Transit Advantages and Transit Signal Priority

02/15/2024

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Executive Summary

Metro Transit and its partners have partnered on transit advantage projects for more than a decade and have an established, aggressive program of transit reliability investments (metrotransit.org/speed-reliability). These efforts improve transit speed and reliability region-wide. 80% of customers benefit from completed or planned projects. Projects include:

- Bus rapid transit (BRT) Lines – A, C, D, Orange and Red; 2025 opening B, E and Gold
- Light rail transit (LRT) Line – Blue and Green
- Better Bus Route improvements – Routes 2, 3, 5, 17, 22, 63; two/year moving forward

Speed and reliability interventions include transit signal priority (TSP), bus lanes, stop spacing and placement, route simplification, and others. Projects that focus on a single element such as TSP alone result in widely varying benefits. Those that bundle elements into a complete package, such as BRT or LRT, realize substantial improvements to speed and reliability.

The regional Transit Advantage and Signal Priority Working Group was convened in response to the 2023 Minnesota Transportation Omnibus bill HF 2887 Section 119, which required the Metropolitan Council and its partners to:

- Assess the current status and capability of transit signal priority systems among the relevant road authorities;
- Identify key barriers and constraints and measures to address the barriers;
- Explore methods for ongoing coordination among the relevant road authorities;
- Estimate costs of potential improvements; and
- Develop a proposal or recommendations to implement transit signal priority systems and related transit advantage improvements, including a prioritized listing of locations or routes.

The working group has enhanced regional collaboration by providing a forum to share priorities, technology, and lessons learned. All participants have a broader and deeper understanding of the context of transit priority projects and the challenges that accompany them. The working group also identified key institutional, data and performance, and technological barriers that slow or impede transit priority implementation. These include insufficient staff capacity, the need for more regular coordination meetings between Metro Transit and roadway authorities, additional learning and data analysis opportunities around TSP, and the need for a multi-year and multi-faceted Transit Advantages workplan.

Crucially, Metro Transit and its partners have started resolving a number of these barriers and the working group will continue meeting after completion of the legislative mandate to maintain progress on matters of regional significance. Recent work has included tripling the size of Metro Transit's Speed and Reliability team, arranging on-going coordination meetings with roadway authorities that have the largest TSP deployments, receiving and analyzing periodic TSP data from the City of Saint Paul, hosting an initial technical training on TSP with the City of Minneapolis, and beginning to develop a five-year Transit Advantages Workplan. Future planned work includes additional Better Bus Routes projects, Spot Improvements, additional coordination, and exploration of future TSP technologies.

The future of transit advantages is bright. Regional governments continue to recognize, support, and invest in fast and reliable transit service. Metro Transit is spending more time and funding on speed and reliability

improvements. The projects completed and planned, and the outcomes of the working group, will ensure continued gains for transit customers for years to come.

This report summarizes transit advantages in general, the outcomes of the working group, and the program of speed and reliability projects for the next several years. It also identifies key barriers and constraints to transit advantage projects with proposed solutions. Additional details on working group meetings and interviews, transit advantages, and peer agency interviews can be found in the Appendix.

Introduction

Metro Transit and regional partners have long collaborated on transit speed and reliability projects. Significant regional investments such as the METRO Orange Line have created fast transit corridors. Smaller investments – such as in bus lanes and transit signal priority – have sped up service in key corridors. Collaboration on roadway reconstructions has resulted in better bus stop spacing and positioning.

Recognizing the importance of transit speed and reliability, the 2023 Minnesota Legislature required the Metropolitan Council to convene a working group to further transit advantage efforts in the region. The legislation required a report summarizing the results of the working group and providing information on:

- The current status and capability of TSP among the relevant road authorities.
- Key barriers and constraints and measures to address the barriers.
- Methods for ongoing coordination among the relevant road authorities.
- Costs of potential improvements.
- A proposal or recommendation to implement TSP systems and related transit advantage improvements including a prioritized list of locations or routes[1].

The working group included these agencies and stakeholder groups:

- Move Minnesota
- Metro Transit
- Minnesota Department of Transportation
- Ramsey County
- Hennepin County
- City of Saint Paul
- City of Minneapolis
- Suburban Transit Association
- University of Minnesota Center for Transportation Studies (CTS)
- SRF Consulting Group

The working group met eight times and discussed types of transit advantages and their relative benefits, current and planned speed and reliability projects, and barriers and solutions to implementation of transit signal priority. Background research and interviews conducted by Metro Transit and SRF provided context for the discussions.

This report summarizes transit advantages in general, the outcomes of the working group, and the program of speed and reliability projects for the next several years. It also identifies key barriers and constraints to transit advantage projects with proposed solutions. Additional details on working group meetings and interviews, transit advantages, and peer agency interviews can be found in the Appendix. The group members have agreed to continue the working group beyond the legislative mandate to discuss transit priority matters of regional significance and enhance collaboration long-term.

[1] Referenced legislation is HF 2887 available at: revisor.mn.gov/bills/text.php?number=HF2887&type=bill&version=5&session=ls93&session_year=2023&session_number=0

Types of Transit Advantages

There are numerous sources of delay on any particular transit trip. Each type of delay has different solutions, each with varying impact. Transit advantage projects that focus on a single type of delay or intervention can have widely varying benefits. Substantial speed and reliability gains are best achieved through a comprehensive package of transit advantage elements. Figure 1 illustrates how the broad package of transit advantages implemented with arterial BRT results in time saved for customers who formerly rode Route 19 (replaced by C Line in 2019). Compared to Route 19, C Line spends less time stopped, more time moving fast, and about the same time boarding and alighting customers even with a substantial increase in ridership.

Figure 1: Bus budget comparison between Route 19 and C Line. A bus budget breaks out the different phases of a transit trip, including time stopped, time spent boarding and alighting customers, and time spent traveling at various speeds.

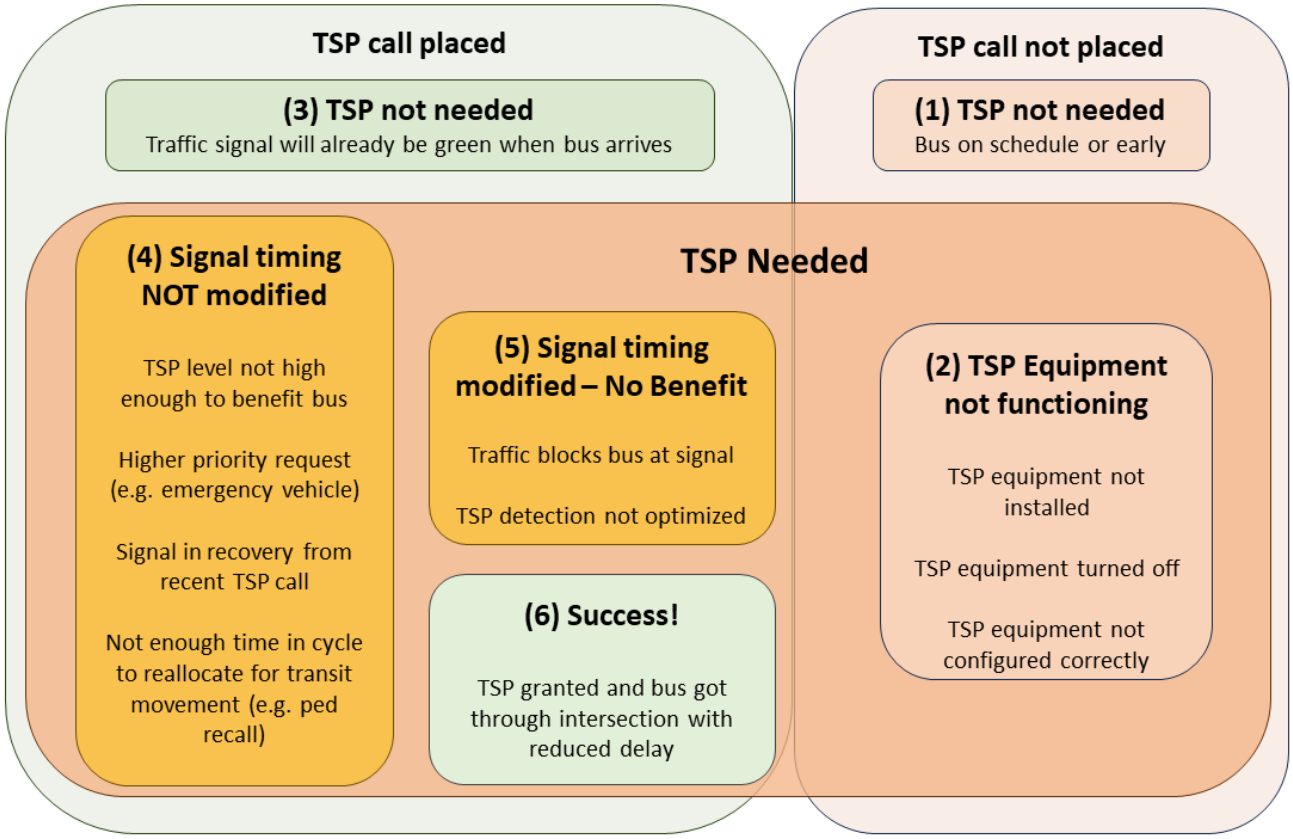
Transit Signal Priority

Transit signal priority modifies the signal timing at an intersection to favor the transit vehicle. Like any vehicle, a bus or train that just misses a green light must wait until the next green, which can take 30 to

60 seconds or more depending on the intersection. By temporarily changing the traffic signal timing, a significant amount of vehicle and transit customer delay can be avoided, improving schedule adherence and the rider experience.

Many factors affect whether TSP is requested and granted – and whether the bus can take advantage of the TSP, or even if it needs that advantage. Figure 2 illustrates the scenarios that can occur for a transit movement through an intersection. Scenario 6 (Success!) occurs only when TSP is requested, TSP is granted, and the bus can take advantage of signal timing modification.

Figure 2: TSP request scenarios. Scenarios 1 through 5 result in no TSP benefit to the bus, even though the bus may pass through the intersection without stopping. Scenario 6 is a successful TSP event.



The transit priority system used locally employs radio communications between the bus and a specialized detector card in the traffic cabinet. The card relays the TSP request to the traffic signal controller, which then decides how to serve the transit movement. A detailed explanation of system functions and hardware can be found in the Appendix.

TSP's benefits vary drastically by the type of priority, the intersection, and the urban environment. Roadway authorities in conjunction with Metro Transit determine the level of priority and acceptable disruption to other modes based on these factors. Policies such as standards for acceptable delay, street design guidance, and overall transportation strategies also inform decision-making on the level of priority to grant to transit.

At the far extreme, transit vehicles can be given a level of priority just below that of emergency vehicles, also referred to as preemption – disrupting signal cycles for minutes. This virtually guarantees that a

transit vehicle will not be delayed by traffic signals but comes at a significant cost to other roadway users. Beyond delays to single-occupant vehicles, pedestrians and cyclists are frequently delayed. Other transit routes that cross these intersections can also be delayed. This can degrade other travelers' experience and may encourage risky behavior such as walking against traffic signal indications. A level of priority this high has been reserved for core, regional transit routes such as the METRO Green Line LRT at lower volume intersections on University Avenue in Saint Paul.

The opposite extreme is providing the transit vehicle additional green time within the tight constraints of short traffic signal cycles, city roadway grids, and higher priority movements such as pedestrians. Operations such as automatically recalling pedestrian movements without requiring pedestrians to push a button limit the ability to change traffic signal timing. With pedestrian recall operations, as little as 1 second may be available to reallocate to transit. These conditions are typical of local bus routes, which best serve dense urban areas where modal balance is critical.

As part of the working group, Metro Transit and SRF performed a literature review and interviews with peer transit agencies to understand more about the TSP state of the practice. Peers at IndyGo in Indianapolis and RTD in Denver have TSP limited to green extension (holding the light green) or red truncation (shortening the cross street green), similar to bus TSP in the Twin Cities. IndyGo is planning to experiment with more aggressive TSP on its Red Line BRT route. This would add the ability to skip phases, a significantly more disruptive level of priority but one which leads to much greater transit advantage. MBTA in Boston has taken the approach of installing TSP at as many intersections as possible with the understanding that many will not provide significant transit benefits. MBTA has a cloud-based TSP system with multiple vendors, so adding new TSP does not require adding any hardware or wiring at an intersection. This contrasts with the system used locally, which requires additional labor, programming, testing, and maintenance to install and maintain. Additional details of the literature review and peer interviews can be found in the Appendix.

Other Transit Advantages

TSP only addresses one source of delay. Figure 3 provides an overview of the menu of strategies used to treat other types of delay. More details can be found in the Appendix. Table 1 summarizes the relative capital costs and benefits of each strategy. Some strategies require additional ongoing cost for maintenance and operation, such as repainting bus lanes every three to five years.

Figure 3. Types of Transit Advantages

Types of Transit Advantages

A **queue jump**—a bus-only lane that exists leading up to an intersection—can allow buses to move ahead of queued vehicles at a signal before merging into general traffic. Used with TSP or a leading transit phase, this tool can generate significant travel time savings where intersection queues are typically long.

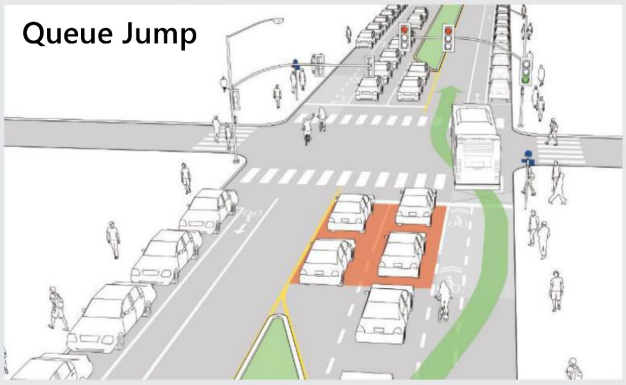


Image source: NACTO

Bus stop placement at the far-side of a signalized intersection can reduce signal delay. In tandem with TSP, buses can pass through the intersection before stopping. This reduces the possibility of stopping twice at an intersection.

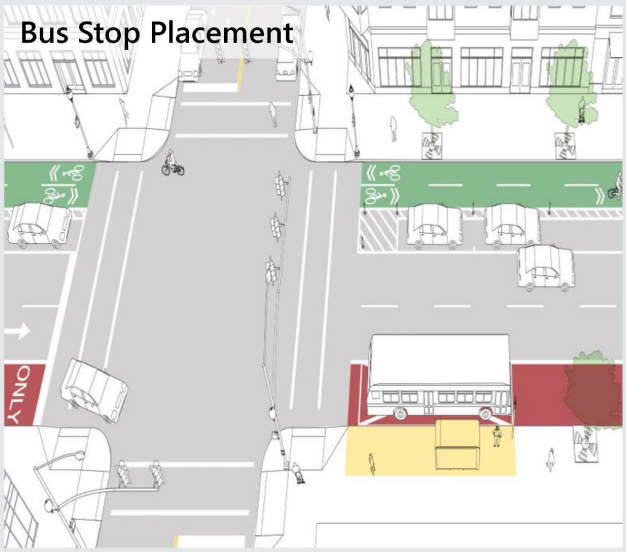


Image source: NACTO

Level boarding refers to bus stop curb heights that align with the vehicle floor. This can facilitate faster boarding and alighting, reducing dwell time. Level boarding also reduces the need for ADA ramp deployment, further improving bus speed and reliability.

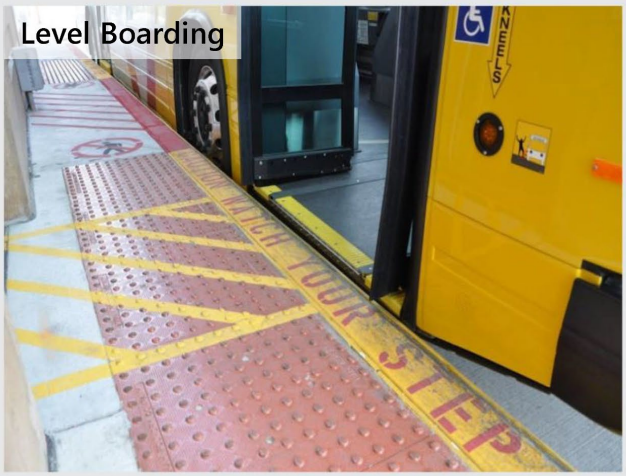


Image source: Metropolitan Council

In-lane stops eliminate the need for buses to leave the travel lane to access a curbside bus stop and then reenter the travel lane. Stopping in the travel lane promotes faster movement between stops by reducing or eliminating merging movements.

