vehicle would likely have much more flexibility than a local bus. However, a local bus operator who watches a BRT vehicle changing lanes may decide that he or she should follow that example. While this alone is not likely sufficient to prevent implementing operator choice for BRT operations, it is something the transit provider should be prepared to deal with. This has the potential to reduce delays and also gives the operator a sense of empowerment to make decisions regarding the efficient operation of their vehicle.

3.1.6 Operating rules on a BRT facility

When operating a separate right-of-way for BRT, it is appropriate to provide a set of operating rules for all users of the facility to follow. Typical rules include the following:

- **Identification of permitted users:** As well as the drivers of the transit vehicles, the list of permitted users may include other transit staff (supervision, maintenance, etc.), emergency services when accessing an incident on the facility, emergency services using the facility as a route to an off-site incident, utilities accessing facilities on the facility, and other transportation service providers that complement the BRT service.
- **Rules of the road:** It is usually best to identify that conventional rules of the road that are common on the public roads adjacent to the facility will apply. Similarly, conventional and commonly used directional and regulatory signage that is the same as that used on the road system should be used whenever possible.
- **Speed of travel:** Standard operating speeds that apply to the full facility will be the simplest to enforce. For example, a maximum operating speed of 50 miles per hour between stations and 30 miles per hour in station areas is applied on Ottawa's Transitway system.
- **Stopping rules:** It may be appropriate to state that regular BRT services will stop and open doors at all stations, while special peak period express routes will stop only at designated stations.
- **Passing:** The operating rules should clearly state when buses are allowed to pass other buses or vehicles on the BRT facility. On most existing facilities, buses are allowed to pass other buses in station areas only where passing lanes are provided. The only other passing that is permitted is around disabled vehicles or maintenance vehicles, and this only at certain designated maximum speeds.
- **Equipment malfunction:** Rules and procedures are necessary to address how to continue operation in the event of a full or partial system or equipment failure (for example, what to do if the off-board

fare collection equipment at a station fails and customers must board without proof of payment, or how to operate if some of the automated passenger information systems are not functioning correctly).

- **Emergencies:** These rules should address what to do when a section of the facility must be closed, when a station must be closed or evacuated, or when a vehicle must be evacuated between stations.

3.2 Operations in stations

3.2.1 Speed through stations

Transit agencies should consider adopting special speed limits for vehicles passing through stations without stopping. This is particularly important in situations where a skip-stop or express service is operating through a station with waiting passengers. These passengers may expect that the bus will slow and stop in the station, and as such may not back away from the platform edge, potentially placing themselves in danger. Another approach could be to have BRT operators sound their horn as they approach the station, warning passengers to back away from the station edge.

It should be noted that there are many heavy-rail commuter operations across the world that operate non-stopping trains at full track speed through stations with passengers present. In these cases, the rail vehicles are typically much closer to the station platform than a BRT vehicle would be, since they are on a fixed rail, and a BRT vehicle would have the ability to move away from the station edge.

In the case of curbside stations, some properties may choose to install grade-elevated pedestrian crossings as a means to limit pedestrian incursions onto the running way, reducing the risk of having buses travel through the station at full speed. In order to encourage pedestrians to choose the grade separated route, a fence or other barrier can be installed on the running way, typically separating the opposing travel lanes. The intent of this barrier would be to make it inconvenient (or preferably impossible) to cross the running way at grade.

3.2.2 High-platform stations

Extra care should be taken when BRT vehicles approach high-platform stations. While side mirrors typically provide enough clearance for passengers waiting on a curb, at a high-platform station these passengers are now at a height that they risk a collision with the side mirrors on the BRT vehicle. Operators must be aware of this and take extra caution when entering the station. Having a marking on the platform edge that passengers stand behind when a vehicle is approaching, and signage reminding passengers about the potential for a mirror collision, can provide extra safety in this regard.

3.3 Queue-jump usage

3.3.1 Mandatory/optional

Transit agencies should consider whether BRT operators must use the provided queue-jump lanes or whether it is their option based on local conditions. The main determinant of this is the configuration of the queue-jump lanes, under what conditions it is beneficial to use them, and whether there are any conditions where it would not be beneficial to use the lanes.

