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WHITE PAPER

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Bus Rapid Transit Working Group

Agency Experiences in Applied Infrastructure Design for Bus Rapid Transit

Abstract: This white paper shares insights on bus rapid transit infrastructure design from transit agencies who participated in an APTA survey and series of interviews.

Keywords: bus rapid transit, BRT, infrastructure design, intelligent transportation systems, roadways, transit signal priority

Summary: Transit agencies are increasingly interested in deploying bus rapid transit (BRT) service thanks to its potential to increase the efficiency and effectiveness of transit service and increase ridership at a lower cost than rail. Roadway design and bus priority are important elements in a BRT system to help the service avoid delays and improve the overall customer experience. This white paper shares the results of experiences and insights on roadway design and infrastructure from agencies who have implemented, or are about to implement, BRT. These agencies responded to a survey with 16 questions on roadway infrastructure design, bus lane enforcement, and ITS. Drawing from these agencies' responses, the white paper offers a set of lessons learned and considerations for agencies to keep in mind when planning and designing BRT in order to achieve maximum benefits and effectiveness. The results can also be used to identify areas for additional exploration and standards development.

Foreword

The American Public Transportation Association is a standards development organization in North America. The process of developing standards is managed by the APTA Standards Program's Standards Development Oversight Council (SDOC). These activities are carried out through several standards policy and planning committees that have been established to address specific transportation modes, safety and security requirements, interoperability, and other topics.

APTA used a consensus-based process to develop this document and its continued maintenance, which is detailed in the manual for the APTA Standards Program. This document was drafted in accordance with the approval criteria and editorial policy as described. Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

This document was prepared by the Roadway Infrastructure Sub-Working Group of the Bus Rapid Transit Working Group, as directed by the Bus Systems Standards Policy and Planning Committee. The sub-working group adapted a white paper developed by the Roadway Infrastructure Subcommittee of the APTA BRT Committee to create this document for the APTA Standards Program.

This document represents a common viewpoint of those parties concerned with its provisions, namely transit operating/planning agencies, manufacturers, consultants, engineers and general interest groups. The application of any recommended practices or guidelines contained herein is voluntary. APTA standards are mandatory to the extent incorporated by an applicable statute or regulation. In some cases, federal and/or state regulations govern portions of a transit agency's operations. In cases where there is a conflict or contradiction between an applicable law or regulation and this document, consult with a legal adviser to determine which document takes precedence.

This is a new document.

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Introduction

This introduction is not part of APTA BTS-BRT-WP-006-25, "Agency Experiences in Applied Infrastructure Design for Bus Rapid Transit."

This white paper was originally a project of the APTA BRT Committee, which formed three subcommittees to focus on specific areas of interest: roadway infrastructure, BRT policy, and vehicles and/or vehicle technology. This white paper represents the work of the Roadway Infrastructure Subcommittee which developed and conducted the surveys and interviews with transit agencies and drafted the original text including the lessons learned and considerations. The APTA BRT Working Group formed the Roadway Infrastructure Sub-Working Group to turn the subcommittee's work into a white paper under the APTA standards program.

APTA recommends the use of this white paper by:

- individuals or organizations that operate or plan to operate bus rapid transit systems;
- individuals or organizations that contract with others for the operation of bus rapid transit systems; and
- individuals or organizations that influence how bus rapid transit systems are operated (including but not limited to consultants, designers and contractors).

Scope and purpose

This white paper represents an effort by the APTA Bus Rapid Transit Working Group and its Roadway Infrastructure Sub-Working Group to allow transit professionals to learn about BRT roadway infrastructure design and implementation through the experiences of transit agencies that have implemented BRT. The white paper is based on a project of the APTA BRT Committee's Roadway Infrastructure Subcommittee, which conducted a 16-question survey of transit agencies and a subsequent series of interviews with six agencies about their BRT roadway infrastructure. These agencies shared their insights on what specific BRT roadway design elements they implemented, how they worked and could be improved, the lessons they learned, and what they would have done differently in hindsight.

The white paper includes a summary of all responses to each survey question; highlights from the six agencies selected for interviews and their interview responses; and what lessons learned and considerations can be derived from the survey results for other transit agencies designing and implementing BRT infrastructure elements.

This document is intended to complement APTA's suite of BRT recommended practices, especially the APTA Recommended Practice on Designing Bus Rapid Transit Running Ways, by providing insights from real-world experiences. The paper's findings could also be used as a springboard for further research and exploration by the Bus Rapid Transit Working Group.

Agency Experience in Applied Infrastructure Design for Bus Rapid Transit

1. Background

The U.S. Federal Transit Administration defines BRT as a high-quality bus-based transit system that delivers fast and efficient service that may include dedicated lanes, busways, traffic signal priority, off-board fare collection, elevated platforms and enhanced stations. These BRT elements, which can be implemented incrementally, can increase the efficiency and effectiveness of bus service, increase ridership, and improve air quality

As congestion continues to grow in most cities, transit travel speeds have declined significantly, creating the need for faster, more comfortable, and more affordable and efficient transit alternatives like BRT. BRT implemented correctly can offer significant benefits to a bus system at a much lower cost (generally about 20% of the cost of fixed rail). Given that in a majority of cities, buses will continue to be the predominant mode of public transit for most riders, BRT will continue to of interest to transit agencies looking to expand or improve service.

Bus priority plays an important role in achieving the operational improvements that make BRT attractive to riders. With the right bus priority features, BRT can avoid the delays that can slow regular bus services, such as traffic congestion, long waits at traffic signals and other intersection delays, or long dwell times at stops waiting for passengers to pay and/or board the bus. In addition to improving operational conditions like speed and reliability, these bus priority features can contribute to a safer operating environment, improve the customer experience, and reduce operating and maintenance costs.

HealthLine (Cleveland, Ohio)

1.1 Objective and approach

There are many resources about BRT, its potential benefits and challenges, and individual design elements that should be considered when implementing BRT. Many organizations have studied, analyzed, and developed BRT design guidelines, including the U.S. Federal Transit Administration, National Association of City Transportation Officials, Institute for Transportation and Development Policy, Transportation Research Board, and others. APTA has published six recommended practices on BRT elements: BRT Branding, Imaging and Marketing; Bus Rapid Transit Stations; Designing Bus Rapid Transit Running Ways; Bus Rapid Transit Service Design and Operations; and Implementing BRT Intelligent Transportation Systems.

This white paper seeks to complement that work by highlighting some real-world experiences with roadway design elements. The findings in this white paper draw directly from the experiences of 12 transit agencies that have implemented BRT and who responded to a survey with questions about what roadway elements they implemented, how they worked and/or did not work, lessons learned, and what they might have done differently in hindsight. Agencies were also asked how they enforced bus lanes and what intelligent transportation system (ITS) elements they have incorporated into their projects. Following this survey, six agencies were selected for follow-up interviews to get a deeper dive into their roadway infrastructure deployments and their lessons learned. The results from these interviews and surveys are summarized in this white paper. Please note that these findings represent the experiences of these 12 agencies; other agencies may have different experiences or lessons.

1.2 Survey and agency example respondents

This survey was posted to the APTA BRT Committee and garnered responses from 12 agencies. Agencies who completed the survey included New York City DOT; City of Madison; AC Transit; Pace Suburban Bus; Valley Transportation Authority (VTA); Community Transit; Tri-County Metropolitan Transportation

District of Oregon (TriMet); Jacksonville Transportation Authority (JTA); and Pinellas Suncoast Transit Authority (PSTA).

The agencies chosen for the case study examples were: Connecticut Department of Transportation; OmniTrans; Metro Transit (Minneapolis-St. Paul); Capital District Transportation Authority; Milwaukee County Transit System; and Greater Cleveland Regional Transit Authority.