Image source: Metro Transit

Fare prepayment speeds up the boarding process by allowing riders to purchase their fares offboard rather than on-board buses. This reduces bus dwell time.

Non-cash fare payment, specifically with Go-To Cards (GTCs), reduces bus dwell times by speeding up on-board payment processes.

Fare Prepayment

Image source: Metro Transit

All-door boarding further decreases dwell time by minimizing choke points and congestion, allowing customers to board and alight buses quickly.

All-Door Boarding

Image source: MoveMN

Signal optimization is generally completed every 3-5 years at traffic signals, which optimizes the movement of vehicles based on current traffic patterns, including buses.

Bus only lanes allow buses to bypass congested travel lanes and operate at faster, more consistent speeds. This can produce significant travel time savings and mitigate travel time variability, especially on streets with both high bus frequency and high general traffic volumes.

Bus Only Lane

Image source: Metro Transit

Bus stop consolidation increases stop spacing to every ¼ mile rather than the current spacing of every one to two blocks, eliminating delays associated with frequent decelerating and stopping.

Route streamlining can improve travel times by avoiding turning movements or congested areas, allowing for increased bus speeds.

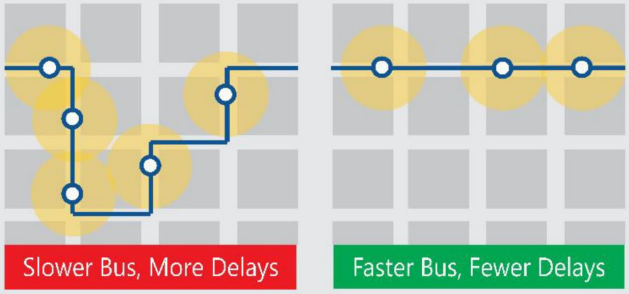


Table 1. Summary of Transit Advantage Strategies

Transit Advantage Strategy	Relative Improvement to Speed	Relative Improvement to Reliability	Capital Cost for Typical Project in Metro Region	Implementation Schedule	Implementation Level
Queue Jumps	■■	■■■	$-$$	Mid	Point
Stop Placement	■	■	$	Near	Corridor
Level Boarding	■■■	■■■	$$	Near	Point/Corridor
In-Lane Stops	■■	■■	$$-$$$	Mid	Point/Corridor
Fare Prepayment	■■	■■	$	Near	System
Non-Cash Fare Payment	■■	■■	$$	Near	System
All-Door Boarding	■■■	■■■	$$$	Near	Corridor/Route
Signal Optimization	■■■	■■	$[1]	Near	Corridor
Bus-Only Lane (Conversion of Existing Lane)	■■■■	■■■■	$-$$[2]	Near	Corridor
TSP	■■	■■	$-$$[3]	Mid	Point/Corridor
Stop Consolidation	■■■■	■■■■	$	Near	Corridor
Route Streamlining	■■■	■■	$	Near	Corridor

Notes:

1) Assumes existing infrastructure and cost is associated with labor to develop optimized timings.
2) Assumes restriping existing lanes.
3) The current TSP system requires equipment at each intersection to run TSP, which has a planning level cost of $11,500 per intersection based on previous installations. This cost includes three items:
   - $1,500 for city equipment installation
   - $7,000 for Emtrac TSP kits, which includes the equipment required in the field
   - $3,000 for design and testing assistance

Matrix Key				
Cost	*To plan, coordinate, and implement this tool will cost…*		**Implementation Schedule**	*To plan, coordinate, and implement this tool will require…*
	$	**Less than $100K**	**Near**	Less than 2 years
	$$	**$100K to $500K**	**Mid**	2-5 years
	$$$	**Over $500K**	**Far**	Over 5 years

Metro Transit Speed and Reliability Program

Metro Transit and its partners have been working on speed and reliability initiatives for over a decade. Metro Transit has had a dedicated Speed and Reliability program since 2018 (metrotransit.org/speed-reliability). Some projects such as Better Bus Routes improve an existing route or build new, fast transit services; others, such as the arterial Bus Rapid Transit program (metrotransit.org/brt), replace routes with enhanced transit service. Other projects enhance key transit corridors and can aid multiple routes. The package of interventions has included transit signal priority (TSP), bus lanes, stop consolidation, fare prepayment, in-lane transit stops, and many other strategies to address all sources of potential delay on a transit trip.

Figure 4 shows the routes that have been or are planned to receive speed and reliability improvements. Approximately 80 percent of riders benefit from completed or planned speed and reliability improvements (see Figure 5). Table 2 shows currently planned speed and reliability projects through 2029.

Figure 4: Routes with recent or planned speed and reliability improvements. Local bus routes are shown in blue; transitways (LRT, highway BRT, arterial BRT) are shown in green.

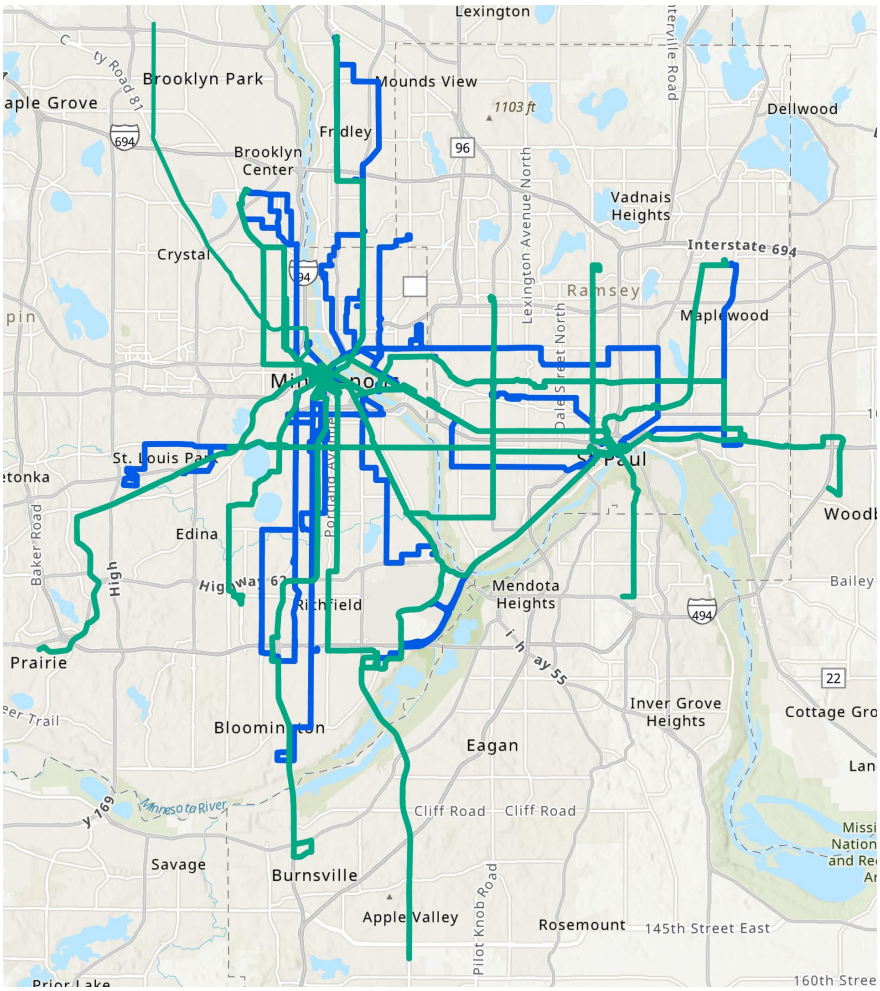


Figure 5: Ridership and routes with recent or planned speed and reliability improvements. Percentage of ridership based on October 2023 ridership (approximately 153,000 riders per weekday).

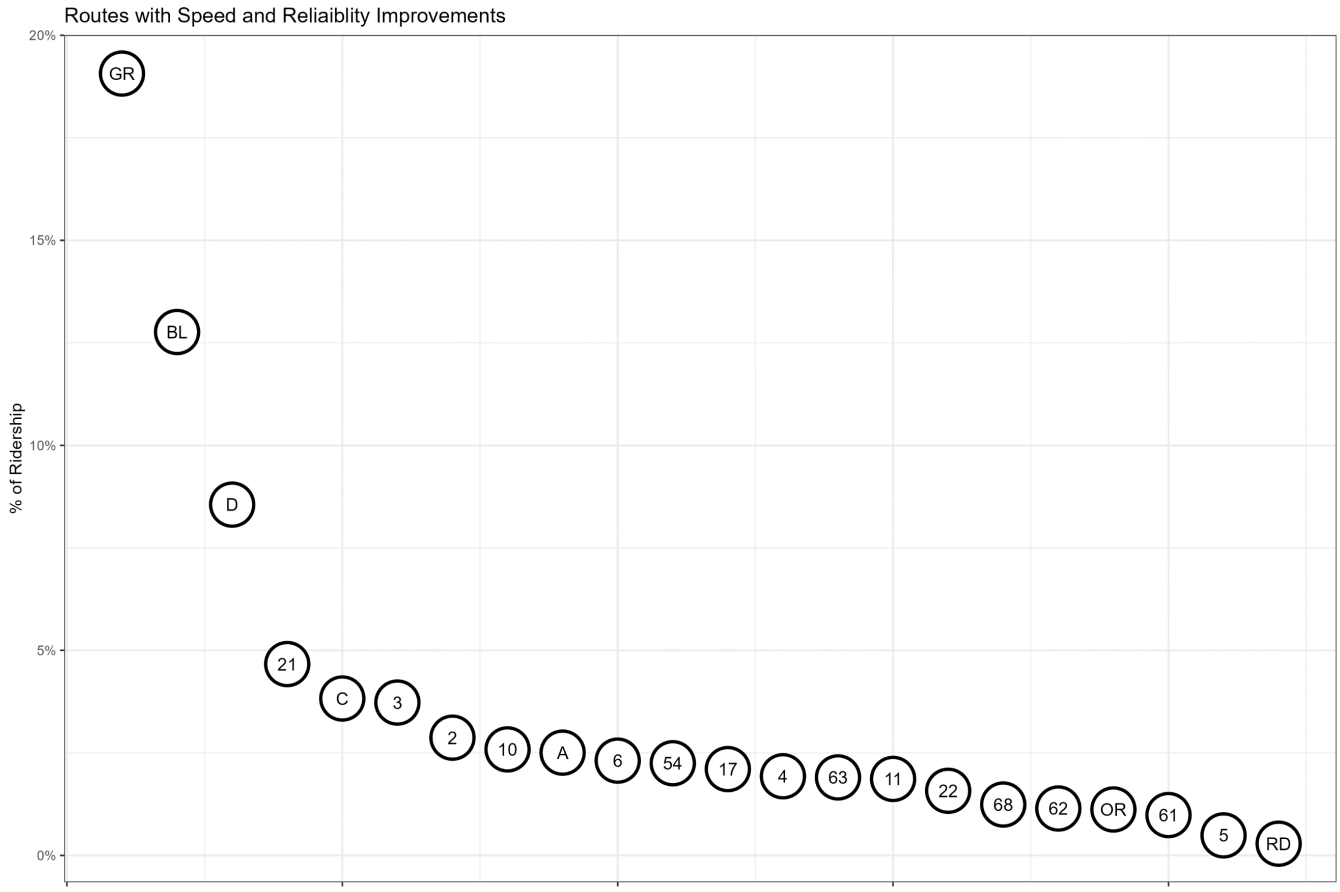


Table 2: Metro Transit Speed and Reliability projects planned through 2029.

Year	Speed and Reliability Projects
2024	• Better Bus Routes: Route 4 • Bus Lanes: Hennepin-Lyndale Commons • Transit Signal Priority: Route 63 (Saint Paul), Lyndale Avenue South (Minneapolis), Lake Street East (Minneapolis) • Spot Improvements
2025	• Corridor Improvements: Lowry Ave NE (Minneapolis) • Better Bus Routes: Route 61, *Route TBD* • Bus Lanes: Hennepin Avenue South, Hennepin/1st Avenue • Spot Improvements • Arterial BRT: B Line, E Line • Transitways: Gold Line
2026	• Corridor Improvements: Hennepin Downtown (Minneapolis) • Better Bus Routes: *Routes TBD* • Spot Improvements • Arterial BRT: F Line
2027	• Corridor Improvements: 7th Street North (Minneapolis) • Better Bus Routes: *Routes TBD* • Spot Improvements • Arterial BRT: G Line • Transitways: Green Line Extension
2028	• Corridor Improvements: 8th Street North/South (Minneapolis) • Better Bus Routes: *Routes TBD* • Spot Improvements
2029	• Corridor Improvements: Nicollet Avenue (Minneapolis) • Better Bus Routes: *Routes TBD* • Spot Improvements • Arterial BRT: H Line

Better Bus Routes

The Better Bus Routes program seeks to make riding local buses easy and enjoyable. Changes generally include quick, low-cost improvements such as bus stop consolidation and relocation, the expansion of no-parking zones to clear curb space for buses, transit signal priority, route streamlining, ADA pads, and new shelters. The program also prioritizes increasing operator satisfaction through more consistent travel times and better recovery times at the end of routes.

Each project consists of a technical advisory committee (TAC) comprised of Metro Transit and partner agency staff. The TAC reviews the unique characteristics of each route to identify potential areas of improvement. Data sources include ridership, on-time performance, and travel speeds. Metro Transit uses this information, along with previous customer comments, input from operators, and data gathered from field assessments, to make an initial set of recommendations that are shared with the public.

Completed Projects

Since 2018, five full Better Bus Route projects have been completed. Information about each project can be found below in Table 3. In 2023, Metro Transit also completed a “mini” project on a portion of the Route 10 in Minneapolis.

Table 3. Summary of Completed Better Bus Routes Projects

Project	Year	Partners	Transit Advantages and Other Improvements	Results
Route 2	2018	• City of Minneapolis • Hennepin County	• Stop consolidation and relocation • Shelter installation and upgrades • ADA pads • TSP (2021)	• 88% of boardings at sheltered stops • Positive operator feedback to recovery time and schedule accuracy improvements
Route 63	2020-2021	• City of Saint Paul • Ramsey County	• Stop consolidation and relocation • Shelter installation • ADA pads • Extended no-parking zones near bus stops • Frequency improvements • Route design simplification • TSP (2023)	• 3.3 – 7.5% decrease in median travel times • 9.4 – 28.5% reduction in the range of travel times (between the 5th and 95th percentiles) • Most significant reliability improvements during afternoon rush hours
Route 3	2021	• City of Minneapolis • Hennepin County • City of Saint Paul • University of Minnesota	• Stop consolidation and relocation • Shelter installation • ADA pads • Route design simplification • Frequency improvements • Extended no-parking zones near bus stops	• 3% decrease in median travel times despite increasing ridership (28.6%) • 8.7 – 34.2% reduction in the range of travel times (between the 5th and 95th percentiles)
Route 22	2022	• City of Minneapolis • City of Brooklyn Center • Hennepin County	• Stop consolidation and relocation • Shelter installation • ADA pads • Pedestrian improvements • Route design simplification • Extended no-parking zones near bus stops	• Travel time changes resulting from these improvements are planned to be analyzed in the future.
Route 17	2023	• City of Minneapolis • City of St. Louis Park • Hennepin County	• Stop consolidation and relocation • Extended no-parking zones near bus stops • Route design simplification • Schedule modification	• Results from these improvements will be made available after allowing time for adequate data collection.

Planned Projects

In 2021, Metro Transit prioritized future Better Bus Routes based on three key principles:

- Provide consistent and competitive travel times for transit customers.
- Improve legibility and accessibility of routes.
- Promote equity of transit service in the region.

The prioritized list is shown in Table 4.

Table 4. Better Bus Route Evaluation Results

Tier	Years	Routes*
1	2022-2024	22*, 4, 17*, 18†
2	2025-2027	14, 11, 61
3	2028-2029	54, 12‡

* Since this process was completed in 2021, Metro Transit has completed improvements to Route 22 (2022) and Route 17 (2023).
† Route 18, a top scorer, was removed from consideration due to other potential projects in the corridor. Metro Transit is re-evaluating Route 18 for potential improvements.
‡ Route 12 is currently suspended with no timeline for reinstatement.