In a situation where a queue-jump lane does not have a dedicated discharge lane on the far side of the intersection, transit priority is achieved by giving the BRT vehicle a transit priority signal while competing traffic continues to face a red signal. The BRT vehicle then merges into the general-purpose lanes on the far side of the intersection. However, if the BRT operator approaches the intersection on a stale green and has not yet merged into the queue-jump lane, it would be more beneficial to remain in the general-purpose lane through the intersection and proceed with moving traffic.

In a situation where the queue-jump lane has a dedicated discharge lane on the far side of the intersection, particularly if the discharge lane is lengthy, it is likely beneficial to use the lane at all times, as the BRT vehicle will never have to merge back into traffic passing through the intersection.

It should be noted that if capital funds are spent on queue-jump lanes, operators should be encouraged to use them as much as practical. If queue-jump lanes are frequently not used, it can call into question whether the initial investment in the queue-jump lane was sound to begin with.

3.3.2 Transit signal priority

Vehicle preemption/priority is deployed to provide certain classes of vehicle right-of-way where potential collisions would prove catastrophic or public purpose is furthered by its use. Some types of vehicles supersede others when potential vehicle conflicts might occur; in general, the vehicle that is more difficult to control is higher in the hierarchy. A typical hierarchy might provide right-of-way in the following sequence:

1. draw or swing bridge
2. railway (freight or passenger)
3. emergency vehicle
4. light rail
5. bus
6. garbage truck/street sweeper

In general, vehicles in emergency response mode receiving preemption (fire trucks, ambulances, police cars, etc.) will receive a prompt display of a green traffic signal, with a special sequence of signal phases and timing to clear the intersection of opposing vehicles and pedestrians. In effect, the intersection is shut down for all opposing traffic movements, often with adverse effects on general traffic flow. Although technically possible to implement, it is not recommended that bus signal priority (BSP) operate like vehicle preemption.

A typical application of BSP will have the traffic signal controller informed of the imminent arrival of a bus requesting priority. The controller will check for conflicts with vehicles calling for preemption or pedestrian request, and in their absence determine where in the signal cycle the bus will arrive at the intersection. If the controller determines that the traffic signal will be displaying red to the bus, then the controller may advance the presentation of the green (early green). If the green is in the process of turning to red, then the controller may hold the green display (green hold) until the bus clears the intersection.

Buses in exclusive rights-of-way will behave similarly to light-rail vehicles in exclusive rights-of-way in terms of signal priority requirements. Being independent of the general traffic flow, these operations may generate a high incidence of requests for signal timing adjustments. Empirical evidence indicates that, once buses in general traffic are keeping up with a traffic platoon, they often will arrive at a traffic signal during a green display and no extraordinary signal timing adjustments are required to clear the intersection.

In most situations, automatic actuation should be used for signal priority. There have been experiments with driver-actuated signal priority, with the instruction that the signal priority be used only if the vehicle was behind schedule. However, it was found that operators were using it when on time or outside of revenue service, which caused disruptions to the overall signal timing patterns in the highway network. Several technologies are available to identify the approach of buses independent of operator intervention, including optical/infrared emitters, pavement loops and GPS/spread spectrum systems. All have proven practical, and transit agencies are encouraged to work with their highway agencies to apply a cost-effective technology to their local environment.

With respect to traffic signal displays, operations in exclusive rights-of-way and at queue jumps may choose to display light rail “bar” signals in BRT application. In mixed traffic, it is generally appropriate to display standard tri-color ball indicators, unless BRT vehicle behavior is different from that of general traffic.

3.4 Use of BRT running way

Once built, transit providers may find themselves under pressure to allow use of the BRT running ways by others. In some cases, a multi-functional BRT running way may be considered by some as a way to increase the overall appeal of a project still under consideration.

3.4.1 Emergency vehicles

Most jurisdictions permit emergency vehicles to use BRT facilities. BRT running ways should be designed such that there is a shoulder wide enough for BRT vehicles to pull over on both sides of the running way so an emergency vehicle can pass between them. Allowing emergency vehicles to use the running ways during non-emergency situations can increase the safety of the overall system, especially in the case of police cars, by increasing the visibility and presence of the police in the transit system.

3.4.2 Other service vehicles

Other service vehicles, such as delivery and maintenance vehicles, should be permitted to use BRT facilities only when necessary to reach their destination. For example, Ottawa permits these vehicles use of the Transitway since they are serving stations and other facilities located on the Transitway. However, in a BRT system where all stations and other facilities are on-street, there is no need for service vehicles to use transit facilities, as they can reach their destinations via the public road network.