2. Summary of survey responses

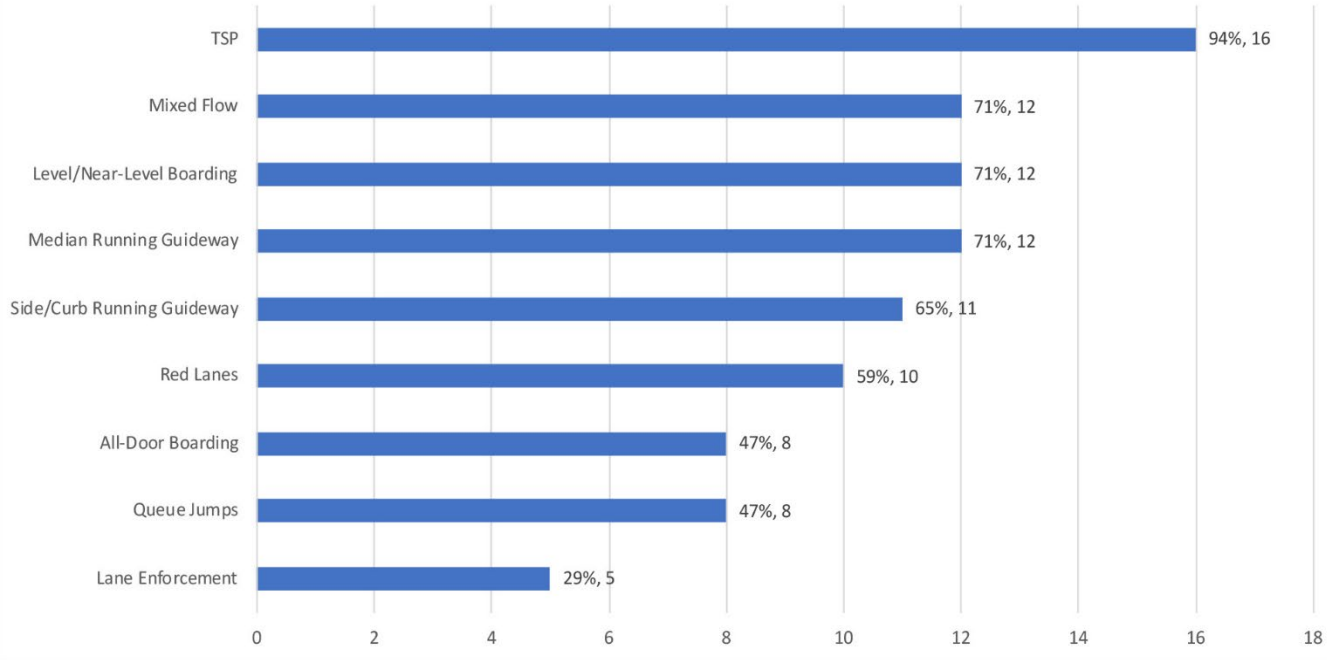
The survey consisted of 16 questions regarding roadway design, as well as a few questions on bus lane enforcement and the implementation of ITS elements. The roadway design questions include topics such as type of guideway, bus priority tools implemented, tough decisions made, safety issues, advice for other agencies/cities and more. See Appendix A for a list of all questions in the survey.

This section provides an overview and summary of what was learned from the survey responses.

2.1 Guideway/design features implemented by agencies

Agencies were asked to provide a list of their BRT roadway infrastructure in terms of the type of guideway and design features. Figure one shows all the BRT roadway infrastructure features identified in the survey and interview responses

FIGURE 1
BRT Roadway Infrastructure Identified in Survey and Interview Responses



The responses reflect the need for flexibility in design to meet the unique demands of the BRT system. On average, respondents selected at least six out of the 11 potential bus priority tools, with transit signal priority (TSP) being the most common tool utilized. This underscores a collective interest in a holistic approach that combines physical infrastructure improvements with operational enhancements.

Tools can be deployed in tandem with one another in the same corridor to provide cumulative benefits. For example, implementing dedicated guideway along portions of (or an entire) corridor in combination with TSP at intersections can improve operations throughout the corridor by mitigating congestion and reducing overall delay.

Approximately 75% of BRT systems from survey responses have a combination of dedicated guideway (median, side or curb running) and mixed flow, which highlights the flexibility of BRT. Notably, participants also introduced novel elements such as "5-door buses," "BAT lanes; HOV lanes," and "truck/transit priority streets or busways," indicating a willingness to explore innovative solutions. The variation in support for TSP suggests differing perspectives on the balance between schedule adherence and operational flexibility.

SBX (San Bernardino, California)

2.2 What agencies wish they'd known before implementing BRT

The survey asked agencies what they wish they had known before beginning to plan or design their BRT roadway infrastructure. A consistent theme is the **crucial need for up-front agreements and strong leadership among collaborating agencies.** A consistent preference for median stations emerged, based on perceived advantages in construction feasibility, cost-effectiveness and enforcement (e.g., stations for side/curb running BRT are more susceptible to encroachments by general traffic, delivery vehicles and bicycles). TSP was emphasized as an ongoing process requiring continuous monitoring and adjustment for optimal performance, highlighting its dynamic nature.

The paramount importance of community engagement was evident, with respondents expressing a desire for early and inclusive involvement, recognizing the substantial influence of community opinions on project

outcomes. Other notable insights include the absence of AASHTO (American Association of State Highway and Transportation Officials) standards for BRT design elements, challenges in persuading cities to prioritize transit over automobiles, and the evolving nature of toolkits and enforcement methods. Collectively, these responses underscore the nuanced nature of BRT planning, advocating for comprehensive agreements, sustained community engagement, and a nuanced understanding of the local context and stakeholder dynamics for successful and sustainable implementation.

2.3 What agencies would change in hindsight

The survey asked agencies what they would change, if anything, with the value of hindsight. A clear and unanimous theme emerged from the responses: **the vital need for improved delineation and separation of bus-only lanes.** Respondents uniformly advocated for clearer demarcation, emphasizing measures like barrier separation and red painted bus lanes, recognizing their significance in enhancing operational efficiency and traffic management within BRT systems.

Another consistent concern was the need for enhanced maintenance practices to ensure the reliability and safety of BRT infrastructure, including snow removal, trash clearance and warning edge strip repair. Additionally, agencies said queue jumps or dedicated right-of-way surfaces are pivotal for prioritizing BRT within traffic flow. Strategic reflections on route alignment underscore the importance of meticulous planning for passenger safety, and concerns about station placement, signage and TSP infrastructure are raised. The responses also highlight the need for adaptive toolkits, emphasizing annual adjustments to suit specific corridor needs in dynamic urban environments.

2.4 Tough decisions made in planning/design of BRT that worked out

Survey responses on what tough decisions they had to make in the planning and design of BRT roadway infrastructure revealed a collective willingness among respondents **to prioritize efficient bus operations over ideal traffic conditions**. The responses served to underscore the importance of making strategic trade-offs for the overall functionality of the BRT system. This theme is evident in decisions like acquiring surface parking lots to compensate for the loss of parking, maintaining center-running bus-only lanes despite resistance, and investing in roadway infrastructure.

One example of a tough decision was Capital District Transportation Authority's decision to include in their plan the space required for a possible conversion to a mobility hub with future electric bikes and charging stations. Importantly, the agency ensured that there would be plenty of conduit for various communications, power and related technology upgrades in the future.

The responses showcase a diverse range of tough decisions, including addressing traffic congestion, removing parking and cutting landscaping beds. Notable choices involve innovations like shared pedestrian/bike platforms and independent investments in roadway infrastructure, reflecting a commitment to explore unconventional yet effective solutions. However, the complexity of decision-making in BRT planning is underscored by some respondents expressing regret for opting for complex construction solutions, emphasizing the need for simpler approaches.

Overall, these survey responses highlight the intricate balance required to navigate competing priorities for optimizing functionality and ensuring the long-term success of BRT projects.

2.5 Bus lane widths

Agencies were asked to provide the width of the bus lanes in their BRT. Bus lanes implemented at those transit agencies surveyed ranged from 10 to 12 ft. However, agencies also acknowledged that **the wider the bus lanes, the better.** They believed that anything under 11 ft seemed to cause incidents and/or concerns.

Highway-based BRTs prefer a minimum of 11 ft and range up to 17½ ft, according to Pace Suburban Bus in Chicago.

2.6 Potential conflicts/safety issues

A critical issue with bus lanes is safety. The survey asked transit agencies to share any conflicts/safety issues they may have experienced along the roadway between buses, pedestrians and bicycles. Agencies reported the following:

- Agencies reported issues in curb lanes
- Pedestrian crossings at signalized and unsignalized intersections raised some safety concerns, including left-turn movements and conflicts with pedestrians from vehicles illegally using the bus lanes.
- Some agencies had issues with multiple municipalities and DOT requirements regarding signalized intersections and control of roads. Agencies were required to make pedestrian improvements to roads that the agency doesn't control, causing a hang-up with regulatory controls.
- Agencies reported conflicts with bicycles, including cyclists using the bus lane as a bike lane and parallel bike lanes at stations. This points to the need to implement protected bike and bus lanes.
- Agencies reported near-misses when there are cars behind the bus and cars already in the interior lane.
- Some had issues with the pull-out on major corridors.
- Some had issues with motorists using the through lanes to make turns rather than the BAT lanes, causing collisions and near-misses.

2.7 Advice agencies would give others regarding BRT planning

All the agencies that answered the survey readily provided advice to those who might be contemplating BRT for the first time. Some of their suggestions are included below:

- Visit other agencies to meet with their operations, maintenance and safety staff.
- Agencies considering precision docking should build a training station platform for drivers to practice.
- Agencies should identify and coordinate with all stakeholders including city stakeholders, traffic engineers, transit provider and DOTs. Work on MOUs early in the planning stages.
- Use median running ways; construction, costs and fleet costs can be high otherwise.
- Plan the service before planning the infrastructure.
- Be bold with the first build. This sets expectations on additional lines, including pushing for the maximum amount of dedicated lane mileage possible.