Bus Lanes

Bus lanes provide dedicated space for buses to operate free from traffic congestion. Bus lanes are especially important in downtowns and commercial corridors where transit speeds can fall dramatically during periods of high traffic.

Completed Projects

Bus lanes have existed in Saint Paul and Minneapolis for many years. This includes 5th and 6th streets in downtown Saint Paul and the Marquette/2nd Avenue corridor in Minneapolis.

Recently, Metro Transit and local roadway authorities added bus lanes on Hennepin Avenue South and 7th Street in Minneapolis.

Hennepin Avenue S

The Hennepin Avenue South bus lanes between Lake Street and Franklin Avenue were implemented in fall 2019. Hennepin Avenue had been one of the slowest transit corridors in the region, with bus speeds slowing to six miles per hour during the rush hour. The lanes provide faster, more consistent rides for 3,000 customers each weekday.

Travel time data from the first few months of operation showed that:

- Travel times were reduced by 15 – 18%.
- Transit reliability increased by 27 – 36%.
- Bus-only lanes were most effective on days with snow, when congestion was at its worst.

These lanes will be improved as part of the City's Hennepin Avenue South reconstruction project. Upon completion in 2025, they will extend the full length of the corridor in both directions with expanded hours.

7th Street

Seventh Street is a key downtown transit corridor with a combination of arterial BRT, local, and express bus service. Both METRO C and D Lines operate along 7th Street.

The bus lane opened in fall 2021. The lanes were implemented without significant impacts to curbside uses like valet zones and deliveries. They extend the full length of the corridor and operate 24/7.

Travel time data comparing October 2019 and October 2023 showed positive results:

- Travel times were reduced by 15%
- Transit reliability increased 18%

Planned Projects

The bus lanes planned in the near term include:

- Hennepin Avenue NE/1st Avenue NE (2024)
- Lake Street and Marshall Avenue (2023 and 2024) in conjunction with the METRO B Line
- Hennepin Avenue/Lyndale Avenue Commons (2024)

The City of Minneapolis is also completing a prioritization process to identify corridors for future treatments.

Arterial Bus Rapid Transit

The arterial BRT Program focuses on building out the METRO network and improving high ridership local bus corridors that connect major destinations. Arterial BRT lines provide an approximately 20% faster trip than the previous local bus. Improvements in conjunction with BRT implementation generally include:

- Making fewer stops, significantly speeding up travel time and helping the bus to stay on schedule.
- Providing fare payment equipment at stations that allow customers to purchase tickets before boarding, so there is no need to line up at an on-board farebox.
- Using low-floor buses and raised curbs at stations, plus wider bus doors and boarding from the front and back doors, to speed up boarding.
- Extending the curb at stations to save time. Buses can merge more easily into traffic after serving a station.
- Adding TSP which allows buses to move through traffic lights a bit faster.

When the system is fully built out, a quarter of the region's residents will live within a ¼-mile of an arterial BRT line.

Completed Projects

Three arterial BRT lines are currently in operation:

- The METRO A Line on Snelling Avenue and Ford Parkway in Saint Paul and Minneapolis began operation in 2016.
- The METRO C Line primarily on Penn Avenue traveling between downtown Minneapolis and Brooklyn Center began operation in 2019.
- The METRO D Line on Emerson Avenue, Fremont Avenue, and Chicago Avenue traveling between Bloomington and Brooklyn Center began operation in 2022.

Planned Projects

Five more arterial BRT lines will open by 2030 (shown in Figure 5):

- The METRO B Line on Lake Street, Marshall Avenue, and Selby Avenue in Minneapolis and Saint Paul is scheduled to open in 2025.
- The METRO E Line on Hennepin Avenue and France Avenue in Minneapolis and Edina is in the engineering phase and is planned to open in 2025.
- The METRO F Line will serve the Central Avenue corridor in Minneapolis, Columbia Heights, Fridley, Spring Lake Park, and Blaine via Central Avenue and University Avenue. The line is in the planning phase and is anticipated to open in 2026.
- The METRO G Line will serve the Rice/Robert Street corridor, traveling between West Saint Paul and Little Canada via Robert Street and Rice Street. The line is in the planning phase and is anticipated to open in 2027.
- The METRO H Line will serve the Como Avenue/Maryland Avenue corridor from downtown Minneapolis to Sun Ray Transit Center in Saint Paul via Como Avenue and Maryland Avenue. The project is planned to open in 2028-2029.

Additional arterial BRT lines are targeted for implementation between 2030 and 2040. These mid- and long-term projects can be viewed here.

Transitway Projects

In addition to arterial BRT, Metro Transit also operates highway BRT and LRT. Compared to arterial BRT, highway BRT and LRT serve longer, more regional trips. Generally, highway BRT and LRT have more dedicated guideway and wider stop spacing with additional transit advantages. This results in the fastest and highest quality transit service. Metro Transit currently operates four such lines:

- METRO Blue Line between Minneapolis and Bloomington.
- METRO Green Line between Minneapolis and Saint Paul.
- METRO Red Line between Apple Valley and Bloomington.
- METRO Orange Line between Minneapolis and Burnsville.

Additional BRT and LRT projects are in various stages of development:

- The METRO Gold Line between Saint Paul, Maplewood, Landfall, Oakdale, and Woodbury.

- The METRO Purple Line between Saint Paul and Maplewood.
- The METRO Green Line Extension between Minneapolis and Eden Prairie.
- The METRO Blue Line Extension between Minneapolis and Brooklyn Park.
- The Riverview corridor between Saint Paul and Bloomington.

Existing and planned METRO lines are shown in Figure 6.

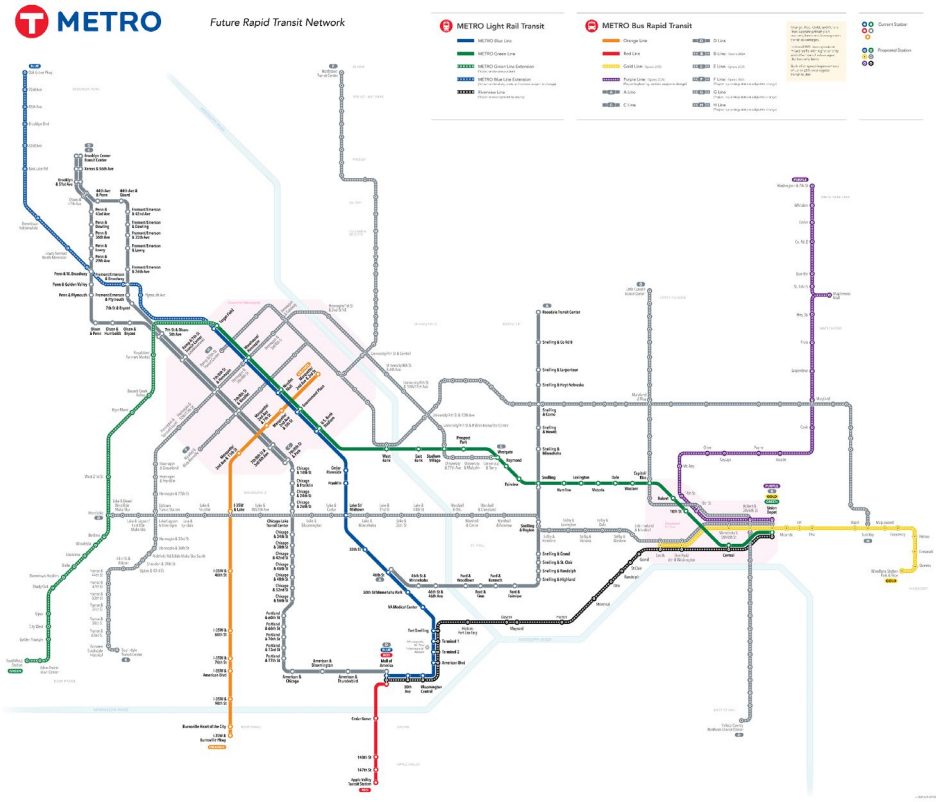
Other Roadway Projects

Street reconstructions offer the opportunity to relocate and consolidate bus stops, simplify bus routes, and improve traffic signals. Roadway agencies partner with Metro Transit to incorporate transit enhancements with many reconstructions. In many projects, Metro Transit has been a key partner from planning to construction.

An example of this collaboration is the Bryant Avenue South reconstruction in Minneapolis. The project led to moving several transit routes to the adjacent Lyndale Avenue. At the same time, bus stops were improved on Lyndale. The resulting routes are straighter than they were before, which avoids delays due to turning movements at intersections.

Future reconstructions such as Robert Street in downtown Saint Paul and Franklin Avenue in Minneapolis will provide numerous benefits to transit riders.

Figure 6. Existing and Planned LRT and BRT Lines



Twin Cities TSP System

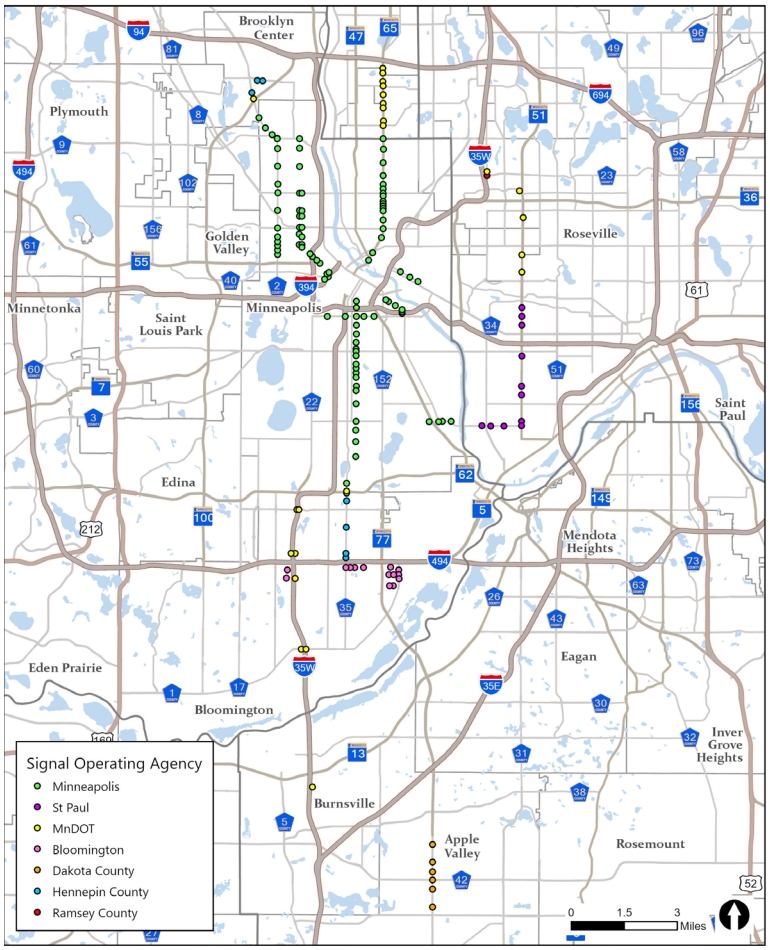
The Twin Cities has 15 years of experience with bus TSP. This system currently has 163 intersections in total, with each roadway authority operating the following number of intersections:

- City of Minneapolis – 96 intersections
- City of Saint Paul – 14 intersections
- City of Bloomington – 14 intersections
- Dakota County – 6 intersections
- Hennepin County – 7 intersections
- Ramsey County – 1 intersection
- MnDOT Metro – 25 intersections

The intersections that currently have TSP are shown in Figure 7. An additional 11 intersections on Route 63 in Saint Paul and numerous intersections on Lake Street and Marshall Avenue will be installed in 2024.

The TSP system used in the region (EMTRAC) requires specialized detector equipment at each equipped traffic signal. Each bus must also have a specialized computer, GPS receiver, and antenna. This contrasts with more recent "hardware lite" TSP systems that use internet communications between the transit operator, a cloud-based server, and traffic signals to generate and send requests for priority.

Figure 7: Current Intersections with TSP for bus. Does not include LRT signal priority.



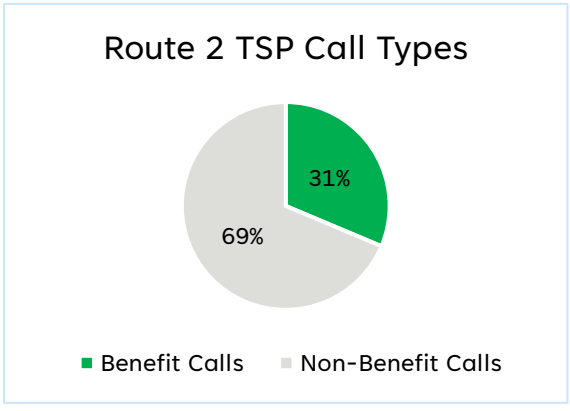
System Performance

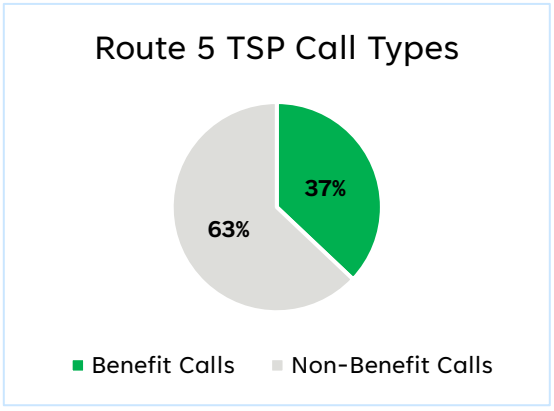
TSP performance in the region has been mixed. As discussed above, much of the region's local bus service operates in dense urban corridors where the available time for bus priority is limited. They typically also operate on major corridors that already receive more green time at traffic signals than lower volume side streets. Additionally, traffic signal controller and bus technology is constantly evolving. What was available 15 years ago when the first TSP was rolled out offered very limited capabilities. With over 150 existing installations and more than 1000 traffic signals just in Minneapolis and Saint Paul, various generations of equipment are in operation, providing varying abilities.

Performance of TSP can be measured in a variety of ways. The most significant is the overall benefit to transit operations in the corridor. One of the original TSP projects (Route 10 on Central Avenue in Minneapolis and Columbia Heights) showed a travel time reduction of 13.2% during the mid-day and evening but a 0.2% increase in travel times during the PM peak for southbound buses. On many corridors, both directions of transit cannot be prioritized equally, leading to imbalanced benefits.

On an intersections level, the number of TSP requests that result in some benefit can be measured. These result in early green or extended green to reduce delay to transit vehicles. Non-benefit calls result in no changes to the signal timing. Non-beneficial calls can occur because the transit vehicle arrived on green without TSP, the signal controller will not provide TSP because of an emergency vehicle call or competing traffic needs, or the signal is at a point in the traffic cycle where TSP cannot be granted. Figure 8 shows the percentage of TSP calls that resulted in benefit on routes 2 and 5 from post-implementation studies completed in 2021 and 2019, respectively. These data show that approximately 30 – 40% of calls resulted in benefit; however, the bus may have passed through the intersection on a normal green, even when TSP did not provide a benefit. Recent analysis of TSP on the METRO A Line in Saint Paul indicates that approximately 47 percent of TSP events are terminated by the bus passing through on a regular green indication.