3.4.3 Other bus operators

There are two approaches to allowing other bus operators to make use of BRT facilities. These two approaches are best illustrated by Ottawa and Pittsburgh.

Ottawa allows other bus operators to use the Transitway, since all operators contribute to taking cars off the road and hence have a goal that is in parallel with OC Transpo. Ottawa does not charge for use of the Transitway. It could be argued that since these bus operators remove private vehicles from the Ottawa road network, there is a reduction in overall road congestion and repair costs, negating any need for the city of Ottawa to collect user fees from the bus operators.

In Pittsburgh, other public bus operators are permitted to operate on certain segments of the busway system. All other operators with routes serving downtown Pittsburgh converge at Penn Station on the East Busway, thus facilitating connections between those services and East Busway routes as well as connections among the other regional transit providers. However, private intercity carriers are prohibited from using any of the busways due to concerns over driver training, liability, safety, operations monitoring, and financial issues.

3.5 Speed through intersections

Additional consideration should be given to speeds traveled between stations, especially through intersections. Many BRT systems that operate along a designated right-of-way may interface with other modes of transportation at intersections, therefore increasing the likelihood of conflict. In an effort to address this safety concern, certain cities, such as Miami and Los Angeles, have found it beneficial to decrease travel speeds through intersections. While it initially may affect overall travel time, these cities have found the difference minimal.

4. Schedule vs. headway operations

From an operational standpoint, there is little difference between headway-based and schedule-based BRT service. With rare exception, public transit service is scheduled, for the purpose of identifying work for the operator and resource allocation, if not for informing the public. The operator of the vehicle is assigned a start time and location for beginning the route; this is true whether the service is local or express and independent of mode.

In scheduled service, operators are assigned interim points of departure along the route; these are often called "time points." Operators are generally discouraged from departing time points ahead of schedule, and service planners generally attempt to space vehicle appearances along the route for the purposes of customer convenience and to prevent overloading vehicles. These time points—or a subset—are often identified on the published schedule.

With headway-based services, efforts are made to maintain periodic vehicle appearances along the route. Schedules may not be published, although route maps are commonly provided and the periods for appearances are identified. Operationally, headway-based services often instruct the vehicle operator to maintain the greatest safe and legal operating speed—bearing in mind passenger comfort—possible for the route.

A hybrid operation is also employed by some transit properties, where a schedule is provided but all time points posted are advisory. Customers are encouraged to arrive sufficiently early at the bus stop in order to make their desired trip; operators incur no penalty for departure prior to the indicated time point.

The decision to provide a public schedule often depends on the perceived customer market being served. Regular customers quickly learn the nuances of operation and choose trips accordingly. Routes catering to more occasional users tend to provide schedules; customers generally have a set trip termination time for their travel (physician appointment, shift start, etc.) that requires a semblance of service reliability.

However, the inclusion of real-time passenger arrival information can help to increase passengers' acceptance of headway-based control, as it eliminates the uncertainty of when their vehicle will depart. Technology advances are making it possible to access this information from computers and personal communication devices, meaning that a passenger could check arrival times before evening leaving their home or place of business, greatly increase their convenience and hence acceptance of headway-based service.

It must be noted that scheduled service can result in suboptimal travel time for customers as drivers wait to depart at interim time points; similarly, headway-based service can result in suboptimal resource use on the part of transit agency if vehicles reach the end of the route sooner than expected and vehicles await subsequent departure. Exclusive rights-of-way or bus signal priority use can reduce adverse outcomes; however, regardless of how the service is marketed, the operation requires proactive management to maximize customer and service provider benefit.

5. Route monitoring and supervision

5.1 Introduction

The introduction of BRT service into a community often results in new challenges for the operations department or contractor of the transit agency. These challenges can include coming up with new procedures to manage high-frequency routes, integrating new technology and information (from automated vehicle location and transit priority systems, for example) into operating procedures, and training supervision staff.

The purpose of this section is to outline the potential differences and similarities between the supervision of BRT services and conventional transit services. This includes a discussion of control center versus road supervision service monitoring, the use of technology and preparing supervision staff for the new service.