2.8 BRT elements believed essential to success

Agencies were asked what elements of their BRT infrastructure were essential to its success. A majority of agencies indicated that the number one key infrastructure element for BRT is **dedicated bus lanes**. Bus lanes coupled with TSP, which all surveyed agencies have, provide the greatest benefits and improvement in travel time and service reliability. Although some agencies have either some segments of their BRT and/or all their BRT in mixed flow, the implementation of dedicated bus lanes maximizes the potential of operational advantages and success.

This, however, speaks to the flexibility of BRT in that an agency can have a mix of BRT configurations to accommodate the different rights-of-way along an alignment and still see significant improvements, particularly when combined with other BRT elements. Other elements employed by agencies include median running; left-door boarding; fiber and communications at signalized intersections and stations; highly visible

stations with strong branding, proper scheduling and operations; dispatching; and a variety of curb-running, center/median-running and mixed-flow BRT.

2.8.1 Bus lane enforcement

The survey results indicated that **lack of bus lane enforcement may have an impact on the effectiveness of the bus lanes**. Lack of enforcement could lead to many violations by regular vehicles operating or illegally parking in the lanes.

A notable number of the agencies surveyed reported a lack of enforcement of their dedicated bus lanes. For those that do have some type of enforcement, some agencies rely on police enforcement, although this is typically not a high priority for law enforcement. Other agencies have implemented sophisticated measures such as camera enforcement using a combination of on-bus and fixed street cameras. Other agencies find that painting the bus lanes red helps with compliance, thereby reducing violations, while others rely mostly on signage and street markings.

2.8.2 Painting of bus lanes

Many agencies have chosen to paint their bus lanes red. This practice is more than an aesthetic consideration: it has shown to result in fewer bus lane violations and conflicts, since the **red bus lanes clearly delineate where regular vehicles should and should not operate**. Several participants said they use red paint in bus lanes, noting an apparent improvement in adherence by regular vehicles, although quantifying this improvement remains challenging. A recurring theme regarding the painting of the bus lanes red is the cost-effectiveness debate, balancing better compliance against the maintenance cost and upkeep of red lanes. The insights suggest that while red lanes are visually striking and potentially improve rule adherence, their upkeep is resource-intensive, raising questions about long-term sustainability and effectiveness.

NYC—Select Bus Service

The Institute for Transportation and Development Policy suggests other means of accomplishing red bus lanes, including the addition of a pigment in the concrete mixture itself. In this case, the coloration is a permanent part of the surface material, which reduces the long-term maintenance issue. As the surface begins to wear down, the color is retained. On the downside, the color tends to be less bright or vibrant that actually painting the lanes red.

Some agencies are choosing to not use red lanes but instead continue to mark bus-only lanes through the use of signage and pavement markings, a solid red stripe to highlight key sections of a bus lane such as at stops or sections with turn prohibitions, or a painted backing applied around the “Bus Lane” markings. Additionally, the painting of bus lanes is now considered an acceptable practice/option by transit agencies in the Manual on Uniform Traffic Control Devices.

2.8.3 Potential safety issues with vehicles traveling in bus lanes

Dedicated bus lanes can improve safety by reducing conflicts between buses and vehicles, thereby potentially reducing accidents on those streets. Many participants indicated minimal safety concerns, with one mentioning the benefits of 24-hour lanes for traffic calming.

Another response highlighted some initial issues with a contra-flow bus lane leading to crashes, but these diminished over time, suggesting a learning curve for drivers. Key insights from these responses include plans for implementing safety measures such as flexible delineators, enhanced pavement markings and additional signage. One notable approach involves a contra-flow bus lane on a one-way street, which has been observed to make unauthorized use by drivers inconvenient rather than dangerous, indicating a strategic balance between safety and practicality.

2.9 ITS elements implemented with BRT

Of the responses received, the following are some of the key intelligent transportation system elements employed as part of their systems:

- Various types of TSP including infrared, GPS radio, centralized software and cloud-based GPS; TSP reduces the amount of time a bus is sitting at a red light.
- Computer-aided dispatch/automatic vehicle location (CAD/AVL) based lane control
- Headway management, which is the process of controlling the spacing and timing of vehicles in a transit system. It is very different from a typical schedule-based service.
- Cameras.
- Passenger information signage/next bus systems.
- SCADA systems/Operations Control Center.

In terms of issues related to some of the ITS elements, TSP raises the most concerns in its effectiveness and the ability to obtain regular reporting. Some agencies are transitioning to cloud-based technology to improve TSP. GPS/cloud-based TSP is best as the maintenance is minimal and priority can be easily adjusted remotely.

Next bus information displays

Transit signal priority


Security cameras

Emergency phones


Ticket vending machines

2.9.1 Potentially outdated and/or underperforming technology

In the survey responses, there was a common theme of dissatisfaction with the suboptimal performance of TSP, though the exact causes of these shortcomings were not always clear. Respondents suggested that the issues might be related to various factors, including operational practices, bus schedules, inherent roadway issues and/or policy restrictions, such as limited frequency of TSP activation, as well as the impending obsolescence of certain hardware components, necessitating upgrades.

Another factor could be related to signal timing or lack of effective signal timing along the corridor. An example of this is at LA Metro, where transit signal priority is granted only every other cycle time. Buses are also granted no more than 10% of the signal cycle time, which turns out to be up to 10 seconds of potential added green time. In addition, when first implemented, all new upgraded traffic control boxes were required along each of the BRT corridors in order to accommodate TSP.

One agency also had concerns with ticket vending machines on their system being overbuilt and having maintenance concerns. These responses underscore the challenges in integrating advanced technologies within existing policy and infrastructure frameworks, highlighting the need for continual assessment and adaptation of technological strategies in BRT systems.

2.9.2 Implementation of newer or more advanced technologies

Additionally, the necessity for technological upgrades was highlighted, with a specific mention of the need to replace communication modules soon due to support and compatibility issues. Several agencies are now looking into or implementing a cloud-based TSP system, which will allow for more TSP capabilities and less maintenance of the existing network and hardware. This response underscores the ongoing challenge in BRT systems of keeping up with technological advancements and ensuring that existing infrastructure remains functional and effective.

3. Case study examples

As discussed in Section 1.1, the second part of this effort was a series of interviews with six transit agencies. These agencies were selected based on existing relationships between the agencies and the BRT Working Group members, as well as willingness to be interviewed about their agency's BRT system. Appendix B contains full responses from these interviews. This section summarizes the agencies' programs and their top lessons learned to convey to other agencies about their experience with BRT roadway infrastructure.

3.1 Connecticut Department of Transportation

The Connecticut Department of Transportation (CTDOT) is responsible for the development and operation of highways, railroads, mass transit systems, ports and waterways in Connecticut. CTDOT manages and maintains the state highway system.

Their key takeaway was the need to sell the benefits of dedicated bus lanes in terms of reliability and frequency of service. Architects and engineers are more familiar with highways and not BRT. A BRT system must meet between highway and transit design. Neither can be too rigid.

https://www.cttransit.com/about/about-ctfastrak

3.2 OmniTrans (San Bernardino, California)

Omnitrans is the public transit agency serving the San Bernardino Valley, providing safe, reliable, affordable, friendly and environmentally responsible transportation. Omnitrans currently operates local and express bus routes; sbX bus rapid transit service; and Access, a paratransit service for people with disabilities.

They advise taking care of utilities early to avoid any surprises later down the road, as well as making sure the agency is deeply involved with the design, including Operations personnel.

https://omnitrans.org/routes/sbx-green-line/

3.3 Metro Transit (Minneapolis-St. Paul, Minnesota)

Metro Transit is the transportation resource for the Twin Cities, offering an integrated network of buses, light rail, BRT and commuter trains, as well as resources for those who carpool, vanpool, walk or bike. Metro Transit is developing a network of enhanced transitways throughout the region.

Their main advice is to not look at corridors in isolation. Design decisions will impact future BRT and local routes. Agencies should take their time making system-wide decisions (platform heights, fleet, platform locations, left-loading doors, etc.).

https://www.metrotransit.org/brt

3.4 Capital District Transportation Authority (Albany, New York)

CDTA provides mobility solutions that connect the capital region with support from a large network of partners. CDTA is focused on expanding its mobility menu to offer a cohesive and flexible transportation network for its customers that includes regular routes, bus rapid transit, express, on-demand transit (FLEX), bike share (CDPHP Cycle!), electric car share (DRIVE), seasonal trolleys, park and ride, and paratransit service for customers with disabilities.

Their key takeaway is that cooperation and partnership is the most important factor. Agencies should establish any necessary partnerships and agreements early on in the project as part of the funding application process by including secured agreements and/or memorandums of understanding. This will help avoid conflicts or issues after the project starts.

https://www.cdta.org/

3.5 Milwaukee County Transit System (Wisconsin)

MCTS is innovating the way people across southeast Wisconsin get to work, school, medical appointments, entertainment and anywhere else they need to go. The East-West BRT route called CONNECT 1 gives riders convenient access to employment, education and recreation in downtown Milwaukee, Milwaukee's Near West Side, Marquette University, Wauwatosa and the Milwaukee Regional Medical Center. Planning is underway to develop a second CONNECT BRT to improve one of the busiest routes in the system along 27th Street.