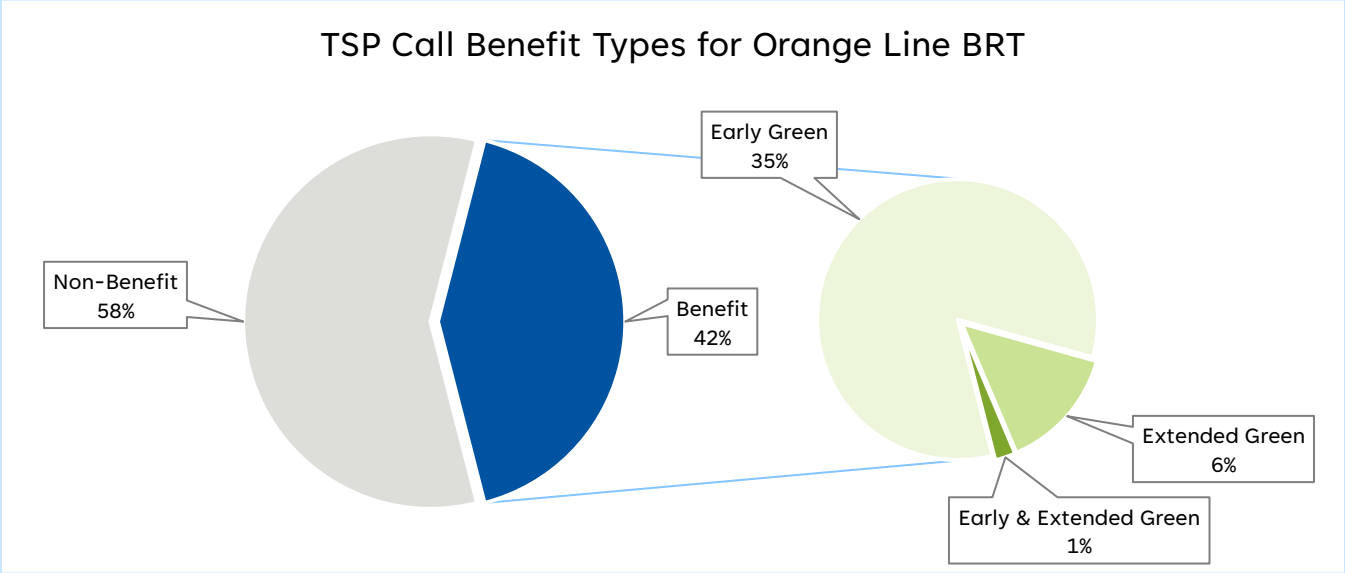
Figure 8. Route 2 and 5 TSP Call Types





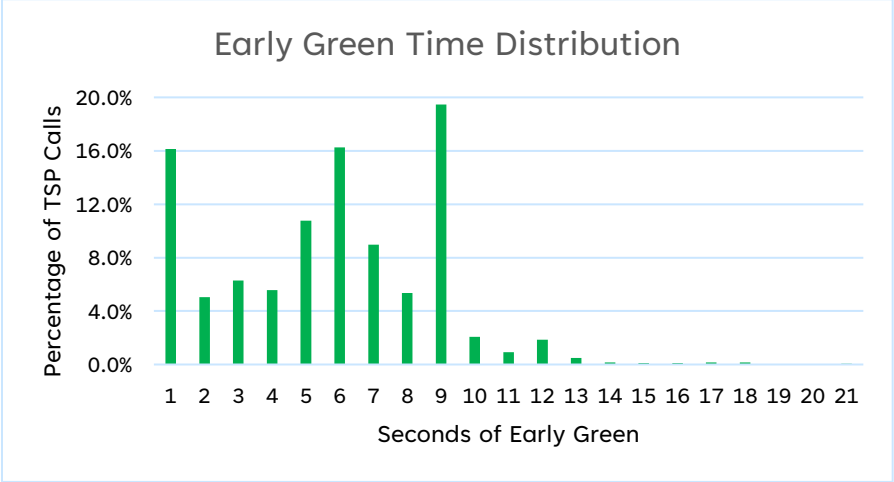
Requests can be analyzed for the type of benefit provided. Figure 9 shows the overall proportion of TSP calls receiving benefit for Orange Line BRT buses and further breaks down the types of TSP benefit provided.

Figure 9. TSP Call Types Along Orange Line BRT



Finally, each call can be analyzed for the number of seconds of benefit provided. The amount time granted for each request depends on factors such as when the TSP request came in, the TSP programming parameters, and the traffic/timing for other movements. Figure 10 shows the distribution of early green time for Orange Line. Approximately 94% of calls receiving benefit were offered between one and ten seconds of early green. Six percent of calls received ten or more seconds, up to a maximum of 21 seconds.

Figure 10: Early Green Time Granted on Orange Line BRT



Coordination with Roadway Authorities

Metro Transit and partner agencies coordinate closely on transit advantage projects. Collaboration begins in project planning and continues through the design and implementation. For example, Metro Transit typically identifies preferred TSP locations. Consultants develop proposed signal timings and TSP parameters. Roadway authorities review the timings and parameters and install field equipment. All

agencies partner in monitoring, evaluation, and maintenance. For other transit advantages, such as bus lanes, a high level of coordination and analysis is required to understand the potential transit benefits and impacts.

Metro Transit and roadway authorities meet as needed to discuss TSP projects, results, and issues. Metro Transit and the City of Minneapolis currently have a standing monthly meeting to discuss TSP. As discussed in the following section, Metro Transit intends to set up recurring meetings with other agencies to maintain coordination and work through any issues that arise.

Barriers to Expanding TSP and Potential Solutions

Barriers have historically slowed TSP implementation and impede understanding of its effectiveness. Barriers identified by the working group fall into three categories: (1) institutional, (2) data and performance, and (3) technology. The working group also identified potential solutions and a timeline for action for each barrier. The barriers and potential solutions are shown in Tables 5, 6, and 7.

As a result of this working group, Metro Transit and its partners are already enhancing data sharing and collaboration. Metro Transit and roadway authorities will continue to collaborate and address the barriers that have been identified.

Table 5. Institutional Barriers

Barrier	Solution	Status
Metro Transit does not have a lead representative involved with all TSP projects from planning process through construction and operations.	Metro Transit will designate a lead representative to be involved with all facets of TSP across Metro Transit, including rail and bus modes.	Complete
There are many roadway authorities that Metro Transit needs to coordinate with, and they each have their own processes and goals.	Set up recurring meetings with roadway authorities to discuss TSP, including future TSP installations and ongoing operations.	<1 Year Goal In Progress
Lack of staff capacity for roadway authorities and Metro Transit to dive into the use of TSP, operations, and maintenance.	Develop an understanding of additional staffing needs, along with specific skill sets and increase staff.	1-2 Year Goal
Processes to create agreements for TSP installations can slow project implementation.	Metro Transit is currently developing a master agreement with Minneapolis. Similar agreements with other roadway agencies could streamline future TSP projects.	1-2 Year Goal In Progress
TSP is currently being implemented on a project-by-project basis. No overall TSP program exists.	Metro Transit is developing a five-year Transit Advantages work plan. The plan will create more consistent communication, streamline contracting, and allow for advance ordering of equipment.	1 Year Goal In Progress
Metro Transit is currently purchasing TSP equipment on a project deployment basis and long material lead times can slow project implementation.	Purchase equipment in advance to have stock for future projects.	2-4 Year Goal (Change in TSP technology could impact this timeline)

Table 6. Data and Performance Barriers

Barrier	Solution	Status
Lack of understanding of the TSP request and service process from end to end.	Host training for Metro Transit and roadway authorities regarding the complete TSP process between the different technology systems involved.	<1 Year Goal In Progress
Limited understanding of TSP performance regionwide.	Many roadway authorities can provide traffic signal reports when requested. Metro Transit plans to request available data and begin to analyze it. Metro Transit and roadway authorities will continue to collaborate to develop a comprehensive understanding of how the TSP system is currently functioning.	<1 Year Goal In Progress
Retrieving signal controller logs is currently a manual process and can be time consuming to pull on a large scale.	Collaborate with roadway authorities to identify the needed data and determine if reports can automatically be generated and sent to Metro Transit.	<1 Year Goal In Progress
Some roadway authorities are concerned about TSP impacts and benefits general traffic.	Further analysis of TSP performance and the impacts to signal operations will be performed and shared with roadway authorities.	1-2 Year Goal
Some stakeholders within Metro Transit are cautious to advance TSP further without fully understanding the benefits	Further analysis of TSP performance and the impacts to signal operations will be performed and shared.	1-2 Year Goal

Table 7. Technology Barriers

Barrier	Solution	Status
The current TSP system, implemented almost 15 years ago, requires hardware at each intersection, which limits the scalability of the system.	Metro Transit has reached out to TSP vendors to hear about their current and future products; the vendors presented their product to the working group. Metro Transit and the roadway authorities will evaluate the best path forward for a TSP system in the Twin Cities.	2-4 Year Goal In Progress
Limited ability for Metro Transit to monitor TSP operations in real-time, for several reasons: 1) TSP operations are not well integrated into roadway authority central signal systems, 2) some central systems limit the number of users who can access the system, 3) IT and network security concerns for providing access, and 4) this level of detail has not been needed or requested to this point.	Metro Transit and regional partners will continue to evaluate options real-time monitoring and determine preferred solutions. Hennepin County has indicated that they can provide read-only access to their central system. Metro Transit is going to provide contact information for the people they wish to have access.	1-2 Year Goal In Progress
Metro Transit does not know if specific TSP equipment is working on the bus or in the field due to not having communication with the equipment. There are IT and security concerns from roadway authorities with having another network in their signal cabinets.	Continue to monitor technology and collaborate with roadway authorities to identify potential paths for Metro Transit to monitor TSP equipment.	1-2 Year Goal
Lack of standard TSP programming and controller settings.	Collaborate with roadway authorities to establish best practices. These could be shared with additional roadway authorities and consultants working with Metro Transit to provide an understanding of how TSP settings should be established and updated.	1-2 Year Goal

The Future of Transit Advantages in the Twin Cities

Metro Transit and its partners are actively expanding transit advantages in the region, with projects in all stages, including planning, design, and construction. Metro Transit recently expanded its Speed and Reliability team from one full-time person and one part-time person to three full-time staff members. The new team is already charting a more aggressive program of improvements, which will result in a five-year workplan guiding investments regionally. The team has also taken on new tasks such as focused improvements to speed and reliability "pain points."

Arterial BRT and Transitway Network

Metro Transit's arterial BRT network will expand to 15 lines by 2040. Other transitways such as the METRO Gold Line and the METRO Purple Line will offer high quality, fast, and reliable service to existing and new transit users. All these projects include transit advantages such as bus lanes, dedicated guideways, TSP, stop consolidation, and fare prepayment.

Better Bus Routes

Metro Transit's Better Bus Routes (BBR) program is a proven success for improving bus routes. Since 2018, one route has been improved per year. In 2023, Metro Transit completed one full BBR project and one "mini" project focused on a portion of Route 10. Beginning in 2024/2025, the Speed and Reliability team aims to improve two routes per year. The route prioritization shown in Table 3 will be refreshed and expanded upon to identify future routes for improvements.

Spot Improvements

The newly expanded Speed and Reliability team will begin a process of identifying "pain points" and potential solutions in 2024. Pain points are specific spots along a bus route that cause significant or frequent delays. Examples include high ridership bus stops with close adjacent parking. In that case, the bus may not be able to pull into and out of the bus stop efficiently leading to delays to many trips. Solutions to pain points can include queue jumps, TSP, or bus stop improvements.

Corridor Improvements

Multiple bus corridors are identified for improvement in the next few years. Planned bus lanes are discussed above. In addition, Minneapolis' corridor prioritization plan will guide future capital investments by the City. These corridors could include a mix of treatments, including TSP.

Roadway Projects

Many planned roadway reconstructions will or could include transit priority elements or make the roadway ready for future transit enhancements. Active and planned projects include:

- Grand Avenue (Saint Paul)
- Robert Street S (Saint Paul)
- Kellogg Boulevard (Saint Paul)
- University /4th Bikeway (Minneapolis)
- Lyndale Avenue South (Minneapolis)
- Franklin Avenue (Minneapolis)

Appendices

1. Working Group Meeting Summaries
2. Roadway Authority Meeting Summaries
3. Peer Agency Meeting Summaries
4. Additional Peer Agency Research
5. Transit Advantages Information
6. Transit Signal Priority Operation

1. Working Group Meeting Summaries

Meeting NOTES

Transit Advantage and Signal Priority Working Group (#2)

Date: 09/07/2023
Time: 01:00 PM

Attendees:

- Sam Rockwell, Move Minnesota
- Julie Johnson, Move Minnesota
- Adam Harrington, Metro Transit
- Paul Lamb, Metro Transit
- Michael Mechtenberg, Metro Transit
- Eric Lind, CTS
- John Fahrendorf, MnDOT Metro District
- Mike Fairbanks, MnDOT Metro District
- Taehyoung Kim, Ramsey County
- Nick Erpelding, Hennepin County
- Mike Klobucar, City of Saint Paul
- Allan Klugman, City of Minneapolis
- Adele Hall, SRF Consulting Group
- Phil Kulis, SRF Consulting Group

Meeting Notes

Transit Advantages, Signal Priority Report development and outline

The group discussed content to include in the report:

- Good examples of other agencies using TSP/queue jumps such as Denver RTD, Boston, Seattle, etc. This peer system review should consider systems, strategies, and tech. Include a peer system outside the US. In reporting to the legislature consider implementation and required processes or politics, logistics, etc and whether the legislature has a role in helping to pave the way for implementation.
- Acknowledging the short time that the working group has to formulate recommendations for the legislature, the report should also include a list of things to further explore.
- Answer two questions for every tool considered: Should we have a (bus lane, queue jump, etc)? What are the steps to implementation such as supplies, logistics, and equipment?
- Legislation only relates to bus but rail also has TSP.

- Ramsey County is the only entity of the ones convened that does not currently have a mode shift goal. The goals are a critical backstop to the advancement of TSP.

Metro Transit TSP local experience

- The problem is a wide range of travel times in certain route segments that make it difficult to schedule reliable service. For example, Route 4 travel times on Lyndale Avenue between Lake Street and Franklin Avenue vary between 5-14 min.
- TSP is one option among several transit advantages (queue jumps, bus stop placement, fare prepayment, all-door boarding, bus lanes, bus stop consolidation, and route streamlining) to improve bus speed and reliability.
- TSP is intended to reduce delay at signals and increase person throughput of an intersection and is used on high ridership local and BRT routes where it benefits most riders.
- Bus enter detection zone and transmits priority request. Bus only makes TSP request when behind schedule. Operator does not make request, happens automatically. TSP on buses is priority not preemption. Buses will not automatically change a red to green like for an ambulance. TSP works two ways: green extension holds a green light for a bus to clear an intersection--most helpful; red truncation a bus asks to shorten the red.
- TSP is on 147 intersections, most on BRT routes. Anticipate an additional 83 locations by 2024 including E Line.
- TSP effectiveness evaluation outcomes:
    - Route 2: TSP added early 2021. TSP on the route 2 had a very small savings across the whole route but stops were not shifted far side as part of implementation.
    - Route 5: TSP added 2019. Near side stops especially those with high boardings can negate the benefits to TSP. See some benefit at the intersection level on the Route 5.
- The TSP development schedule is roughly two years and includes:
    - Identification: Metro Transit looks to add TSP in full corridors, not individual intersections. Most considered corridors are BRT or Better Bus Routes.
    - Signal timing analysis to determine if signal is a good TSP location. This work is done by consultants.
    - Recommendation.
    - Installation: Buses all have the equipment. Minneapolis intersections are generally ready to accept TSP at any intersection. Some Saint Paul intersections have older equipment that would need updates but most can connect. Metro Transit procures TSP kits (they do not keep them on hand) and the roadway authority installs them.
    - Testing.
    - Update the bus schedule.

- Total TSP costs are $11,500/intersection. $7,000 for hardware, $3,000 for analysis and design, and $1,500 for installation. This cost is for up-to-date cabinets.
- TSP limitations: TSP can only reduce signal delay; Most bus routes operate on busy roadways that already have the majority of green time; TSP can't be used effectively where two busy routes cross; TSP only works at signals where there is excess green time to reallocate.
- Topics for upcoming meetings:
    - TSP approach/philosophy.
    - Spectrum of TSP implementation: room for aggressive implementation or light touch.
    - Agency concerns with TSP.
    - Intent of TSP: speed or reliability.
    - Buses calling TSP only when running late and how it relates to scheduling.
    - Comparison to LRT might be helpful because it uses more sophisticated technology that Minneapolis and Saint Paul could eventually adopt.
    - Splits at signals--Minneapolis may be going to shorter cycles.
    - Assigning operating dollars for TSP.
    - Efforts to bring down speeds for vehicles while still keeping buses moving.

Upcoming meetings, first Thursday at 1pm

October 5, November 2, December 7, January 4, February 1.