5.2 BRT vs. conventional transit service

There are both similarities and differences between BRT services and conventional transit service. Understanding these similarities and differences is key to successfully managing the operation of BRT. These similarities and differences include the following:

- **Frequency:** BRT services are often planned to operate at high frequencies so customers do not have to use a timetable to plan their trips during most time periods. Headways of no more than every 10 minutes during peak periods are common, and routes as frequent as every two or three minutes exist (Ottawa's Route 95 is one example). High frequencies such as this can make service control more difficult using the conventional schedule monitoring techniques that many transit agencies are accustomed to. Rather than controlling BRT service using traditional adherence to schedule methods, it may be necessary to use headway control techniques. These can require use of dedicated on-street service control staff and/or the extensive use of vehicle location technologies and communication systems for remote service control.
- **Vehicle size:** High-capacity articulated vehicles are commonly used in BRT applications, and in some communities this is the only place where these vehicles might be used. These larger vehicles require longer stop areas, extended servicing facilities and reconfigured vehicle storage facilities compared with conventional vehicles. It should be noted that articulated vehicles do not generally require a larger turning radius than conventional vehicles do (although fixed-body 42- or 45-foot vehicles do often need a larger turning radius). If high-capacity vehicles are used exclusively on BRT service, then service control staff must take this into account when trying to replace a delayed or disabled vehicle. As a result, a larger proportion of spare vehicles may be required in order to maintain service.
- **Vehicle style:** As well as uniqueness caused by vehicle size, some BRT services will be stylized and branded in a manner that makes them stand out from the conventional service. In order to maintain the integrity of the BRT brand, it may be a requirement to only use the branded vehicles. This will likely require a larger proportion of spare vehicles in the BRT mini-fleet compared with the conventional fleet and create extra operating costs because vehicles aren't supposed to be crossing over for use on other services.
- **Fare collection:** Some BRT services allow for all-door boarding of vehicles with proof of fare payment. Passengers already have either a valid pass, a transfer receipt from a previous trip or a ticket purchased from a fare machine on the platform. These unique fare collection approaches often require different operating policies that must be managed by service control staff. In addition, off-board fare-collection equipment creates new security, technology and maintenance requirements that do not usually apply in a conventional system.
- **Safety and security:** BRT services often include substantial new infrastructure in the form new stations with substantial shelters and other passenger amenities, and sometimes new right-of-way infrastructure. All these facilities require appropriate monitoring and inspection in order to ensure the safety and security of staff, customers and the infrastructure itself. This could require patrolling by dedicated security or enhanced operations staff and/or the use of closed-circuit monitoring by staff in a control center facility.
- **Control center:** The addition of BRT service and infrastructure to a transit system often requires substantial changes to conventional control or communications center activities. The BRT infrastructure often has closed-circuit monitoring that requires a control center area for monitoring equipment and staff. One or more additional work stations may be required for staff to complete ongoing monitoring of the BRT service itself. In some cases, it may be necessary to develop a

separate BRT control center (as was required in Brisbane, Australia, because the BRT infrastructure was built and maintained by the state government while the various local public and private service operators provided the transit service on the facility).

5.3 Technology for BRT operations supervision

One of the primary elements of BRT implementation is the use of a variety of ITS technologies. The full range of possible ITS applications for use on BRT is described in the APTA Recommended Practice "Implementing BRT Intelligent Transportation Systems." The following points summarize those that apply to BRT operations:

- **Communications systems:** The fundamental building block of any transit or BRT ITS application is the availability of a modern communications system. This requires the ability to provide voice and data communications between the vehicles and service control, security and maintenance staff. Most other ITS applications cannot be successful unless there is an appropriate communications system available. There are a wide variety of technologies available to accomplish this, and agencies should consider integrating the BRT communications system in to their overall communications system.
- **Automatic vehicle location:** An AVL system involves the ongoing detection of the location of transit vehicles and communicating this information to service control staff. Most modern AVL systems employ a GPS technology to detect vehicle locations on a coordinate system, and software available to the service control staff provides information on location and compares this with the planned schedule.
- **Transit signal priority:** This refers to the process of dynamically changing the timing of traffic signals in order to improve the travel speed and reliability of transit service. Buses are detected in advance of signalized intersections, and changes are made to the traffic signal cycle in order reduce or eliminate the delay time at the intersection. The detection is made either using the AVL system or through on-site methods. When service is not frequent, it is often possible to allow every trip to take advantage of the signal priority. However, with frequent service found in many BRT applications, it is more common for the signal priority to be applied only if the bus is found to be behind schedule or if headway management is being applied for service control.
- **Closed-circuit monitoring:** This can occur at stations in order to monitor activity on the platforms and in vehicles. It can be applied for both customer safety reasons and for service demand management.
- **Panic button, emergency response:** The most common application of this technology is on board the vehicles. If an incident occurs on the bus, the driver is able to press a hidden panic button. This immediately triggers an alarm in the control center that causes action by the service control staff. When combined with an AVL system, the service controller is able to immediately determine the location of the vehicle and dispatch the nearest mobile service control staff and/or emergency services if necessary.