Their top recommendation is maximizing far-side stations.

https://www.ridemcts.com/who-we-are

3.6 Greater Cleveland Regional Transit Authority (Ohio)

The Cleveland Regional Transit Authority provides transportation services for 150,000 to 200,000 customers on a typical weekday, or about 45 million rides annually, through a variety of services. The BRT HealthLine on Euclid Avenue provides service and operational characteristics associated with rail, with rubber-tired rapid transit vehicles. The HealthLine operates 24/7, with a rush-hour frequency of every eight minutes. In December 2014, RTA added a second BRT service, the Cleveland State Line, which connects the West Shore communities with downtown, via Clifton Boulevard.

Their top recommendation was to make a plan for continued city coordination on TSP.

https://www.riderta.com/overview

4. Overall lessons learned

One of the most prominent lessons learned from these agencies was the need to coordinate early with the local DOT and city traffic engineers. It is important to bring the DOT in as an actual project partner, as it needs to be more than just a stakeholder.

Other top lessons learned included the following:

- Be bold with first build if it's even remotely possible; it sets expectations for future lines. Start with the most assertive design and then compromise where necessary.
- Make sure to visit other systems, talking to operations, maintenance and safety teams.
- Implementing BRT requires a shift in how a city allocates space on the roads to protect long-term capacity, not just short-term solutions to increase vehicular traffic flows.
- Establish inter-local agreements with roadway owners for long-term maintenance.
- Consider jurisdictional permitting requirements early. Signal upgrades at one agency triggered a full intersection reconstruction with new stormwater facilities. Involving the city earlier as part of the project could have changed the outcome.
- Coordination at the highest levels between operating agency and DOT/streets agency is critical. Have an MOU that determines who is responsible for what, and work constantly at coordination and understanding each other's issues.
- Plan the service before planning the infrastructure (will you have curb/side-running or center-median bus lanes).
- If flexibility is needed to reflect changing travel patterns and travel demand, then choose side-running lanes as they may be less of an investment than center/median-running; If center/median-running, consider removing left-turns and set up an MOU to help protect that decision (center/median running).
- For precision docking, build a "training station platform" at the facility for drivers to train on.
- Opposition will be likely if converting a general use lane into a BRT lane if there is not a lot of service operating in the lane or high ridership in the corridor. Service is what generates ridership, not infrastructure, and the two are needed together to get good results and make a strong case for the capital investment.
- Know why you are building the BRT and make it be known. Build political will early and often. Communicate that BRT is more than a new bus line. Identify stakeholders and create a space where the rider has a voice.

5. Considerations

In both the survey response and individual interviews with transit agencies, there were some overarching themes and/or thoughts on best practices when considering BRT. Some of these overarching themes:

- Bus lanes/dedicated ROW were recognized as providing the greatest speed and reliability benefits of all BRT elements. Agencies with mixed flow-only may want to consider this as a next phase.
- TSP is the second most important BRT element, particularly when applied along with dedicated bus lanes. However, even without bus lanes, improvements in travel times can be realized with TSP, particularly with some of the other BRT elements, like-less frequent stops.
- Most agencies had a combination of side-, center- and median-running BRT, which illustrates the flexibility of BRT vs. rail.
- Some preferred median running bus lanes, as they believed they created a better sense of permanence. However, it was observed that they are not practical in all circumstances for various reasons, including additional right-of-way needs and elimination of left turns, hence the use of multiple configurations for many agencies.
- Most agencies did not have lane enforcement, though more than half had red-painted lanes, which helped but also requires more maintenance.
- ITS elements mainly included TSP and some ITS elements at stations.

6. Conclusion and Future Needs

The results of the roadway infrastructure and design questions demonstrate the flexibility of BRT systems. Flexible systems are important, especially since many BRT systems operate in dynamic urban environments. Respondents utilized a mix of roadway infrastructure tools to implement various unique BRT systems. While a majority of BRT agencies in this survey operate at least a portion of the system in some form of dedicated bus lanes (median, side or curb-running), a majority also have a portion of the system that also operates in mixed flow, which highlights the flexibility of BRT. It was frequently mentioned that upfront agreements and strong leadership, along with community engagement, are vital in the planning of BRT systems.

Many of the challenges associated with implementing BRT are related to making strategic trade-offs for the overall functionality of the BRT system, including repurposing parking and general travel lanes, and impacting existing curbside use. Other challenges include the struggles of efficiency and effectiveness of TSP. However, respondents are hopeful that a shift toward GPS and cloud-based TSP systems will increase reliability. Another key theme of TSP is that it requires ongoing assessment and adaptation (don't "set it and forget it").

What's next? The survey responses noted that there is a lack of national standards. Moving forward, the transit community would benefit from unified standards and best practices. However, there could be issues with adoption of national standards at a local level, so guidance, rather than standards, may be easier to implement at a national level. Region-level guidance may also be more applicable to BRT since BRT is meant to be flexible and not constrained to national standards. Whether regional or national, the Infrastructure Working Group believes that standards could be developed and adopted across the industry to the benefit of all transit agencies implementing BRT.

Related APTA standards

APTA-BTS-BRT-RP-001-10, "BRT Branding, Imaging and Marketing"
APTA-BTS-BRT-RP-002-10, "Bus Rapid Transit Stations"
APTA-BTS-BRT-RP-003-10, "Designing Bus Rapid Transit Running Ways"
APTA-BTS-BRT-RP-004-10, "Bus Rapid Transit Service Design and Operations"
APTA-BTS-BRT-RP-005-10, "Implementing BRT Intelligent Transportation Systems"
APTA BTS-BRT-GL-007-25, "Bus Rapid Transit Program Development and Financing"

Definitions

arterial: A moderate- or high-capacity roadway designed for the continuity of movement. Arterials are usually broken into categories by their throughput ability, with principal arterials being of higher capacity than minor arterials.

at-grade: Operation at the ground level running way that may require signals or other traffic controls at junctions with other facilities, depending on volumes of traffic, visibility and other factors such as speed that determine the extent of the probable conflict between the traffic flows.

bus lane: A traffic lane for dominant or exclusive use by buses, generally used to speed up public transport otherwise held up by traffic congestion.

bus rapid transit: Frequent, faster and higher-capacity bus service designed as an integrated system of service, facilities and strategies that distinguish it from regular bus service. The elements of bus rapid transit can vary depending on the operating environment and may include priority through separate right-of-way, preferential treatments at intersections, intelligent transportation systems, as well as other actions that improve bus speed and reliability, including limited stops, vehicle design, fare collection systems and high-quality bus stations. Bus rapid transit is often branded to promote the service as unique from regular bus transit service.

center platform: A horizontal surface above the level of rails or roadways and positioned in the center to allow boarding and alighting of passengers. Center platforms make it difficult to separate passenger and vehicle flows and can require crossing vehicles to reach the platform to board and alight passengers if vehicles are not equipped with left-side doors.

dedicated lane: A lane set aside for a specific mode so that that mode can operate separately from all others.

guideway: A grooved or channeled pathway that controls the direction in which a moving object travels. For rubber-tired transit, an automated guideway is a fully automated, grade-separated system in which buses operate across these grooves and channels.

HOV lane: A traffic lane limited to carrying high-occupancy vehicles designated by a minimal vehicle occupancy requirement. This includes carpools, vanpools and buses.

Level/near-level boarding: Boarding where the station platforms match the vehicle floor height as closely as possible. This is in contrast to a raised platform, where the platforms are build higher than a standard curb but below the floor height of a bus, and a standard curb where the platform heights match the typical surrounding roadway curb height.

median busway: A middle section of a roadway reserved for buses only.

mixed-use lane: A roadway lane designated for use by different types of vehicles and users. Shared use lanes may be limited to specific users and include business-access transit lanes, HOV lanes and lanes designated for both motorists and bicyclists.

queue jump: Usually a form of transit signal priority, where there is a separate signal phase for transit vehicles so they can get ahead of other traffic. Queue jumps can be partnered with a queue bypass lane or may operate from a regular traffic lane.

ramp: An inclined roadway connecting roads of differing levels. (Source: BTS Dictionary)

reserved bus lane: A lane on an urban street or freeway for bus use only, separated from other lanes by pavement markings, signs or rubber cones, but not by fixed physical barriers. Also known as an exclusive lane.

reversible lane: A single, exclusive BRT-only lane that changes direction to each peak traffic direction. right-of-way segregation: A fully controlled legally and physically separated strip of land for use by transit vehicles without grade crossings or any legal access by other vehicles or pedestrians.

running way: A path that provides exclusive lanes and roadways in which transit vehicles travel.

separate running way/busway: A roadway reserved for buses only. It may be grade-separated or a controlled-access roadway. (Source: BTS Dictionary)

shoulder: An edge or border running on either side of a roadway, generally kept clear from traffic, that provides a place of refuge in emergencies.

side platform (lateral platform): A horizontal surface above the level of a rail or roadway, and positioned on each side of the roadway or rail tracks to allow boarding and alighting of passengers. Lateral platforms can easily separate the directional flows of passengers and minimize conflicts with vehicles without requiring vertical pedestrian movements.

transit signal priority (TSP): An operational strategy that facilitates the movement of transit vehicles, either buses or streetcars, through signal-controlled intersections. Signal priority modifies the normal signal operation to provide speed and reliability to transit vehicles. The priority offered to transit may vary from preemption to a request for priority that considers operating plans (priority for a particular segment or route) and schedule factors, such as minutes behind the published schedule, spacing between transit vehicles, etc.