Follow up

Action item	Who is responsible	Due date
1. Set agenda for next meeting	Metro Transit	September

Meeting NOTES

Transit Advantage and Signal Priority Working Group (#3)

Date: 10/05/2023
Time: 01:00 PM

Attendees:

- Sam Rockwell, Move Minnesota
- Julie Johnson, Move Minnesota
- Adam Harrington, Metro Transit
- Michael Mechtenberg, Metro Transit
- Michaela Ahern, Metro Transit
- John Fahrendorf, MnDOT Metro District
- Mike Fairbanks, MnDOT Metro District
- Nick Erpelding, Hennepin County
- Mike Klobucar, City of Saint Paul
- Allan Klugman, City of Minneapolis
- Adele Hall, SRF Consulting Group
- Phil Kulis, SRF Consulting Group

Meeting Notes

Introductions

Ryan Heath introduced himself as the new Manager of Transitway, Speed, and Reliability Planning. He has been at Metro Transit for several years and worked on TSP on LRT. He will be forming a team with Michael Mechtenberg and Michaela Ahern to advance transit advantages with partners.

Adam noted that Metro Transit is laying out agendas for the near-term working groups to enable report writing but would also like to continue convening the group beyond that. Sam suggested identifying things in the report that are out of the working group's control. The intent is to speed up the transit system as much as possible; if the agencies in the working group need help beyond the technical side the report should say so.

Overview of transit advantages

Michael stated that the last meeting was focused mostly on TSP. Today Metro Transit would like to broaden the discussion to additional transit advantages that are meant to improve speed and especially reliability. Michael showed an example of speed and reliability challenges on Nicollet Mall and Adam commented that even with transit-exclusive lanes the corridor still has challenges. Speed and reliability are important because customers rank "on time" and "travel time" as two of the three top factors related to

customer satisfaction. Operator satisfaction is also tied to speed and reliability since it is tied to recovery time. Finally, the wider the variation in a route time the longer the recovery time at the end and the greater the route's operating costs.

Speed is how fast the bus travels, reliability describes the consistency of departure times. Sam questioned whether Metro Transit considers transit travel within the context of travel times by other modes. Adam said at a system level Metro Transit measure by time as well as frequency. Comparisons to car are difficult because the nature of the service is so different though it is easier to make this comparison with express service. Michael added that another option is to improve bus speeds at the expense of cars. Adam suggested that the new configuration of Hennepin Ave is a good test case for this. Michael concluded that Metro Transit's goal is to make transit more attractive and if by doing so we make driving less attractive that is bonus.

There are many variables that affect speed and reliability: on-board fare payment, weather, construction, events, street/lane configuration, rail road crossings, stop placement, congestion, etc. Some of these are external and Metro Transit has little control, some Metro Transit has more control over. An example of this is operators; Adam noted that in the last year 300 new operators have started at Metro Transit. This loss of experience is a big factor in operating efficiency over the last year. Alan commented that the City of Minneapolis has been talking with the railroad about the crossing at Webber. The City would like to collaborate with Metro Transit on this; the Route 22 is constantly behind because of that crossing.

BRT addresses many of the variables. LRT addresses even more of them. Better Bus Routes addresses very few. Adam commented that LRT on-time performance has gone down because of customer interactions such as door holds and issues on the train. Ryan commented that LRT and bus look very different in our systems but management really matters. A dedicated guideway doesn't solve the issues on its own; needs to be well-managed. Factors affecting speed are general traffic congestion which Metro Transit can schedule for, and speed limit.

Metro Transit has several methods of measuring reliability:

- On-Time Performance (OTP): Metro Transit's OTP goal is 85 percent. It varies a bit with type of bus service. If it were 100 percent many schedules would need to be slowed to try to meet it. OTP is easy to measure and communicate but misses some of the story. It doesn't capture the number of passengers affected and doesn't capture extreme impacts on certain trips at the route level.
- Delay: measured by a stop-to-stop travel time above the fastest 2 percent of travel times for a stop pair. The intent was to pick the fastest time—barely achievable but possible. Metro Transit does not schedule buses to this 2 percent.
- Passenger delay: stop-to-stop delay multiplied by the number of passengers on board.

Ryan asked the traffic engineers in the group: from a vehicular perspective what order of magnitude delay is level of service (LOS) E or F and how does this compare. Alan said that LOS E to F is roughly 1 minute of delay. Minneapolis has not linked volume to LOS to measure "driver delay". The City has analyzed volumes of cars impacted by detours but not daily use. Ryan noted that the LOS system is clear; we have no such similar set up on transit.

Improvement strategies: MT has a table of strategies where they identify effectiveness of the strategies, their potential costs, and implementation. Strategies include:

- Stop spacing: Metro Transit has been working on this for last five years and aim for ¼ mile between stops. This is a relatively fast, low-cost strategy with tangible benefit though not extraordinary.
- Bus lanes: most effective on high bus volume streets. Are almost always taking something away—parking or travel lane. Needs a longer lead time for implementation and has maintenance costs.
- Off-board payment: reduces dwell time. Raises questions about fare enforcement. MT has taken a few different approaches and now will be using ambassadors to help with this. C and D Line have resulted in increased ridership and decreased fares; people are not paying. MT decided several years ago not to do rear-door card readers and could reopen this conversation.

Metro Transit is taking action on speed and reliability improvements through:

- Better Bus Routes (low cost, quick turnaround improvements on six routes, one route annually. Currently planning Route 4.
- Bus lanes: will be adding Henn/1st NE, Lake, Hennepin S in the next year. MT want to connect w St. Paul.
- TSP: has been mostly focused on BRT and Better Bus Route projects.
- An OTP committee.
- Ryan commented that TSP can apply to all scales. BRT projects are pretty big but TSP coordination can also be focused on one signal or changing to an in-lane stop, for example. This kind of coordination is happening all the time at MT.

TSP strategies

SRF and Metro Transit would like to meet with each of the operating agencies over the next month. This presentation is meant to prompt potential topics for discussion.

TSP is shifting time around at the signal to try to get the bus through the intersection faster. Ryan pointed out that different agencies are using different controllers and have different capabilities. Phil agreed that the benefits vary widely.

Priority vs preemption: TSP shifts time between phases but the phases are constant and coordination between signals is maintained. Preemption skips or omits phases and dwells on certain phases. TSP does not do this.

Operations: Slack time is the difference between minimum and maximum splits. The amount of benefit TSP can provide depends on how much slack time is available. TSP can shift some or all slack time to the transit phase but this doesn't mean that it is happening. Allan noted that longer cycle lengths make signal coordination easier but they may result in long waits for pedestrians. Of the 820 signals in Minneapolis nearly all are on ped recall where the walk sign comes up every time (this was a change during covid so people wouldn’t have to push a button). Ped recall times are longer so slack time is reduced. The only place where ped recalls have been removed and signals are once again actuated is on BRT/high frequency transit corridors. Ryan added that this conversation played out on the LRT corridor because ped recalls trip up preemption and end up generating longer wait times for bikes and peds. Allan added that the City of Minneapolis has a federal grant to retime the signals across the city and will be defining what is "transit friendly" and "ped friendly" as there are some conflicts between these. Sam asked what

other cities like Boston and NYC that have high pedestrian volumes and transit use do. Michaela said that MBTA (Boston's transit agency) said that their cities are on board with TSP; MBTA gets a lot of data and cities update signals when reconstructing streets but they don't have strong measures for success.

Mike K said he didn't have comments on the slack slide; it's all very context specific. He noted that at busy intersections there are often bus routes in both directions so it's hard to say what helps.

Unconditional TSP: if a bus is coming the request is made no matter what. Unconditional TSP is not used in the Twin Cities. The request is "conditional" and only if the buses are behind schedule. Could put other conditions on it. With very high bus volumes unconditional can become difficult to manage.

Sam commented that headway based service would allow Metro Transit not to manage routes to a schedule. Adam noted that Metro Transit tried this on A Line during the fair and it worked pretty well.

Ryan added that management of transitways takes time. There are eight people monitoring at a given time: senior supervision, three on the desk, and four field supervisors with two shifts each day

Mike K stated that if buses are consistently running ahead the schedule needs to be adjusted. Adam said that Metro Transit does not always know buses are running early because operators will slow down to meet their timepoints.

In the agency discussions SRF would like to cover:

- Selection of locations for TSP
- Installation
- Operations
- On-going maintenance such as retiming or failures.

Additional topics and strategies for discussion are:

- Phase reduction time: how much of the available slack is being shifted
- Insertion: is there a special phase inserted to serve transit more often
- Sequence change: to get to the transit phase more quickly
- Far side/near side: geometrics and where detection zones go
- Ped recall: where it's on/off
- Conditional TSP
- Reservice time
- Mainline vs side-street differences: typically buses on mainlines are getting majority of green time and on a side street there may be slack
- TSP with crossing route: what to do here--routes with TSP crossing each other. First come, first served or do certain lines get preference

Allan commented that under operations/maintenance we talked about data sharing between Metro Transit and signal operators; this is worthy of its own bullet/discussion.

Follow up

Action item	Who is responsible	Due date
2. Set agency discussion times with goal of having most or all by November meeting date	SRF	November 2

Meeting NOTES

Transit Advantage and Signal Priority Working Group (#4)

Date: 11/02/2023
Time: 01:00 PM

Attendees:

- Sam Rockwell, Move Minnesota
- Julie Johnson, Move Minnesota
- Adam Harrington, Metro Transit
- Michael Mechtenberg, Metro Transit
- Michaela Ahern, Metro Transit
- Kyle O'Donnell Burrows, Metro Transit
- Paul Lamb, Metro Transit
- John Fahrendorf, MnDOT Metro District
- Mike Fairbanks, MnDOT Metro District
- Nick Erpelding, Hennepin County
- Mike Klobucar, City of Saint Paul
- Allan Klugman, City of Minneapolis
- Jerry McDonald, Suburban Transit Providers
- Adele Hall, SRF Consulting Group
- Phil Kulis, SRF Consulting Group

Meeting Notes

Pipeline of projects

Arterial BRT

Kyle presented an overview of planned arterial BRT projects. A network of 12 BRT lines is planned by 2040.

- A, C, and D Lines are operating.
- B Line is under construction east of Hiawatha and in design west of Hiawatha; started planning in 2019, opening 2025.
- E Line in design. Started planning in 2019, opening late 2025.
- F Line in design. Started planning 2021, opening late 2026. First Small Starts ABRT project; this project is the subject of intensive coordination with MnDOT.
- G Line in planning. Started planning 2022; planned opening north-of-downtown segment late 2027 and south late 2028.
- H Line in early planning. Planning and engagement begins mid-year 2024 with stakeholders; public engagement typically happens 12-16 months after that. Planned opening 2028-2029.

Beginning in 2024-2025 the ABRT office will conduct another planning process to identify the J, K, and L Lines.

Sam noted that the soft goal of ABRT is a 20 percent speed increase and asked if that goal drives implementation of transit advantages along the route. Kyle said yes, though Metro Transit doesn't want 20 percent to be a limiting factor; they want the service to be as fast and reliable as possible. Reliability is just as important if not more. Ryan commented that now that Metro Transit has more ABRT routes online, the agency has more operational coordination across service development and operations and maintenance.

Adam noted that the 20 percent speed increase goal is from the regional transitway guidelines from 2012 when Metro Transit only operated Blue and Red Lines; now Metro Transit has more lines and more measures. Sam commented that it would be helpful to have a clear target for speed. Our goal is X and we need X things to make it happen. Adam responded that it's easier to come up with a goal on a corridor-by-corridor basis, but also don't want to hold up corridors if it won't meet the goal. Need to balance this against the "get it done" aspect of ABRT. Ryan added that ABRT is beginning to interface with partner projects far in advance of projects.

Kyle noted that Metro Transit has seven additional corridors that will be reevaluated and sequenced. This is important because it gives ABRT staff a chance to coordinate in advance which allows for enhancements outside of the project. For example E Line stations were built as part of the Hennepin Ave project downtown and they are already in operation for local bus. Staff start from the assumption that every signal along a corridor except those with LRT will have TSP.

Sam added that another metric of success would be accessibility of each corridor and the network. Kyle responded that Metro Transit measures anticipated changes to accessibility in the corridor planning phase.

Better Bus Routes

Better Bus Routes program (BBR) BBR started in 2018 to improve speed, reliability, and customer experience on local bus routes. Completed routes include Route 2 (2018), Route 63 (2020), and Route 3 (2021); the goal is to complete one route annually. To select the routes in the past Metro Transit considered speed, on-time performance, passengers per in-service hour but didn't capture other measures. Now they are using the same metrics used for the arterial BRT evaluation in Network Next for a more rigorous evaluation.

The principles of BBR are to provide consistent and competitive travel times for transit riders measured by speed, reliability, and delay; improve route legibility and accessibility; and promote equity of service.

BBR program is focused on relatively high-ridership routes excluding existing and identified BRT routes and commuter express routes.

An analysis of candidate routes identified the Routes 18, 22, 17, 18, 4, 14, 54, 11, 61, 12 for BBR.

Route 18 was removed from this list because it was still under consideration for streetcar at the time.

The routes were then prioritized by year:

- 2022-24: Routes 22, 4, 17
- 2025-27: Routes 14, 11, 61
- 2028-29: Routes 54, 12

Sam said as we think about improvements to transit there's a line by line approach and a system approach. Has there been any consideration of the broader network improvements when selecting routes or is it only based on corridor priorities? Sam referenced the New York City approach of using streets differently in pilot programs and then evaluating them in real time. Instead of doing one route at a time could Metro Transit do stop consolidation on 10 routes at a time, for example. Michael responded that while Metro Transit is adding capacity to this program they are limited in what they can accomplish in a year. Julie noted that from an organizing perspective lifting the whole network is an easier sell than a route-by-route approach and pointed out that if people are transit riders they likely ride more than one route.

City of Minneapolis Transit Priority Project update

Allan noted that in 2020 the City of Minneapolis published the Transportation Action Plan that identifies transit corridors the City will improve and additional to be considered. Michael, who is working closely with City staff on the transit priority project, added that there were city-owned and non-city owned corridors. Now the City, with its partners, are prioritizing those corridors, and removing and adding a couple. Part of the evaluation was an equity analysis using transportation equity score developed by the City. The evaluation of corridors is now complete; the next step is assigning years to corridors to help with budgeting and planning to be completed in the next few months.
Metro Transit is interested in working with the City of Saint Paul on a similar process.

Agency discussion summary

Phil presented a summary of the themes SRF staff heard at meetings with each of the roadway authorities (MnDOT, Ramsey County, City of Minneapolis, and City of Saint Paul) and Metro Transit. SRF will meet with Hennepin County after today's meeting so that summary is not included.

- One of the themes from the Better Bus Routes meeting was that there is "no urgency" to TSP implementation. Michael clarified that Metro Transit has urgency around this, but that it has taken a long time to coordinate and implement with partners.
- One of the themes from the Arterial BRT meeting was that with headway-based service Metro Transit has seen issues with TSP if the bus is not "behind schedule". Ryan clarified that Metro Transit's Transit Master software system tells the bus it can request TSP but that's based on a schedule. When A Line was run on headways during State Fair it never requested TSP because there was no "schedule" to tie it to.
- A theme from the Metro Transit Operations meeting was that networking devices back to a central location about what the signal is doing would help data collection considerable. Ryan added that there are a lot of variables--controllers, reports, vendors. Capacity on the Metro Transit side as well as on the partner agencies side is a major consideration.
    - Sam recommended that the report be clear about what capacity is needed. Is it a single FTE in each jurisdiction and several at Metro Transit? Allan responded that capacity is one thing but process mapping is an issue. It's not just about how many people but when. Michael added that Metro Transit and the City of Minneapolis are working through a master agreement to replace the individual agreements that take time. Allan noted an example of the capacity constraint: BBR projects are on an August-to-August timeline. All the City electricians need to do is wire some cabinets but every street reconstruction project ends in October so they become very busy then. If the BBR schedule slips at all TSP gets bumped to April. Mike F. noted that if MnDOT gets the agreement in time it works out but best to know in advance.

- A theme from the Saint Paul meeting was that Saint Paul could set up emailed reports of log histories for short term studies. Mike K. commented that Saint Paul doesn't share data in real time with anyone. They would rather know what Metro Transit is looking for and what the City can provide instead of providing direct access to their system.
- Allan asked to add ped recall to the summary of the Minneapolis meeting. TSP service competes with other priorities at signals.
- Sam asked if mode share as well as ridership should be considered as a potential impact of TSP implementation. Does ridership increase with TSP?
- Overall, all agencies would like more insight into TSP and how it's working, including how it's impacting bus travel times/reliability and other movements at intersections.