5.4 Supervision strategies

Conventional transit service control methods typically involve positioning staff at key locations around the system. Their job is to monitor the arrival and departure of the transit service at these locations and make adjustments as required in order to maintain the planned schedule. In medium and larger-sized systems, it is common for these on-site service control staff to be supplemented by one or more staff in a control center.

The volume of customers and frequency of service typically associated with BRT service can make it cost prohibitive to control these routes in the conventional manner—at least one service control person would be required at each end of the route and may not be able to address other routes at these locations. As a result, agencies often seek out other techniques to manage the service. Most common is making greater use of the control center and appropriate technology. One service controller at a work station displaying AVL information for the BRT service can monitor the location and schedule of all the buses on the route and be in touch with all drivers to ensure that they are maintaining headways and/or schedules. By viewing the service as a whole, the controller is often able to anticipate potential problems and take corrective action before they seriously impact the service to the customers.

6. Connection protection

The availability of relevant real-time transportation system data assists public agencies with the management of a region's multi-modal network of transportation services and infrastructure. Travelers in the region directly benefit from public management of the transportation network but also benefit from the availability of real-time data to help make informed travel itinerary decisions. While infrastructure may be currently in place to collect real-time transportation information, the data may not be integrated between modes (highways, streets, transit, etc.) and is not widely available to the traveling public.

Today, a significant and growing amount of real-time electronic data is being generated through a region's network of ITS infrastructure. Data being generated includes but is not limited to roadway travel speeds, traffic incidents, CCTV feeds and public transit vehicle location and schedule adherence. This information is used by roadway and transit operators to better maximize the efficiency of the region's multi-modal transportation network.

An Advanced Traveler Information System (ATIS) server can function as a central real-time data processing hub for public use applications. Potential applications include a multi-modal real-time transportation information Web site, a telephone-based "next-bus" system that will allow passengers waiting at a bus stop to call an automated phone system to identify when their bus will arrive at their specified location, on-street variable message signs displaying when the next bus will arrive or the estimated travel time from one location on a highway or roadway to another common location, and other public use traveler information systems.

6.1 Transit connection protection system

The transit connection protection (TCP) concept is modeled after a system used by the Utah Transit Authority (UTA) to improve the reliability of transfers from higher-frequency light -rail trains to lower-frequency bus routes. The TCP system examines the schedule status of the LRT trains and buses to determine if transfer connections are in danger of being missed. If the lateness of a train is within a pre-determined threshold (e.g., three minutes), a "hold at {station name} until {time}" message will be transmitted to appropriate buses waiting at the connecting rail stations via the bus onboard mobile data terminal (MDT).

General implementation requirements for deploying the TCP system include the following:

- Develop hardware and software specifications for the TCP server.
- Define and implement software development and customization needs.
- Define data input and output standards.
- Purchase and install TCP server.
- Identify, purchase and implement the data communications system network to accommodate data transmission between the TCP server and in-vehicle MDTs.

7. Public/rider education on BRT-specific items

Depending on the type of BRT service operated, the transit agency may need to educate its riders and citizens 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:

- **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 pre-payment 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).
- **Motorist education:** Education of the automobile driving population may be needed to advise them of BRT signalization, queue jumpers, lane changes, etc.
- **Dynamic message signs:** 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?).

Abbreviations and acronyms

ATIS	Advanced Traveler Information System
AVL	automatic vehicle location
BRT	bus rapid transit
BSP	bus signal priority
EmX	Emerald Express (Eugene, Ore.)
GPS	Global Positioning System
HOV	high-occupancy vehicle
ITS	intelligent transportation systems
LACMTA	Los Angeles County Metropolitan Transportation Authority
LRT	light rapid transit
MDT	mobile data terminal
TCP	transit connection protection
TSP	transit signal priority
UTA	Utah Transit Authority