Abbreviations and acronyms

AASHTO	American Association of State Highway and Transportation Officials
BAT	business access and transit
BRT	bus rapid transit
CAD/AVL	computer-aided dispatch/automatic vehicle location
CDTA	Capital District Transportation Authority
CTDOT	Connecticut Department of Transportation
DOT	Department of Transportation
FTA	Federal Transit Administration
GPS	Global Positioning System
GTFS	General Transit Feed Specification
GTT	Global Traffic Technologies
HOV	high-occupancy vehicle

ITS	intelligent transportation system
JTA	Jacksonville Transportation Authority
MCTS	Milwaukee County Transit System
MOU	memorandum of understanding
NIMBY	not in my backyard
NYCDOT	New York City Department of Transportation
PM	project manager
PSTA	Pinellas Suncoast Transit Authority
QJ	queue-jumpers
ROW	right-of-way
RRFB	rectangular rapid flashing beacons
RTA	Greater Cleveland Regional Transit Authority
RTPI	real-time passenger information
SCADA	Supervisory Control and Data Acquisition
TSP	transit signal priority
TriMet	Tri-County Metropolitan Transportation District of Oregon
UHMWPE	ultrahigh molecular weight polyethylene
VTA	Valley Transportation Authority

Document history

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Appendix A: Study survey

APTA BRT Committee—Roadway Infrastructure Subcommittee
Survey Questions for Transit Agencies and Local DOTs

Roadway infrastructure/design

1. Please provide a brief overview of your BRT roadway infrastructure (type of guideway or other design features to reduce delays and improve the performance of the BRT system). (Median guideway, side/curb running guideway, mixed flow, red lanes, TSP (conditional or unconditional), queue jumps, lane enforcement, all-door boarding, level/near-level boarding, other)
2. What do you wish you knew before you began the planning and/or design of your BRT roadway infrastructure?
3. What, if anything, would you change with respect to your BRT roadway infrastructure in hindsight (e.g., near-side vs far-side stations, jay walking at stations, etc.)?
4. What tough decision did you make in the planning and/or design of your BRT roadway infrastructure that in hindsight you are glad you made (loss of parking, some element you wanted to include but couldn't, etc.)?
5. What are the widths of your bus lanes? If you could revise the design, would you change the bus lane widths and why?
6. What are some of the conflicts/safety issues you may have encountered along the roadways between buses, pedestrians, and bicycles?
7. What advice with respect to BRT roadway infrastructure would you give to other agencies or cities who are embarking on their first BRT system?
8. What elements of your BRT infrastructure are essential to its success?
9. Who maintains the different elements of your BRT roadway infrastructure?
10. Is there anything else you would like to share with us about your system?

Enforcement of bus lanes/BRT system

1. Do you have enforcement of the dedicated bus lanes? If yes, what type of enforcement is used (dedicated police or camera enforced, any other means of enforcement)? If not, do you plan to implement enforcement in the future?
2. Do you utilize red coloring in any of your bus lanes? If so, do you have any insights into general purpose compliance with red lanes vs. those without red coloring? Pros and cons of end-to-end painted bus lanes, including maintenance of the painted lanes.
3. Have you experienced any safety-related concerns due to general purpose vehicles traveling in the bus lanes? If so, how are you approaching the issue?

ITS related

1. What types of ITS are you using in your BRT system? Based on your experience, what are the pros and cons of the system?
2. What technology did you implement in your BRT roadway infrastructure that is now out of date, or did not perform up to expectations?
3. Are you considering the implementation of newer and/or more advanced technology, such as moving toward a more cloud-based technology in optimizing BRT performance and managing bus signal priority, traffic, etc., along roadways?

Appendix B: Agency interviews

1. Connecticut Department of Transportation (CTDOT)

Interview conducted by Steve Scheerer on 9/7/2023

Contact name: Mike Sanders with Rich Armstrong

Contact information: Mike was CTDOT's transit administrator during the planning, design development, and construction. Rich has a highway background.

Roadway infrastructure/design

1. **Please provide a brief overview of your BRT roadway infrastructure (type of guideway or other design features to reduce delays and improve the performance of the BRT system). (Median guideway, side/ curb running guideway, mixed flow, red lanes, TSP [conditional or unconditional], queue jumps, lane enforcement, all-door boarding, level/near-level boarding, other.)**

   Type of guideway: dedicated guideway. At-grade intersections (3-5); signalized. Have worked on signal preference (originally actuator with pavement loops). 300–500 yards; generally worked OK. Extensions of 9.6-mile guideway at intersections. Enforcement by state police. All-door and level boarding. All platform access payment; no payment on bus. Rub rail on platform. Level boarding for floor height. Boarding ramp for wheelchairs. The ramps couldn't deploy. Stripe for operators to align front door.

   Working on autonomous operations—precision docking—the technology contractor is asking to back out (from New Flyer). Some rub rails have taken a beating, but buses have been generally OK—minor markings from rub rail. Deceleration length and approach angles help with docking. Passing lanes—bus pullout—at each station. Architects went with 90 ft instead of 120 ft platforms—wish they would have gone with 120 ft.

   Two artics can't dock.

2. **What do you wish you knew before you began the planning and/or design of your BRT roadway infrastructure?**

   Architects and engineers are highway and don't understand BRT. "Just building a highway"—but didn't understand transit amenities. Shelters don't reach the edge of platforms—get wet between shelter and bus. Gaps in sidewalls of shelters due to design issues. DOT didn't have dedicated PM. Fought for concrete roadway, only got concrete at stations. Thankful for no asphalt rutting at stations, would have liked full concrete. Life cycle cost analysis? One of first to go through new start. Applied earlier than they should have. Start/different marketing from the very beginning. Promote as a grander system. Called New Britton to Hartford busway originally—many people didn't understand/care. Too many cooks in the kitchen; too many consultant designers; expected coordination, but not much incentive.

   Internal opposition at DOT.

3. **What, if anything, would you change with respect to your BRT roadway infrastructure in hindsight (e.g., near-side vs far-side stations, jaywalking at stations, etc.)?**

   Ped signals with push buttons and crosswalks; no RRFBs at the time—eventually built station landscaping; parking lot design—minor issues.

4. **What tough decision did you make in the planning and/or design of your BRT roadway infrastructure that in hindsight you are glad you made (loss of parking, some element you wanted to include but couldn't, etc.)?**

   One section was going to be one-way due to budget, but bids came in low so they could change order "full" design. Cost-effectiveness measure from New Starts. Why not just buy the railroad? Amtrak wanted out at the beginning. Maybe a little light on parking. Bought out three businesses. Didn't get a lot of "why didn't you do this" after operations started.

   (Spent a lot of money on RR issues $100/$500 million—ROW acquisition, bridge over RR, at-grade crossing, rail traffic control.)

5. **What are the widths of your bus lanes? If you could revise the design, would you change the bus lane widths and why?**

   12 ft—no median barrier, rumble strips (?) (wanted them, but DOT maybe said no?) Limited shoulders; 12 ft bus pull-off stops with median barriers.

6. **What are some of the conflicts/safety issues you may have encountered along the roadways between buses, pedestrians and bicycles?**

   4-5 miles of SUP parallel. Only interaction at stations.

7. **What advice with respect to BRT roadway infrastructure would you give to other agencies or cities that are embarking on their first BRT system?**

   Different advice for fixed vs on-street. Service planning—try to sell benefits of dedicated lanes. Reliability, frequency of service.

8. **What elements of your BRT infrastructure are essential to its success?**

   Guideway, shelters (with heat—presence detectors), off-board fare collection (proof of payment), "make it pretty." "Didn't go cheap," built things that look nice, and maybe cost more.

9. **Who maintains the different elements of your BRT roadway infrastructure?**

   DOT—state highway number; amenities "we" maintain, DOT via contract—shelters, TVM roadway/signals—DOT.

10. **Is there anything else you would like to share with us about your system?**

    Meet between highway and transit design. Neither side can be too rigid. Original haters are now in support.