Upcoming meetings

Ryan will reschedule the December meeting to Tuesday, December 5 and the January meeting to Thursday, January 11.

Follow up

Action item	Who is responsible	Due date
3. Reschedule the December meeting to Tuesday, December 5 and the January meeting to Thursday, January 11.	Metro Transit – Ryan Heath	November 24

Meeting NOTES

Transit Advantage and Signal Priority Working Group (#5)

Date: 12/05/2023
Time: 01:00 PM

Attendees:

- Sam Rockwell, Move Minnesota
- Ryan Heath, Metro Transit
- Michael Mechtenberg, Metro Transit
- Michaela Ahern, Metro Transit
- Paul Lamb, Metro Transit
- Eric Lind, CTS
- John Fahrendorf, MnDOT Metro District
- Mike Fairbanks, MnDOT Metro District
- Nat Gorham, MnDOT Metro District
- Nick Erpelding, Hennepin County
- Taehyoung Kim, Ramsey County
- Mike Klobucar, City of Saint Paul
- Allan Klugman, City of Minneapolis
- Jerry McDonald, Suburban Transit Providers
- Adele Hall, SRF Consulting Group
- Phil Kulis, SRF Consulting Group

Meeting Notes

Jerry reported that MVTA is interested in TSP on CR 42 in Burnsville. Jerry and Ryan will work together to set up a meeting with MT, MVTA, and Dakota County.

Peer Agency Review

Michaela presented a summary of Metro Transit's meetings with staff from RTD in Denver, IndyGo in Indianapolis, and MBTA in Boston.

RTD: TSP is only active in the city of Denver on Colfax Avenue. They started with unconditional TSP but are shifting to conditional based on riders on board. RTD pays for TSP controllers and installs them. They always satisfy minimum greens. Denver and RTD are working toward a centralized TSP system on a timeline to be determined.

IndyGo: IndyGo operates TSP on Red Line BRT. Indianapolis has a single roadway authority—so IndyGo has lots of agency to make decisions. IndyGo directly plugs cell modems into the signal controller; their future system will be cloud based and centralized. TSP dashboards are supplied by a vendor. They are experimenting with ped calls in advance of bus arrival to enable people to safely reach stations when the bus is coming. This is feasible with the centralized system.

Boston: MBTA was the most advanced agency Metro Transit met with on TSP. Operating agencies seek guidance on TSP and operators are open to putting TSP anywhere. MBTA deliberately uses many different vendors to remain vendor neutral. They have created dashboards by route to wrangle the large data sets they are creating as the TSP cabinets must send data to MBTA every hour and report several metrics. As they move toward their next gen system: they need to work with lots of cities, AVL data is too granular, they are working on a system that uses a manual stop bar to estimate travel time and give the green in time (place geofence downstream, measure distance to stop bar, then estimate travel time—brings together AVL, vehicle detection, TSP, and is vendor agnostic. With the stop bar model they may use several detection zones to improve the travel time prediction to the stop bar.

Sam asked if an agency is more advanced what are the factors that allowed them to accomplish what they did? Michaela responded that with Boston it's clear that they have the data to make decisions on a route level. Their vision and documentation is far above the others. They have one person who is a point person. IndyGo is on par with Metro Transit, though they have less coordination to do. RTD is doing less than Metro Transit. Michael added that Metro Transit is planning to explore vendor technologies over the next year. Eric noted that the multiple vendor approach would require procurement reform at Metro Transit. Ryan noted that he is not convinced that this is the way to do it when we're already in such a diverse operating environment. Sam asked if Boston attributed any of their success to the Boston mayor being so transit-supportive? Michaela said there was no mention of politics in the conversation but they did emphasize relationships. Even though they have a lot of performance data they didn't talk about performance at all; they assume TSP is a benefit and are pushing it out as much as possible including to intersections that weren't for specific projects. They didn't discuss TSP's interplay with other transit advantages. In Indy their TSP is on Red Line which has center-running bus-only lanes. RTD noted a 10 percent time savings with TSP on Colfax.

Key Barriers and Constraints

Phil presented an overview of identified barriers to optimal TSP implementation, operation, and maintenance. Barriers are broken into groups: institutional, data, performance.

Institutional:

- There isn't one person at Metro Transit that oversees TSP from start to finish, knows how it's going, and leads planning. Ryan commented that with the new Speed and Reliability group structure Metro Transit is addressing this with his position. May or may not include both bus and rail in one position.
- Limited capacity at Metro Transit and roadway authorities: what each agency can do to address operations, performance, maintenance are different as are the needs at each of the agencies. Ryan commented that Metro Transit is making progress toward setting up data analysis processes, etc.
- Metro Transit has many roadway authorities to coordinate with: Meeting with each roadway authority can help advance the practice.

- Metro Transit has implemented TSP on a project-by-project basis which has been slow. Metro Transit is planning to create a five year workplan within their broader Better Bus Routes workplan.
- Similarly, purchasing equipment on an ad hoc basis slows the process. Planning will help to address this.
- Agreements take a long time to finalize. Master contracts and work orders can help streamline these.

Data and performance barriers:

Lack of understanding of the complete TSP process from MT's systems and the signals. A training for MT and roadway authorities could help with this. The first training is scheduled for next week for MT and Mpls staff as guinea pigs. The intent is to have several of these trainings to achieve widespread understanding. Emtrac will be providing the training.

Limited controller data has been shared with Metro Transit. St Paul requested that this is clarified because the City shares anything that's requested. SRF will make this change—data needs to be requested and the requests will be fulfilled. Most roadway authorities have said they'll share data; work needs to be done to clarify what data and how and when. Sam added that though operators are willing to share requested data there are also a lot of ways that we could make sharing much easier. No one will allow Metro Transit in their cabinets. Sam emphasized that the report should include political barriers, too. Ryan added that collectively we have to get past the manual nature of data collection from many of the controllers. The cumbersome nature of manual data pull isn't amenable to the type of analysis MT wants to do.

There is a large range of programming for TSP. Operators are reluctant to implement aggressively because they don't know how well it's operating. Once the data comes in and is processed this will be addressed. Ryan noted that it is ok to say that TSP has messed up a few intersections.

The TSP system is hardware focused. If you want to put it anywhere you have to install at the individual intersection which makes it harder to maintain. Metro Transit will be reaching out to vendors to hear what can be done. There are also few staff who know the equipment—one person who is supporting the contract with the vendor. If you're implementing on a wide scale it can slow things down to only have one person who does it. The vendor often only has one contact, too.

Uncertainty about whether equipment is working in the field.

There's no programming framework for intersections—how aggressive, what are the cycle recovery, etc. Metro Transit needs to figure out exactly how they want it to operate. Ryan noted that Metro Transit's equipment could also be standardized. Eric Lind noted that how much time from side streets is taken is a political question and Ryan responded that Metro Transit doesn't have the technical foundation yet—there's a knowledge gap. Paul added that Metro Transit contracts the programming to different consultants who have different backgrounds, styles and Metro Transit also operates in different conditions—highways and arterials. Sam stated that the report is an opportunity for action both technically and politically. The working group should prepare for a meeting of the agency heads because most people here are technical. The group has an opportunity to set some things up for legislative action which is aggressive but at minimum we need a clear path for what it will take—technically and politically—and those things need to be identified in the report. Ryan noted that he doesn't want to preempt the technical discussion and that discussions at a high level need to be informed by technical

work; there is more foundational work to do before we approach political leaders. Sam noted that if this were a priority for leadership we would have addressed it by now. Ryan said that Metro Transit would happily take additional staff capacity but he is reluctant to push for more before we can deliver it.

TSP Working Group

Metro Transit proposes a quarterly meeting to continue the TSP working group. Additional meetings will support specific technical information and issues.

Metro Transit/Agency Meetings

Metro Transit and the City of Minneapolis have a reoccurring meeting set up. Metro Transit will follow up to set up the same with Saint Paul, MnDOT, and Hennepin County.

Tentative Topics at Upcoming Meetings

January 11: draft report review (report will be available immediately after the holidays.) Hear from vendors to give an overview of the product and how it might address some of the issues.

February 1: report will be wrapped up, looking ahead to future meetings.

Sam noted that the report is an opportunity for everyone to think about whether there are things we need to do that have funding attached to them. There are going to be explicit monetary asks from other reports like this. There's not a good reason not to do this. The ask doesn't have to be for funding it could also be for staff.

Follow up

Action item	Who is responsible	Due date
4. Distribute draft report.	SRF, Metro Transit	January 3
5. Review draft report	Working Group	January 11 Working Group meeting

Meeting NOTES

Transit Advantage and Signal Priority Working Group (#6)

Date: 1/11/2024
Time: 01:00 PM

Attendees:

- Ryan Heath, Metro Transit
- Adam Harrington, Metro Transit
- Michael Mechtenberg, Metro Transit
- Michaela Ahern, Metro Transit
- Paul Lamb, Metro Transit
- Claire Curd, Metro Transit
- Hollie Clancy, Metro Transit
- John Fahrendorf, MnDOT Metro District
- Mike Fairbanks, MnDOT Metro District
- Taehyoung Kim, Ramsey County
- Mike Klobucar, City of Saint Paul
- Allan Klugman, City of Minneapolis
- Jerry McDonald, Suburban Transit Providers
- Adele Hall, SRF Consulting Group
- Phil Kulis, SRF Consulting Group
- Bob Riebe, Lyt
- Tony Kendall, Miovision

Meeting Notes

TSP products overview

Lyt

Lyt uses AI and machine learning that is ETA based to provide TSP. Have an open architecture cloud-based solution that communicates from the signal to the cloud via the cellular network. They work with King County, MBTA, and other transit agencies.

Traditional TSP systems don't provide as much insight into the operations of TSP; Lyt offers 100+ performance metrics. Lyt is interoperable with all systems as long as they are NTCIP 1211 compatible. They don't require a line of sight to an intersection. They incorporate a very high level of security and

require just one piece of hardware at each jurisdiction called a Maestro. The system does not require hardware installation in the cabinet.

They have an analytics platform to show the full regionwide picture and can customize reports based on agency needs. Bob showed an example of a dashboard from an FX line in Portland where they were able to reduce red light delay by 80 percent. The system is learning the route and will continue to refine the signals.

Miovision Opticom

Opticom is the product name; it was acquired by Miovision last year and is headquartered in Saint Paul. The company operates in 180,000 intersections and have 5,000 customers.

Opticom was originally infrared, then migrated to GPS and radio to eliminate line of sight, then in the last five years migrated to cloud-based solution that does not rely on hardware. The vehicle communicates with the cloud which communicates with the controller via cellular or several other paths. Can plug directly into controller if it is NCTIP compatible. Miovision Core can be added at intersections to provide additional features and traffic analytics. The technology can be used for buses as well as emergency vehicles and others. Cloud platform allows for performance monitoring and spatial review.

Questions

Michael asked about the cost structure for Lyt and Miovision. Miovision can do a payment structure where the agency pays up front as a capital cost all at once. More recently they have been doing an annual fee for service. The cost is based on the number of intersections and vehicles. The system can be setup with one set of numbers and then additional intersections and vehicles can be added at a per vehicle/intersection cost. They can also bring in additional jurisdictions: for example if MVTA wanted to join, they could pay for the system on their vehicle. Lyt is a true software as a service (SaaS) model and they charge based on the number of intersections based on a contract. If an agency contracts beyond three years, there is an opportunity for a discount.

Hollie asked how the software is hosted. Lyt and Miovision both use AWS but an agency can also opt to host locally.

Discussion

Michaela commented that a pilot project would be welcome and others agreed. Claire said that Metro Transit spoke with Lyt about a pilot project on Snelling Avenue at one point and is still interested in this if there is an opportunity. Claire thinks a system with less equipment in signal cabinets is preferred. Ryan noted that for the cloud system to work there needs to be a way of communicating to the signals, whether that is fiber or cell, which brings up network security. Claire added that Lyt requires their black box to sit at an agency's ATMS and MnDOT was concerned about having their equipment connected to their network. Mike F agreed regarding connected equipment security. Mike K added that they would also share the concern about something running top-down instead of at the intersections; if fiber goes down, TSP is no longer running at intersections. Potential concern with having another agency rely on a signal operator's network reliability. Allan thought it would be useful to set up meetings with some of the other signal operators who have these cloud based solutions to learn more about them from the users. Adele

noted that it would also be good to talk with the transit providers who use these systems. Claire shared that she is in a national TSP working group and there has been some concern that Lyt is growing fast and their ability to keep up with the current pace of growth.

Julie noted that she would like to hear how the two companies address security concerns. Michael commented that they would like a full understanding of how TSP is performing, which cannot be done with the current system. The current system is hardware intensive and hasn't changed much over the past ten years. It is understood that the cloud based solutions look promising and there's an interest in learning more about how they could operate for Metro Transit. Claire commented that F Line installation could be an opportunity. Ryan added that MBTA in Boston uses multiple vendors, which could be beneficial, so vendors keep advancing. Julie noted that security and cost are two major issues; are there others? Ryan said that because there is no hardware, the marginal cost of installing it is low. Michael agreed and is interested in doing pilot programs with multiple vendors and evaluate how well they work. With the cloud based solutions, intersections could be swapped out relatively easily if TSP is only providing marginal benefits at some intersections. It is likely that many intersections that would have TSP are NCTIP compliant and already have communication.

Allan K recommended digging into the data a little. Ryan noted that controllers are getting smarter, too, and the only way to take advantage of them is by providing a steady stream of data to make informed decisions. Mike K commented that they can't provide the same level of priority to transit everywhere as they do with the Green Line LRT along University Avenue. The benefits that TSP can provide are still dependent on the programming in the signal controller and other constraints at an intersection. Phil noted that in downtown environments, peds are typically the top priority and that shorter cycle lengths are favored, which limits the amount of time that TSP can shift around in the signal timing to favor the bus.

Ryan will try to have Emtrac at the February working group meeting to share their product.

Report Review

Report comments are due to Ryan by Friday, January 19. Metro Transit wants to stress the importance of partnerships with operating agencies and that these relationships have been in place. The report is due to the legislature on February 15. The legislation was specific about who would be in the working group and noted that the councils needed to appoint someone. Saint Paul didn't go through this process and Mike K questioned if they were supposed to. There was agreement in the room that appointment at the staff level was appropriate and council action was not necessary.

Ryan noted that Metro Transit met with MVTA to discuss TSP deployment on CR 42. MVTA is interested in moving ahead with it.

Next meeting is the last official working group meeting, and then Metro Transit will schedule meetings, but less frequently.

Follow up

Action item	Who is responsible	Due date
6. Review draft report	Working Group	Comments to Ryan by January 19
7. Respond to comments and issue final report	Metro Transit and SRF	February 15 (with final comment discussion to occur at February 1 working group meeting)

Meeting NOTES

Transit Advantage and Signal Priority Working Group (#7)

Date: 2/1/2024
Time: 01:00 PM

Attendees:

- Ryan Heath, Metro Transit
- Michael Mechtenberg, Metro Transit
- Michaela Ahern, Metro Transit
- Paul Lamb, Metro Transit
- Kyle O'Donnell Burrows, Metro Transit
- Sam Rockwell, Move Minnesota
- John Fahrendorf, MnDOT Metro District
- Mike Fairbanks, MnDOT Metro District
- Nat Gorham, MnDOT Metro District
- Nick Erpelding, Hennepin County
- Mike Klobucar, City of Saint Paul
- Jerry McDonald, Suburban Transit Providers
- Eric Lind, CTS
- Adele Hall, SRF Consulting Group
- Phil Kulis, SRF Consulting Group

Meeting Notes

Report review

The full group walked through the report with Ryan highlighting places where Metro Transit had made substantial revisions in response to comments. The group suggested the following changes:

- Define "transitways" eg LRT, BRT, etc.
- In the narrative near Figure 2, add percent of overall transit ridership that is express ridership. At this point in the report the scope of speed and reliability interventions have not been defined. We may need a reference forward to those definitions in the transit advantages graphic. (Later it was determined that the transit advantages section would be moved ahead of this section so this reference is no longer needed.)
- ABRT should be "arterial BRT" throughout.

- Under Table 3 note that Route 18 is being considered again for Better Bus Routes. It had previously been excluded because of the potential for streetcar. With recent legislative changes Metro Transit is once again considering it.
- Figure 4 could be replaced with an actual bus time budget graphic instead of the "dummy" version that it is in the report right now. The Route 19 would be a good one to use because an "after" graphic could show how the split of time changed when the C Line was implemented.
- Page 13 add the impact to crossing routes of giving a lot of signal priority to the main route. The group decided not to use the term "transit signal preemption" and instead to say that TSP can give levels of priority up to those used by emergency vehicles. Note in the appendix that both directions in an intersection cannot have priority.
- Transit Signal Priority section: mention of the current use of hardware at each intersection and opportunity for cloud-based system. This is important to understanding barriers to implementation. Nick commented that there's a recent law that requires signals to be retimed every five years. Most agencies are already programming the signals to passively give more time to buses. This happens when the agency is trying to keep traffic on the street moving and if it's a street with buses they'll give more green to that mainline. The "one second" sounds small but if the bus arrives at that time it saves quite a lot of time.
- Transit advantages graphic: Extend to two pages. Should say "non-cash fare payment" and "fare prepayment". Will also add level or almost-level boardings, in-lane stops/bumpouts, and passive signal timing.
- Metro Transit is running the Routes 32 and 62 fare free right now. Boardings are up 30 percent on the Route 32 and on-time performance hasn't changed.
- Figure 8: It's worth mentioning that calls are only granted an advantage about 30 to 40 percent of the time. Emergency vehicles get it 100 percent of the time so it's good to make the distinction. The Figure 7 charts include calls that didn't get a benefit because the signal was already green. Need to show when TSP was needed and of those times how many times the bus received it. The group decided to make this broader in the narrative with text like "Recent data show that most of the time TSP is not needed because the light is already green."
- Strategies in Figure 4 should be tied to their explanations in Figure 5.
- Table 4: Will need to add the additional transit advantages that are in the graphic. There was discussion of costs. A column will be applied for the type of project. Costs will be clarified as "capital" costs and ongoing maintenance costs acknowledged in the narrative with an example. Prepayment will be changed to off-board fare payment.

Eric proposed moving sections: Intro, types of transit advantages, then what Metro Transit has been doing. The group agreed.

Executive summary: Eric suggested bolding the "Crucially…" sentence. Sam recommended lengthening the executive summary since that will be all many legislators read and including examples of the barriers, the ones that have been resolved, and those that still need to be addressed.

Next steps

Metro Transit will finalize the report by next Friday. No presentation or additional action is planned.

Follow up

Action item	Who is responsible	Due date
1. Finalize report	Metro Transit	Friday 2/9

2. Roadway Authority Meeting Summaries

Record of Meeting

SRF No. 17112

Location: Virtual

Date: Friday, October 20, 2023

Subject: Transit Advantages & TSP Meeting: Metro Transit/SRF

Attendees: Michael Mechtenberg (Metro Transit)
Adele Hall, Phil Kulis (SRF)

Summary of Meeting with Metro Transit

Better Bus Routes (BBR) Program and Transit Advantages

- TSP is important to the BRT program. For a long time, TSP and limited stops were the principal improvements for BRT projects
- BBR evaluates service, route legibility, and customer accommodations on local bus routes that are not BRT. Metro Transit implements one BBR project a year on a modest budget.
- A PMT that meets monthly is set up for each project that includes cities and/or counties the route operates through. The agencies sometimes send someone from planning, sometimes from traffic operations. The main focus of the partnership with agencies is bus stops and changes at them. Metro Transit implements stop location changes and ADA improvements. Agencies implement adjustments to bus stop zones, parking, and associated signage. This can add up to hundreds of small changes throughout a corridor. Metro Transit develops a signage plan and then the agencies implement them. The partnership between Metro Transit and the City of Minneapolis has gone well on this.
- Metro Transit has worked with Hennepin and Ramsey Counties, the Cities of Minneapolis and Saint Paul, and the U of M on BBR. MnDOT tends to leave the signage and signals to the other agencies and does not participate. Partnerships with agencies have gone well.
- As part of BBR there has been a TSP component on the following routes which has not gone as well.
    - Route 2 (TSP implemented)
    - Route 22 (started to consider TSP but paused because Metro Transit didn't have budget for implementation)
    - Route 63 (TSP going live this fall)
    - Did not do TSP on Routes 3, 17.
- BBR projects take about a year; starts in August one year and implemented in September the next year. TSP comes later (and often lags way behind); ADA improvements also come later—that's a Metro Transit internal coordination issue.
- A list of upcoming routes could help with creating longer timelines which could help with implementing TSP. The longer timelines on BRT projects have helped those projects with implementation.

- Metro Transit has hesitated because the implementation process hasn't been that smooth but also because the TSP benefits aren't clear.
- Actions related to TSP seem to take a long time – can be limited urgency. Council processes can take a long time. Installation is slow in part because procurement of the TSP kits takes time and Metro Transit isn't purchasing equipment in advance. Route 63 TSP took four years.
- BBR have seen a modest improvement in median travel times and a bigger improvement in reducing the range of travel times.
- For BRT there has been no before/after study of performance and it's hard to know if travel time reductions are from changes to boarding, traffic, stop consolidation, etc. BBR results:
    - Route 3: Metro Transit has done travel time analysis; modest improvement and strong improvement to reliability. Implemented 2020, studied in 2022. Made major ridership gains in this time and still had travel time improvements.
- Route 17: haven't done a before/after study.
- Route 22: have done before conditions; waiting for detour to end for after condition.
- Route 63: have documented before conditions but not after.

Bus lane program

- Have some successes to show but a slower process.
- Metro Transit works primarily with City of Minneapolis to implement bus lanes. There is interest from the city, but hesitation to move forward with specific projects.
- Completed projects:
    - Hennepin Ave
    - 7th Street downtown
    - Chicago (was replaced with current D Line bus lane)
- Next year bus lanes on the following will go into service:
    - Hennepin/1st NE
    - Lake Street and Marshall Ave (B Line)
- Working on:
    - Hennepin/Lyndale (Franklin to Dunwoody); taking a long time, City uncertain. Holds up progress on other projects (like 8th Street)
- City of Minneapolis ending a process to evaluate and prioritize upcoming transit advantage corridors. Their starting list was in 2020 action plan; Metro Transit has been part of the committee assisting the City with advancing the plan. By the end of the year the City will have a five-year plan for transit advantage corridors (approval by City Council may take longer).
- Metro Transit would like to use the Minneapolis plan as a model and do a similar process in Saint Paul.
- Metro Transit is also working with the City of Minneapolis on a cost-sharing agreement regarding cost splits for future projects—a master funding agreement to better define implementation and maintenance costs such as analysis, paint, controller, maintenance. This is overdue especially for determining maintenance on bus lanes.

Record of Meeting

SRF No. 17112

Location: Virtual

Date: Monday, October 23, 2023

Subject: Transit Advantages & TSP Meeting: MnDOT/Metro Transit/SRF

Attendees: Martin Carlson, Mike Fairbanks, Derek Lehrke, Kevin Schwartz, Kao Soua Yang (MnDOT)
Michaela Ahern (Metro Transit)
Adele Hall, Phil Kulis (SRF)

Summary of Meeting with MnDOT

General perspectives on TSP

- MnDOT has been working with TSP for 15 years. It's generally messaged that TSP helps transit and doesn't hurt other modes of transportation, but MnDOT doesn't know this based on data.
- MnDOT gives as much green as possible to mainline so there's not a lot of savings for buses because most are on mainline already.
- MnDOT times their signals to clear the queues on the side street. If TSP reduces the green time, it can impact things as it doesn't account for queues. If queues don't clear, this impacts the overall system.
- MnDOT is curious about how significant the benefits of TSP are, particularly at their signals due to how they're timed.
- On TH 65 south of I-694, there were issues with TSP and the controllers went into flash because the signal couldn't figure out how to serve it. It was programmed with one set of assumptions and then it was retimed, which caused issues.
    - MnDOT has a budget for retiming signals and tries to do a certain number per year. They can't always accommodate TSP retiming as that impacts their budget. Need cost participation. MnDOT might shut TSP off for signals when optimizing timings and then Met Council would need to come in later.
    - A lot of TSP is black box; if it fails MnDOT may turn as they don't have staff capacity to analyze the issue and develop a solution.
- Have had issues with buses preempting signals instead of placing a TSP call.
- Current TSP system requires hardware in every signal cabinet desired to have TSP, which reduces the scalability of the system.
- Ped and bike priorities also at intersections, such as Ped Omit FYA (POOFYA) and leading pedestrian intervals (LPI). There can be conflicting priorities at an intersection and having them all can be a challenge.

Selection of locations

- Metro Transit generally informs MnDOT where they want TSP and ask what be required to implement TSP at specific locations. MnDOT generally doesn't comment unless the install would be problematic.
    - MnDOT has a concern for how it could be viewed if they say "no" for a location.
    - On E Line at TH 62/France Avenue, the benefit of TSP looked like it would be about one second and the requirements and issues with implementation were high, so MnDOT and Metro Transit agreed to forego TSP at this location.
    - MnDOT's corridors are heavily traveled—for the F Line left turn at 53rd there are heavy peds and when TSP is on it's probably not going to run because it will be in transition. It's probably not worth for TSP, but MnDOT wasn't asked until Metro Transit had already identified this location for TSP.
- MnDOT no longer runs TSP on ASC/3 controllers and needs to be a Cobalt running EOS.
- Transit projects don't have state funding so it can be a challenge to pay for MnDOT time. For Metro Transit to pay for MnDOT's time they have to write an agreement against the master contract which takes a long time.
- Metro Transit seems to be finding more slack on non-state signals which are very mainline-oriented.
    - Phil noted that cities often consider slack as extra beyond the minimum as opposed to MnDOT considering slack as time beyond the queue clearing, which there's very little of.
- MnDOT doesn't allow other networks in their cabinets due to IT and security concerns.

Installation

- The cost of putting in equipment compared to the benefits may potentially not have a high-enough benefit depending on the location.
    - A cloud-based solution that anticipates the bus better could derive much more benefit and be scalable to other intersections.

Operations

- TSP software has a lot of bugs and they can take a long time to be fixed. Vendors do this as part of their work, but with four or more software updates a year that can disrupt TSP it might not be fixed for a long time.
- Think TSP should primarily be used with far-side stops.
- Data is readily available indicating that a TSP call was received, but unless you view the controller it's not obvious what changed.
- MnDOT would like the ability to track how the calls affect pedestrians and other priorities.

On-going maintenance

- MnDOT is curious about where Metro Transit is seeing the most benefit across all TSP locations.

Record of Meeting

SRF No. 17112

Location: Virtual

Date: Monday, October 23, 2023

Subject: Transit Advantages & TSP Meeting: Ramsey County/Metro Transit/SRF

Attendees: Taehyoung Kim, Joe Grothjan (Ramsey County)
Michaela Ahern, Michael Mechtenberg (Metro Transit)
Adele Hall, Phil Kulis (SRF)

Summary of Meeting with Ramsey County

General perspectives on TSP

- Ramsey County roads in Saint Paul are managed by Saint Paul, so Ramsey County only has a few locations in suburban parts of the county that are operating TSP.
- Ramsey County is very supportive of installing TSP on their intersections.
- From a maintenance and operations perspective, they don't have a lot of familiarity because they don't have many. They haven't had any issues. Cleveland and County C has an Emtrac unit in the cabinet, which was implemented in 2010 possibly with the park and ride nearby.
- Ramsey County would like to be involved in the TSP discussion and see specific data on the benefit to bus versus impact to vehicles.
- Ramsey County signals do not operate on ped recall.
- Ramsey County cabinets have ethernet switches and would be able to share data per consultation with IT. Staff were not sure if Metro Transit has access to Ramsey County's cabinets.
- Ramsey County has entirely Econolite controllers. They operate ASC/3 software. TCC has been a great resource for them with signal operations and TSP.

Record of Meeting

SRF No. 17112

Location: Virtual

Date: Friday, October 27, 2023

Subject: Transit Advantages & TSP Meeting: Metro Transit/SRF

Attendees: Claire Curd, Hollie Clancy, Steve Rippey (Metro Transit - Technology)
Ryan Heath, Michael Mechtenberg (Metro Transit - Speed & Reliability)
Adele Hall, Phil Kulis (SRF)

Summary of Meeting with Metro Transit

General perspectives on TSP

- Concerns with limited data to know how TSP is operating.
    - Limited BBR data analysis showed mixed results of how well TSP is improving travel times and a lack of data has created issues with communicating how effective TSP is.
- The technology group would like more cohesion internally regarding TSP. There is an internal working group on TSP (bi-monthly), but having TSP roles spread across many groups has made it a challenge. One idea is for TSP to be its own group somewhere in the agency.

Installation

- The biggest challenge (historically and now) has been networking the signal devices back to a central system to even know if the device is working.
- The technology group operates the devices and maintains them. Metro Transit has heard from some agencies that they aren't able to get access until their central systems are upgraded.
    - Concern once the systems are upgraded that there will be IT and network security issues to navigate. A cloud-based central system would be beneficial.
- The fact that all agencies have different central systems is an issue. No overall governing body. Ideally every agency would report to MnDOT to have one point of contact of TSP data and one set of IT security.

Selection of locations

- This group doesn't need to be involved in the process of determining which locations to put TSP, but it would be good to know decisions earlier as it helps to get equipment ahead of time.

Operations

- Agencies are too busy to provide support for TSP.
- Metro Transit also needs to do more work internally to coordinate and develop solutions. Treating BRT and LRT separately can create issues.

- There needs to be policy support to make things happen so that it isn't up to individuals to make things happen; it's important to set a goal publicly for implementing TSP.
- If all of the agencies Metro Transit works with uploaded their data to a centralized location, Metro Transit could do the analysis. Metro Transit could set up a central location to dump the data and write a script that pushes the logs out to this location each night.

On-going maintenance

- Metro Transit is on top of their on-board unit maintenance.
- They don't have the data from the agencies to know if things are operating properly at the intersection.
- Timing changes need to be coordinated with Metro Transit so they can be updated based on timing changes; this doesn't always seem to happen.

Record of Meeting

SRF No. 17112

Location: Virtual

Date: Friday, October 27, 2023

Subject: Transit Advantages & TSP Meeting: City of Saint Paul/Metro Transit/SRF

Attendees: Mike Klobucar (City of Saint Paul)
Michaela Ahern, Michael Mechtenberg (Metro Transit)
Adele Hall, Phil Kulis (SRF)

Summary of Meeting with The City of Saint Paul

General perspectives on TSP

- The City looks to Metro Transit to define its priorities: where there are conflicts, what's more important? It's a challenge to have TSP in multiple directions with high frequency transit. At lots of intersections, the City is open to TSP. The City likes to keep cycle lengths shorter though, which can limit the time available to shift around.
- The City and other agencies have a list of upcoming projects. The City recommends Metro Transit review this list and be proactive about getting TSP included when the City is planning projects. Mike noted that if he knows Metro Transit's priorities, he can keep a look out for when there are upcoming projects.
- Biggest hurdle to implementing TSP is infrastructure age. Signal reconstructs offer an opportunity to update infrastructure (15-20 signals a year over the next 5 years).
- Metro Transit should make sure there is funding available for TSP when there are projects coming through.
- City priorities are pedestrians, bikes, and then transit.
- Getting agreements done is the biggest effort.
- When it comes to bus lanes, most City streets aren't very wide and there isn't room for bus only lanes. It's hard to justify widening the street. If traffic volumes don't warrant multiple lanes, the City would often prefer to narrow the street to improve conditions for pedestrians and cyclists.

Installation

- TSP needs an ASC/3 or Cobalt controller. The City generally prefers TSP on the fiber network, though they have allowed one controller on low voltage copper.
- Route 54 doesn't have TSP because of signal conditions; MnDOT is replacing signals and there may be an opportunity to put in TSP.
- Route 63 has many TSP locations. They have all been installed but not yet turned on. Saint Paul is okay with Metro Transit installing TSP but Metro Transit also needs to provide fiber and upgrade controller if needed based on existing infrastructure.

Selection of locations

- Saint Paul defers to Metro Transit on TSP locations. They have said "no" to only one location: PM peak at Marshall/Snelling. If Metro Transit thinks it's worth it to deploy, Saint Paul is usually on board.
- Likely wouldn't deploy TSP for busses at locations with LRT because already trying to give priority to train.