Enforcement of bus lanes/BRT system

1. **Do you have enforcement of dedicated bus lanes? If yes, what type of enforcement is used (dedicated police or camera enforced, any other means of enforcement)? If not, do you plan to implement enforcement in the future?**
2. **Do you utilize red coloring in any of your bus lanes? If so, do you have any insights into general purpose compliance with red lanes vs. those without red coloring? Pros and cons of end-to-end painted bus lanes, including maintenance of the painted lanes.**
3. **Have you experienced any safety-related concerns due to general purpose vehicles traveling in the bus lanes? If so, how are you approaching the issue?**

ITS related

1. **What types of ITS are you using in your BRT system? Based on your experience, what are the pros and cons of the system?**
2. **What technology did you implement in your BRT roadway infrastructure that is now out of date, or did not perform up to expectations?**
3. **Are you considering the implementation of newer and/or more advanced technology, such as moving toward a more cloud-based technology in optimizing BRT performance and managing bus signal priority, traffic, etc., along roadways?**

Other discussion

- Fiber the entire length? Either in guideway or along Amtrak
- Occasional trespassers (vehicles)
- Cameras along length
- Some drug user issues at stations

2. OmniTrans (San Bernardino, CA)

Interview conducted by Peter Merry on 6/26/2023

Contact names: Anna Jaiswal, development planning manager; Ben Greenbeck, system coordinator for ITS; Thomas Dahlin, capital project services manager

1. **What are the infrastructural elements of this BRT line?**
    - The sbX Green Line is a 15-mile corridor, 5 miles of which are dedicated median-running
    - Elevated 13 in. platforms with level boarding
    - Center running is left-door boarding, side-running is right-door boarding
    - TSP system connects to wireless network which “checks in” with the next intersection
        - No feedback from the intersection controller
        - 10-year-old system has aged the system, repairs currently in progress

2. **Is there anything that you wish you knew before you began the planning or design of your BRT infrastructure?**
    - Lack of communication with the jurisdiction over funding (city was in bankruptcy)
    - Many municipalities have not worked with TSP
    - Many cities don’t have emergency vehicle preemption
    - Municipalities are worried about cyber-security (traffic data being sent to the control center and potentially being hacked into)

3. **In hindsight, is there anything that you wish you could change with respect to your BRT infrastructure?**
    - Due to lack of right-of-way acquisition, a jog in the lane at some intersections has caused safety concerns for drivers.
    - Installing physical barriers (curbs in the median), to prevent people from making left-turns out of driveways into bus lanes.
    - The unique branding of sbX has caused many customers to think it’s a completely different agency. New branding will incorporate the Omnitrans brand more fluidly.
    - In core urban areas, station stops were too far away, causing some people to not want to walk. The next line will have stops more frequently in dense areas.

4. **What are the widths of your bus lanes? If you could revise the design, would you change the bus lane widths and why?**
    - 11 ft minimum, but most are 12 ft.
    - Lanes can feel tight on winding roads, but hasn't been a safety issue

5. **What are some of the conflicts/ safety issues you may have encountered along the roadways between buses, pedestrians and bicycles?**
    - There are intersections with left-turn pockets to the right of the bus. When the bus gets a green, cars will often jump out in front of the bus assuming it's also going to make a left turn.

6. **What advice with respect to BRT would you give to other agencies or cities that are embarking on their first BRT system?**
    - Take care of utilities early in order to avoid any surprises later down the road.
    - Ensure that there are no issue areas along the route with regard to utilities.
    - Get lots of peer review on the plans.
    - Make sure the agency in question is deeply involved with the design, particularly people in operations.

7. **Who maintains the different elements of your BRT roadway infrastructure?**
    - Omnitrans maintains the immediate station areas, and the cities maintain everything else (landscaping, dedicated lane medians).
    - Make sure to be very specific about who does what when in the planning phase.

ITS related

1. **What types of ITS are you using in your BRT system? Based on your experience, what are the pros and cons of the system?**

    Some of it is cloud-based, and they are moving further in that direction.

2. **What technology did you implement in your BRT roadway infrastructure that is now out of date or did not perform up to expectations?**

    The heat, in addition to the age of the system, has led to a fair amount of maintenance and replacement. And much of the technology is now out of date.

3. **Are you considering the implementation of newer and/or more advanced technology, such as moving toward a more cloud-based technology, in optimizing BRT performance?**

    A three-year contract for TSP monitoring and control from a third party that will oversee and maintain the whole system.

Enforcement

1. **Do you have enforcement of dedicated bus lanes? If yes, what type of enforcement is used?**

    There is a patrol in the evening hours, and the police have a general knowledge of enforcement, but there is very little enforcement. Bicyclists often get in the median lanes

1. **Do you utilize red coloring in any of your bus lanes? If so, do you believe there is any impact on compliance with red lanes vs. those without red coloring**

    There is a general consensus that red lanes lead to a better compliance with the rules.

3. Metro Transit (Minneapolis-St. Paul, Minnesota)

Interview conducted by Angie Christo

Contact name: Jonathan Ahn

Roadway infrastructure/design

1. **Can you please provide a brief overview of your BRT roadway infrastructure (median guideway, side or curb running, other design features to reduce delays and improve the performance of the transit system, etc.)?**

   Currently not major dedicated BRT infrastructure. Metro Gold Line will be the first dedicated guideway. Currently block by block designation need Lake St. Highway BRT (Red & Orange). A line is arterial BRT (no dedicated lanes, does run on shoulder for parts of Hwy 51).

2. **What do you wish you knew before you began the planning and/or design of your BRT roadway infrastructure?**

   Better coordination with the roadway authorities on project timing. Impacts project development and timing. If BRT in the corridor does not line up with city/county timelines, that creates issues. Example, Lake St was reconstructed recently, so this constrained BRT project elements.

3. **What, if anything, would you change with respect to your BRT roadway infrastructure in hindsight (e.g., near-side vs far-side stations, jaywalking at stations, etc.)?**

   Far-side by default, and Metro Transit is happy with that configuration. Any near-side is due to constraints. Some location-specific coordination is done for shared local and BRT platforms. Looking at longer term coordination of overall routes and BRT.

4. **What tough decision did you make in the planning and/or design of your BRT roadway infrastructure that in hindsight you are glad you made (loss of parking, some element you wanted to include but couldn't, etc.)?**

   Originally A line platform (first BRT) designed with BRT stopping in front, local buses behind (in a slight cutout). There is a splitgate at some locations. Passengers are confused about where to wait, and this impacted dwell time. Scrapped practice after A line. BRT platform is now shared with local routes, so there is one stop location.

5. **What are the widths of your bus lanes? If you could revise the design, would you change the bus lane widths and why?**

   Preferred is 11 ft, absolute minimum is 10½ ft. Absolute minimum may be on a curb lane (with extra 2 ft).

6. **What are some of the conflicts/safety issues you may have encountered along the roadways between buses, pedestrians and bicycles?**

   9 in. boarding platform and seeing some incidents where the mirror is within the platform area when docking.

7. **What advice with respect to BRT roadway infrastructure would you give to other agencies or cities that are embarking on their first BRT system?**

   Not an isolated corridor, design decision will impact future BRT and local routes. Take your time making system-wide decisions (such as platform height, fleet, platform locations, left loading door etc.; impacts the whole system).

8. **What elements of your BRT infrastructure are essential to its success?**

   Higher platform and off-board fare payments at all stations, consistency is essential.

9. **Who maintains the different elements of your BRT roadway infrastructure?**

   Metro Transit maintains BRT stations. Road authority maintains roadways, including red paint. Working to have a cost sharing agreement to maintain the red paint. Metro Transit would maintain an exclusive guideway (in future when Gold Line is operating).

10. **Is there anything else you would like to share with us about your system?**

    Trying to be flexible and nimble of what the system looks like. Highway BRT, arterial BRT and guideway. Working to be consistent under the branding to provide service quality to customers. Using different tools for different contexts.

Enforcement of bus lanes/BRT system

1. **Do you have enforcement of the dedicated bus lanes? If yes, what type of enforcement is used (dedicated police or camera enforced, any other means of enforcement)? If not, do you plan to implement enforcement in the future?**

   No current enforcement. Working with roadway authorities to formalize the agreement on how this will work. Metro Transit does have its own police force.

2. **Do you utilize red coloring in any of your bus lanes? If so, do you have any insights into general purpose compliance with red lanes vs. those without red coloring? Pros and cons of end-to-end painted bus lanes, including maintenance of the painted lanes?**

   Yes, there are currently some in blocks and for queue jumps. Costs of paint have been significantly higher in the past couple of years. Looking into options/alternative painting that is consistent with MUTCD (waiting for new guidance to be published).

3. **Have you experienced any safety-related concerns due to general purpose vehicles traveling in the bus lanes? If so, how are you approaching the issue?**

   Not a large number, so it may be more of an issue with vehicles parking in the bus lane. Not a safety concern at this time.

ITS related

1. **What types of ITS are you using in your BRT system? Based on your experience, what are the pros and cons of the system?**

   CAD/AVL is the same system as the local buses. TSP at most intersections in the BRT corridors. The parameters for BRT station intersections are different than local routes (varies by near and far side). Not sure of pros and cons, they do not have access to the roadway signal logs; would need to get a data request to know if the TSP call was accepted.

2. **What technology did you implement in your BRT roadway infrastructure that is now out of date, or did not perform up to expectations?**

   Not sure if the TSP is performing up to expectations (based on #1).

3. **Are you considering the implementation of newer and/or more advanced technology, such as moving toward a more cloud-based technology in optimizing BRT performance and managing bus signal priority, traffic, etc., along roadways?**

   Started looking into next-generation TSP that provides a more predictive technology and reliability. Looking at active headway management (vs. measuring schedule adherence). Would look at headway-based service.

4. Capital District Transit Authority (Albany, NY)

Roadway infrastructure/design

1. **Can you please provide a brief overview of your BRT roadway infrastructure (median guideway, side or curb running, other design features to reduce delays and improve the performance of the transit system, etc.)?**

   CDTA operates two BRT lines (Redline in 2011/Blueline in 2020) with a third (Purpleline) coming online on November 5, 2023. All three include a combination of TSP and queue jumpers with dedicated bus only lanes (for QJ only) and curb bump outs and cut ins at select locations. Limited stops, near side stops, combined with TSP, QJ, and 8–15 minute frequencies help to optimize the overall performance. The third BRT will have a dedicated roadway through the University at Albany campus, which will be built by CDTA. Also, CDTA built a traffic circle at the entrance to the largest major shopping mall in the region, which is also a key timepoint along the BRT line designed to improve the overall running times and performance of the route and general traffic flows. Traffic simulation modeling is underway to assess the effectiveness of traffic signal preemption at three intersections along the newest BRT line to minimize the overall impact on traffic flow within the city of Albany.

2. **What do you wish you knew before you began the planning and/or design of your BRT roadway infrastructure?**

   The largest challenges surrounding the project elements involve third-party stakeholder cooperation. At least a couple of bus stops were either moved or eliminated based on community feedback and NIMBY resistance to BRT station construction at certain locations. The larger TSP, QJ and dedicated bus lane infrastructure required similar cooperation with third-party stakeholders. Dedicated bus lanes proving to be much more difficult along the Purpleline BRT through the NYS Harriman Office Campus in Albany. More recently, local pro-pedestrian groups in the city of Albany requested to have permanent pedestrian first calls without activation at every intersection in the City of Albany (76 total), which if passed would remove any existing benefits of traffic signal priority. This remains under discussion with some consideration being given to several alternative approaches. Finally, the project would have benefited greatly by having a better understanding of the underground infrastructure layouts at all BRT stop and construction locations. Moreover, there were several long lead times for critical infrastructure such as signal poles and cabinets, which could have been mitigated with a better understanding of these risks.

3. **What, if anything, would you change with respect to your BRT roadway infrastructure in hindsight (e.g., near-side vs far-side stations, jaywalking at stations, etc.)?**

   One obvious change would be to ensure no turn on red adjacent to traffic signal priority intersections, queue jump lanes, traffic signal preemption, and bus pads at all stations.

4. **What tough decision did you make in the planning and/or design of your BRT roadway infrastructure that in hindsight you are glad you made (loss of parking, some element you wanted to include but couldn't, etc.)?**

   The planning for enough space for possible conversion to a mobility hub with future electric bikes and charging stations. Most importantly, ensuring plenty of conduit for various communications, power and related technology upgrades in the future.

5. **What are the widths of your bus lanes? If you could revise the design, would you change the bus lane widths and why?**

   n/a, no change to the design was considered.

6. **What are some of the conflicts/safety issues you may have encountered along the roadways between buses, pedestrians and bicycles?**

   No significant conflicts occurred. On a related note, CDTA recently implemented video detection with traffic signal priority to gather more data and identify future opportunities to adjust traffic signal timing plans and add other pedestrian amenities, such as information kiosks. CDTA will be able to follow up on this later this year as data is collected and analyzed.

   As was mentioned above, there are local pro-pedestrian groups in the city of Albany requesting to have permanent pedestrian first calls without activation at every intersection in the city of Albany (76 total), which if passed, would remove any existing benefits of traffic signal priority. This remains under discussion with consideration to several alternative approaches.

7. **What advice with respect to BRT roadway infrastructure would you give to other agencies or cities that are embarking on their first BRT system?**

   The most important factor is cooperation and partnership or a lack thereof. If possible, establish any necessary partnership and/or agreement early on in the project as part of the funding application process by including secured agreements and/or memorandums of understanding. This will help avoid conflicts or issues after the project starts. Some more specific roadway infrastructure examples include snow removal, curb bump-outs, cut-ins, etc.

8. **What elements of your BRT infrastructure are essential to its success?**

   The larger elements that put the rapid in bus rapid transit include but are not limited to traffic signal priority/preemption, queue jumpers, station cut-in design/improvements, and of course the aesthetic design improvements at each station, including related community improvements such as landscaping, lighting and cameras for safety (or at least the perception of safety).

9. **Who maintains the different elements of your BRT roadway infrastructure?**

   The majority of roadway infrastructure is maintained by each of the different municipalities where it resides. All infrastructure connected directly to the station is maintained by CDTA, including TSP and QJ, shelters/stations, and related amenities such as landscaping, garbage cans at select locations, and any response to acts of vandalism or safety concerns.

10. **Is there anything else you would like to share with us about your system?**

    The project is not only a way to increase the overall running times of services, but a way to correct age-old infrastructure issues. The coordination with municipalities and other stakeholders to work together to solve overall transportation issues is a rare opportunity to make on-street improvements

that are visible to the community at large. This also helps to build stronger relationships with stakeholders, while also making streets safer and more efficient for general traffic flow.

Enforcement of bus lanes/BRT system

1. **Do you have enforcement of dedicated bus lanes? If yes, what type of enforcement is used (dedicated police or camera enforced, any other means of enforcement)? If not, do you plan to implement enforcement in the future?**

   No; nothing planned at this time.

2. **Do you utilize red coloring in any of your bus lanes? If so, do you have any insights into general purpose compliance with red lanes vs. those without red coloring? Pros and cons of end-to-end painted bus lanes, including maintenance of the painted lanes.**

   Yes for QJ and bus-only approach lanes. No significant pros or cons. They have held up well (since 2011 with first redline BRT) and compliance issues are kept to a minimum, which is likely due to the lower traffic volumes in the capital region.

3. **Have you experienced any safety-related concerns due to general purpose vehicles traveling in the bus lanes? If so, how are you approaching the issue?**

   Only occasional use by unsuspecting drivers.

ITS related

1. **What types of ITS are you using in your BRT system? Based on your experience, what are the pros and cons of the system?**

   CAD/AVL, RTPI-GTFS, cameras, TSP, QJ

2. **What technology did you implement in your BRT roadway infrastructure that is now out of date, or did not perform up to expectations?**

   Fiber. We have moved on to cellular. It works really well and reliably. Fiber optic communications infrastructure proved to be unnecessary. Kiosks and digital displays have been rethought several times. Solar powered kiosks with limited to no power infrastructure requirements have proven to be the most effective solution. https://soofadigital.com/

3. **Are you considering the implementation of newer and/or more advanced technology, such as moving toward a more cloud-based technology in optimizing BRT performance and managing bus signal priority, traffic, etc., along roadways?**

   - We are moving to the cloud for pedestrian and vehicular video detection and TSP with a new Miovision/GTT solution in the city of Albany at 76 intersections.
   - We are utilizing more crowdsourced big data with Replica, Remix, Microsoft and Moovit to analyze origin-destination travel patterns.
   - We are considering digital bus stop signs to replace analog signage.
   - We are expanding our network of solar powered information kiosks to select BRT timepoints and mobility hub locations.
   - A more advanced mobility as a service mobile application with on-demand microtransit; payment integration; and advanced trip planning with bikeshare, Uber and Lyft is to be deployed in late 2023.

5. Milwaukee County Transit System (Wisconsin)

Interview conducted by Scott Tallman (HNTB) on 8/21/2023

Contact name: David Locher, manager of enhanced transit

Contact information: dlocher@mcts.org, 414-343-1727

Roadway infrastructure/design

1. **Can you please provide a brief overview of your BRT roadway infrastructure (median guideway, side or curb running, other design features to reduce delays and improve the performance of the transit system, etc.)?**

   East-West BRT is Milwaukee County's 9-mile, regional, modern transit service connects major employment, education, and recreation destinations through downtown Milwaukee, Milwaukee's Near West Side, Marquette University, Wauwatosa, and the Milwaukee Regional Medical Center. BRT provides improved access to the region's most vital, most traveled and most congested corridor.

2. **What do you wish you knew before you began the planning and/or design of your BRT roadway infrastructure?**

   If you know the vehicle specifications, everything else will flow from that. For example, MCTS was going to pursue a purist BRT with 14 in. curb heights. However, as a mixed fleet operation (battery electric and diesel), 12 in. became required. A difference in bus ride height would offer an inconsistent product when boarding or alighting the vehicle. Designing to cover your fleet initially is much easier than midway through.

3. **What, if anything, would you change with respect to your BRT roadway infrastructure in hindsight (e.g., near-side vs far-side stations, jaywalking at stations, etc.)?**

   Maximizing far-side stations would be a great idea. However, in BRT design, MCTS adopted a lot from previous routes, and complete redesign or ground-up design was not always possible. Where room was tight at stations, some concessions may be necessary. For example, providing consistency to ADA ramp design is very important. If you are going to have a sloping ramp and a step-down on either side of the platforms, you're not delivering consistency. Having sloped ramps on either side would be ideal, if possible.

4. **What tough decision did you make in the planning and/or design of your BRT roadway infrastructure that in hindsight you are glad you made (loss of parking, some element you wanted to include but couldn't, etc.)?**

   Dropping from 14 in. to 12 in. curb height proved to be a good decision in a mixed-fleet operation. There is a trend for low-floor 40 ft buses and getting close to the curbs at stops. With a 12 in. curb height, MCTS anticipates greater longevity for the vehicles and platforms.

5. **What are the widths of your bus lanes? If you could revise the design, would you change the bus lane widths and why?**

   12 ft in the wider locations down to 11 ft. MCTS would never go below 11 ft based on the width of the vehicles.

6. **What are some of the conflicts/safety issues you may have encountered along the roadways between buses, pedestrians and bicycles?**

   The Milwaukee BRT is still relatively new. However, they have approximately 3,200 average riders on a weekday and operated for Summerfest recently where the ridership was over 6,000 per day. Fortunately, there have been very few conflicts to date.

7. **What advice with respect to BRT roadway infrastructure would you give to other agencies or cities that are embarking on their first BRT system?**

   Connect with utilities as soon as possible and make connections in the community early. Also make design second to outreach. Members of the community need to clearly understand what BRT will mean to their communities and roadways. It will prevent misunderstandings and upset in the long run.

8. **What elements of your BRT infrastructure are essential to its success?**

   There is not one element in particular but four items that are essential. The combined groupings of dedicated lanes and traffic signal prioritization are key. Additionally the pairing of platforms and off-board fare collections are essential to successful operations.

9. **Who maintains the different elements of your BRT roadway infrastructure?**

   It is a shared responsibility between MCTS, the respective municipalities and Milwaukee County. MCTS maintains the property in the stations themselves and has an underground snow melt system. The city sidewalks behind the platforms are maintained by respective municipalities, and the county maintains the roads. However, where there are dedicated lanes for bus-only, MCTS receives an invoice for services rendered.

10. **Is there anything else you would like to share with us about your system?**

    MCTS has the first and only BRT in the state of Wisconsin.

Enforcement of bus lanes/BRT system

1. **Do you have enforcement of the dedicated bus lanes? If yes, what type of enforcement is used (dedicated police or camera enforced, any other means of enforcement)? If not, do you plan to implement enforcement in the future?**

   There is a partnership with local and county law enforcement who deter and monitor the route. There are four cameras at each platform being constantly monitored by MCTS staff. We monitor use of the dedicated lanes and have recorded 85% to 90% compliance.

2. **Do you utilize red coloring in any of your bus lanes? If so, do you have any insights into general purpose compliance with red lanes vs. those without red coloring? Pros and cons of end-to-end painted bus lanes, including maintenance of the painted lanes.**

   No. Pigmentation was considered, but in a harsh uneven pavement and cold weather environment such as Wisconsin, it was deemed impractical.

3. **Have you experienced any safety-related concerns due to general purpose vehicles traveling in the bus lanes? If so, how are you approaching the issue?**

   No. MCTS relies on local law enforcement to deter and prevent unauthorized use of the lanes. MCTS trains the bus operators thoroughly to be aware of hazards present. There are sections where we share the lane with bicyclists, and the operators are trained to use a safety buffer to prevent incidents.

ITS related

1. **What types of ITS are you using in your BRT system? Based on your experience, what are the pros and cons of the system?**

    - Traffic signal prioritization
    - Variable message signs
    - GPS

2. **What technology did you implement in your BRT roadway infrastructure that is now out of date or did not perform up to expectations?**

    There are certainly bugs in every system. Most issues with current technology can be traced back to human error. It is essential to make sure MCTS keeps data clean in order to receive correct outputs. For instance, completely understanding the functionality of software to identify bus activity is key. If you are not correctly telling the system what is occurring, bad reporting on scheduling may occur.

3. **Are you considering the implementation of newer and/or more advanced technology, such as moving toward a more cloud-based technology in optimizing BRT performance and managing bus signal priority, traffic, etc., along roadways?**

    MCTS already has TSP installed, and it is viewed as a key element to the BRT success. There is strong consideration being given to lane delineators or rounded curb ridging to deter entrance to the lanes by unauthorized vehicles. This is still under consideration and may be used in future segments.

6. Greater Cleveland RTA (Ohio)

Contact name: Joe Shaffer

Contact information: jshaffer@gcrta.org, 216-356-3269

Roadway infrastructure/design

1. **Please provide a brief overview of your BRT roadway infrastructure (type of guideway or other design features to reduce delays and improve the performance of the BRT system). (Median guideway, side/ curb running guideway, mixed flow, red lanes, TSP [conditional or unconditional], queue jumps, lane enforcement, all-door boarding, level/near-level boarding, other.)**

    - Median guideway with near-level boarding
    - Mixed use lanes with standard curb heights
    - One queue jump
    - All-door boarding
    - Business access transit lanes

2. **What do you wish you knew before you began the planning and/or design of your BRT roadway infrastructure?**

    We wish we knew all the hassles that TVMs on the platforms would bring. We now have fareboxes on the vehicles again. It does affect dwell time. But there were just too many issues with the off-board fare collection.

    GCRTA expanded the area for end of line operations at Windermere.

3. **What, if anything, would you change with respect to your BRT roadway infrastructure in hindsight (e.g., near-side vs far-side stations, jaywalking at stations, etc.)?**

   Not much. Uplights in the 4 ft paved medians all failed within a year. That aesthetic feature was a waste of money.

4. **What tough decision did you make in the planning and/or design of your BRT roadway infrastructure that in hindsight you are glad you made (loss of parking, some element you wanted to include but couldn't, etc.)?**

   There was about a mile of overhead power. Although it was expensive and a lot of work, we are very glad to have coordinated with Cleveland Public Power to get the overhead power lines rebuilt underground.

5. **What are the widths of your bus lanes? If you could revise the design, would you change the bus lane widths and why?**

   - 12 ft—no change is needed.
   - Rumble strips have been effective
   - Embedded reflectors were installed at intersections, but they have all been destroyed.

6. **What are some of the conflicts/safety issues you may have encountered along the roadways between buses, pedestrians and bicycles?**

   Riders on the platforms stand too close to the boarding edge and have been struck by the mirrors of the bus.

7. **What advice with respect to BRT roadway infrastructure would you give to other agencies or cities that are embarking on their first BRT system?**

   Make a plan for continued city coordination on TSP.

8. **What elements of your BRT infrastructure are essential to its success?**

   - Dedicated lanes
   - Portions that exhibit true permanent investment

9. **Who maintains the different elements of your BRT roadway infrastructure?**

   - GCRTA maintains stations—glass elements are standard sizes (Bryan Moore could elaborate on station maintenance).
   - City maintains signals—TSP has rarely been functioning as desired.
   - City maintains street—brick paver crosswalks have been failing.

10. **Is there anything else you would like to share with us about your system?**

    - HealthLine vehicles have wheels for operator use in precision docking (New Flyer will void warranties if those are on new vehicles, so GCRTA is going to a UHMWPE bus curb).
    - No platform snowmelt on the platforms—that was felt to be a good decision.
    - Shelters were UL-listed and pre-manufactured, which made installations simple.

Enforcement of bus lanes/BRT system

1. **Do you have enforcement of the dedicated bus lanes? If yes, what type of enforcement is used (dedicated police or camera enforced, any other means of enforcement)? If not, do you plan to implement enforcement in the future?**

   Rely on city police for enforcement.

2. **Do you utilize red coloring in any of your bus lanes? If so, do you have any insights into general purpose compliance with red lanes vs. those without red coloring? Pros and cons of end-to-end painted bus lanes, including maintenance of the painted lanes.**

   No red pavement used.

3. **Have you experienced any safety-related concerns due to general purpose vehicles traveling in the bus lanes? If so, how are you approaching the issue?**

   Some bicycles use the bus lane, but it has not been a significant issue.

ITS related

1. **What types of ITS are you using in your BRT system? Based on your experience, what are the pros and cons of the system?**

   Opticom was installed originally. The system worked fine when it was operating as designed. City tinkered with signal timings.

2. **What technology did you implement in your BRT roadway infrastructure that is now out of date, or did not perform up to expectations?**

   Camera detection is being replaced with radar detection, as the cameras were often too dirty to function.

3. **Are you considering the implementation of newer and/or more advanced technology, such as moving toward a more cloud-based technology in optimizing BRT performance and managing bus signal priority, traffic, etc., along roadways?**

   That would be ideal, but we would have to have the city of Cleveland lead that effort. And it is not high on their priorities right now.