Operations

- There are opportunities at more minor intersections with less frequent transit to program TSP more aggressive, such as phase insertion.
- At more congested spots, need to have further conversations about how aggressive settings are.
- Ped Recall typically isn't active on the side streets.
- When it comes to data sharing, Saint Paul is willing to provide data when requested. They can set it up to provide automatic reports out of Centracs on a daily or weekly basis. The City has not received these requests to date outside of the reports they provide for Green Line.
- It is more manual labor to get high resolution logs and likely more data than needed at this point.
- More hesitant to provide Metro Transit with a direct connection to Centracs for security reasons and it's likely more data than needed.

On-going maintenance

- Staff have expressed concerns if a cabinet gets hit, how does Metro Transit come out and determine if it's salvageable and get it hooked back up. The City and Metro Transit have an O&M agreement signed last year. Under that agreement the City does not do maintenance for the Emtrac.
- City doesn't interact with TSP too much, more or less assume it's working. They would encourage and be okay with Metro Transit looking at the settings annually. The City doesn't actively see issues, but isn't looking. They haven't received any feedback to warrant additional looks.

Record of Meeting

SRF No. 17112

Location: Virtual

Date: Friday, October 27, 2023

Subject: Transit Advantages & TSP Meeting: Metro Transit/SRF

Attendees: Evan Owens-Ambrogio, Kyle O'Donnell Burrows (Metro Transit - ABRT office)
Jonathan Ahn (Metro Transit - ABRT Operations)
Ryan Heath (Metro Transit - Speed and Reliability)
Adele Hall, Phil Kulis (SRF)

Summary of Meeting with Metro Transit

General perspectives on TSP

- TSP is important to the BRT program. Though it is difficult to evaluate and quantify benefits of TSP with many changes being implemented at once.
- Generally Metro Transit's goal is to add TSP to all intersections along a BRT route though they will identify signals that aren't compatible or roadway authority doesn't want it. The City of Minneapolis has been on board with this approach, but some other agencies would like to see data showing the benefits of TSP at specific locations.
- City of Minneapolis is generally supportive of TSP implementation. However, staffing issues with Minneapolis can be challenging and result in delayed installations. Saint Paul typically would like to see data or rational for TSP at intersections but they respond fast once decisions are made.
- Impressions from operators – don't know if TSP works well or provides benefit promised. It has been messy on corridors with both BRT and local bus routes. ABRT has encountered challenges implementing anything beyond standard green extension.
- There seems to be limited on-going coordination with signal operators once TSP equipment is operational. Minimal data has been shared back and forth.
- Metro Transit would like to see regular data from the signal operators. Metro Transit pays for the equipment, but then they don't get any input back from the devices or know if they're working as intended. Metro Transit has the resources to work with the data generated by the controllers. They need to set up efficient ways of obtaining the data with the signal operators.
- The technology has major limitations. Metro Transit would like to coordinate with operators on new systems that allow for actual data. Seems like universal agreement on this.
- Conditional use of TSP has typically been a negotiation. ABRT would like TSP to be less conditional than it is. They have adapted their scheduling practice to write aggressive schedules to be more than a minute late continuously so that TSP is requested. This seems to be happening as they hear from operators that they're always behind.

- The team has considered headway based instead of schedule but then TSP isn't requested because the software system is schedule based. There have also been issues with CAD AVL software that Metro Transit needs to address with the vendor before trying again.

General perspectives on other transit advantages

- Queue jumps are key to achieving speed and reliability benefits at certain intersections. Metro Transit has encountered some concerns from City of Minneapolis on implementing on E Line. They are concerned with bus drivers not going on green when they can and waiting for the bar signal. There is an existing queue jump at Chicago and Lake where the City reviewed video that indicated that buses weren't needing it so it hasn't been turned on. Metro Transit would like to be included with these discussions and decisions. Saint Paul seems to be on board with queue jumps.
- Bus Only Lanes: evaluating the effects of bus only lanes can be a challenge. Metro Transit knows they provide large reliability benefits, but it has been difficult to capture this in traffic analyses done during planning and thus can be tough to make the case for these to the roadway authorities and they struggle to maintain stakeholder commitment to continue with the design. There is concern from roadway agencies that implementing bus lanes will create traffic diversion. ABRT office would be interested in study of an "after" condition to understand how actual operations are different than what was modeled.

Record of Meeting

SRF No. 17112

Location: Virtual

Date: Monday, October 30, 2023

Subject: Transit Advantages & TSP Meeting: City of Minneapolis/Metro Transit/SRF

Attendees: Ryan Anderson, Ryan Armstrong, Ben Brasser, Alan Klugman (City of Minneapolis)
Michaela Ahern, Ryan Heath, Michael Mechtenberg (Metro Transit)
Adele Hall, Phil Kulis (SRF)

Summary of Meeting with The City of Minneapolis

General perspectives on TSP

- Metro Transit and the City have a group that regularly meets to discuss TSP and corridors that are being evaluated for TSP. The process has worked well on the City side and they have had good coordination.

Installation

- Minneapolis is interested in all the different solutions and pilot tests prior to mass deployments of new solutions. They are committed to working with Metro Transit and would like to reestablish monthly meetings.

Selection of locations

- Minneapolis has been heavily involved with BRT projects. Initially they look at every intersection in a BRT corridor to see if there is time available to provide TSP.
- Within framework of large project, Alan suggests putting the Emtrac at every signal, since conditions change throughout the life of the BRT line and it may be advantageous to activate an intersection later.
- TSP has been implemented prior to BRT implementation in some cases. On the Route 5 and 31, TSP was implemented with 10 more added with D Line.
- Largely no TSP in downtown because signals are pretimed.

Operations

- Minneapolis is using an Emtrac card for EVP.
- The City wants clear answers on some of the operational characteristics of TSP: Does TSP call drop if the bus pulls out of lane?
- The City would like to understand TSP and pedestrian interactions better. For example, a TSP call could restrict someone's access to the bus stop. Metro Transit knows that IndyGo is working on automatically calling peds prior to transit vehicle arrival.

- There are at least four signals on Penn Avenue that are running free. It gives C Line and the vehicles good service. Instead of having a fixed cycle length it stays green until there's an approaching side street vehicle. This works well on Penn Avenue because other signals aren't on subsequent blocks. To run Free, ped recall also needs be turned off.
- Haven't had operational issues with TSP in the past few years. The City operates about 80 signals with TSP.

On-going maintenance

- The City monitors operations via TMC to see if TSP is running. They used to have regular meetings with Metro Transit technology staff, but those have fallen off. The City is aware of Metro Transit's desire for additional data.
- The City's signal management system, Tactics, cannot send automated emails. However, the City is planning to upgrade Tactics soon. A read-only user ID might be given to Metro Transit. Metro Transit has access to Spinnaker (Peak controllers) already.
- Priority reports from Tactics have been pulled previously and shared. The process is time intensive to run the reports and share them, so have provided discreet time periods when requested. The report is extensive – shows everything happening with the controller when TSP call comes in, such as how many seconds of green shifted and what phase was green. The holy grail is to tie bus performance data to the TSP data.
- The City and Metro Transit are working on a maintenance agreement now. TSP is in the cost sharing splits. Looking back on maintenance needs and setting up an agreement that reflects that.
- The City knows where they have TSP equipment, so they can salvage them and reach out to Brett Lievers (ACT) if they need new equipment after a cabinet strike– goes on agreement that ACT has with Metro Transit. The City does not have any spare TSP cards.
- Minneapolis focuses more on health of the system and less on logging and data analysis due to staffing. Analysis will need to be done on Metro Transit side.
- A pilot exercise could help Metro Transit and the City to test what data can be tracked and how to do it. Data compilation for one day on C Line would be a good sample.

Record of Meeting

SRF No. 17112

Location: Metro Transit Heywood Room 316

Date: Thursday, November 2, 2023

Subject: Transit Advantages & TSP Meeting: Hennepin County/Metro Transit/SRF

Attendees: Nick Erpelding (Hennepin County)
Michaela Ahern, Ryan Heath, Michael Mechtenberg (Metro Transit)
Adele Hall, Phil Kulis (SRF)

Summary of Meeting with Hennepin County

General perspectives on TSP

- Hennepin County has a 25 percent VMT reduction goal so anything they can do to help transit is beneficial to reaching that goal.
- TSP coordination is difficult in the metro area because every agency is doing something different and there are many people involved. Saint Cloud, for example, had one central system that simplified the installation and operations.

Installation

- All controllers TSP compatible, 90% of cabinets are compatible, ~50% of conduits can accommodate cable.
- County requires Cobalt controller running EOS for all TSP due to ETA feature.

Selection of locations

- Anywhere Metro Transit has asked for TSP, Hennepin County has given it.

Operations

- Minneapolis controls signals on Hennepin County roads within the city, so Hennepin County only has about five signals with TSP.
- TSP has the most benefits on side streets. There is not a lot of additional benefit from TSP for buses on the mainline. Potential to set up base timing to favor bus progression speeds. A lot of things need to go right for TSP to work each call; the most benefit to buses will come from having good base timing and from removing signals if possible.
- Hennepin County retimes about 20 percent of their signals every year. There could be an opportunity to set timings for bus speeds. The County refers to consultant recommendations. If they recommend benefiting the bus because of ridership they're open to it though it's tough with all the factors that impact bus speeds.

On-going maintenance

- Agreement in place with Metro Transit for TSP. County will let Metro Transit know if there are any issues and provide access to cabinets as needed.
- Hennepin County is willing to give read-only access to their signal management system (Kinetics). Metro Transit needs to provide contact information for those they wish to get access and then they'll get access.
- The County doesn't currently run TSP reports as Econolite controllers don't work well with Kinetics.
- Hennepin County IT is not okay with giving Metro Transit access to cabinets due to networking and security concerns.
- Bi-annual meetings are set up.

3. Peer Agency Meeting Summaries

SRF

Record of Meeting

Denver TSP Discussion:

Attendees:

- Michael Ahern, Michael Mechtenberg, Paul Lamb, and Claire Curd (Metro Transit)
- Li-Wei Tung and Douglas Monroe (Denver)
- Phil Kulis (SRF)

Discussion: Metro Transit wants to know how to measure the success of the system.

- Existing Status:
    - Denver is working to implement TSP on their first BRT project, though they already have TSP on another bus route.
    - Have 14 signals with TSP along E. Colfax Avenue and four signals along the US 36 corridor.
        - Reaches multiple signal operators (Denver, Aurora, and East Minster)
        - Wayside units for TSP
- Operations:
    - Unconditional priority to the buses
    - Some issues with ghost calls, causing TSP shut down for one of the agencies
    - No phase skipping, always satisfy min green
    - Ped call inhibits TSP
    - Coordinate with roadway authority for install – they do it in the presence of City staff
    - Agency only involved if software upgrade is needed
    - Now some local governments are providing input and assistance for TSP to implement
- Evaluation of Systems:
    - Denver has a system to look at speed and delay of before and after TSP to determine the improvement of transit speed
        - This analysis is done for both intersections and segments
        - They have seen a 10-12 percent improvement in travel time
        - Ontime performance was about 60 percent before but has improved based on an updated schedule because of improved travel times
    - Get feedback from operators to see where they experience congestions
    - Service development did TSP Feasibility study that now guides corridor approval
- Issues:
    - Some agencies don't have TSP ready controllers and expect Denver to pay for it
    - Trouble getting the data from signal operators of what's going on at the signals
        - It's a problem to not know when it's working
    - Agency has concern with security and people being able to hack these
- Future goals:
    - Work towards a centralized TSP system
    - Work towards a conditional priority for the buses

SRF

Record of Meeting

MBTA TSP Discussion:

Attendees:

- Michael Ahern, Michael Mechtenberg, Paul Lamb, and Claire Curd (Metro Transit)
- Jay Jackson (MBTA)
- Phil Kulis (SRF)

Discussion:

- Challenges
    - 13 core communities to cover
    - Each system is different. Different controller vendors and signal operations.
    - Equal distribution of vendors. Two GPS units on the bus.
    - 4 vendors pulling data from API
    - High fidelity data
    - They're receiving data from all signals and processing the data. Receiving it every 1 hour. Read only.
    - Agencies were looking for guidance on signals operations.
    - Cell modems, AI, fiber
        - Purchased AI units, agencies own, but MOU for how they're setup
    - Lots of synergy from agencies to improve TSP
- Innovative Strategies
    - SPMs are one step beyond just signals and overlaid with AVL. Did the bus make it?
        - Using INRIX Signal IQ
            - Using high-resolution logs to determine if bus made it through on green, using dummy phases for recording phases – no action being taken to change anything.
        - Look at the time-space diagrams of buses: what are their trajectories?
    - AI, ThruGreen, pilot with LYT, Surtrac (Miovision)
        - Use stop-to-stop data for performance evaluation.
    - Lots of TSP is more on not on grid. Trying to get more routes through the signals with TSP.
    - Bus Priority Vision- Rehauling the network, 26 corridors with high need and high delay
        - Putting it in at most intersections on a route – thinks the data is valuable to understand if TSP is actually providing benefit
        - Some agencies are willing to shift as much time as possible to get the bus moving, look to MBTA for recommendations, some agencies willing to make it be similar to priority, systems with ETA is making it more possible. Miovision Surtrac is adaptive.
        - Looking at whether the bus would have arrived on green anyways.

SRF

Record of Meeting

IndyGo TSP Discussion:

Attendees:

- Michael Ahern, Michael Mechtenberg, Paul Lamb, Claire Curd, and Ryan Heath (Metro Transit)
- Matt Duffy (IndyGo)
- Phil Kulis (SRF)

Discussion:

- Existing System
  - 75 signals with a similar system to Metro Transit
    - Red Line built in 2019
- Operations
  - Green extension and red truncation both used
  - New Econolite Cobalt/ASC3, but switching to EOS
  - TSP comes through cell modem plugged into the controller ethernet port
  - IndyGo is purchasing cell modems for the city and they are on their network
- Evaluation of Systems:
  - IndyGo wants to know how the controller is programmed, they generally want more involvement in the process
  - They get a weekly report on is the TSP is functioning, but not on how well it is functioning
  - From 2020 to 2021: IndyGo's goal was to understand the state of the system, though a lot of what they wanted to do needed further vetting
  - From 2022-2023: IndyGo had a Purdue research study of transit automated traffic signal performance measures (ATSPMs)
    - Goal was to understand the operations of transit and the impacts to other traffic
  - From 2023-2027: Route Prioritization Study
  - IndyGo would like to look at MOEs to analyze the systems to eradicate bias
- Future
  - Cloud based TSP systems
  - Develop transit Signal Performance Measurements
  - Possible change of sequences to accommodate TSP
  - IndyGo would like to call the pedestrian phase 90 seconds prior to the bus arrival (when arriving in the center) to allow pedestrians to reach the station
  - Developing about 100 more signals for TSP on non-BRT routes
  - Trying to modify schedules based on TSP on an annual basis
  - Align the "pick dates" with the TSP performance
  - May choose to put some intersections to run FREE
  - Coordinated timings are being timed for bus speeds (that are trying to get to 30mph)
  - Leaning towards EOS that allows extension

4. Additional Peer Agency Research

Additional Information on MBTA TSP Systems

A 2018 report on TSP performance in the Boston Region displayed five existing TSP corridors, with plans to upgrade nine more bus line corridors to use TSP since the report date. These corridors stretch far beyond the central Boston downtown grid, reaching suburbs of Cambridge, Arlington, Watertown, and Everett. The Boston TSP performance has been such a success at the point of the report's publishing that the MBTA was working to secure funds for TSP on all nine planned bus routes.

A recent meeting with MBTA staff revealed some of the challenges related to developing TSP lines within the Boston Metro area: the large regional area of coverage (13 core communities) causes diverseness for controllers and signal operations. Additionally, different communities are loyal to their traffic signal vendors, which can make implementing new TSP systems challenging. MBTA is also working to create an efficient and bus regional network of 26 corridors with high ridership and frequency. These 26 corridors can benefit from bus priority treatments such as bus-only lanes, TSP, and improved bus stops.

MBTA has initialized high-resolution logs to determine bus locations, as well as implementing Inrix IQ software to evaluate corridors. High-resolution logs are helpful when determining if buses arrive on a green light and can help in tracking their trajectories along their routes as well. Inrix IQ software analyzes different performance measures of a signal timing system, such as vehicle arrival on green, turning movement delays, and travel time for different movements. Other artificial intelligence (AI) software such as ThruGreen, LYT, and Sharetrack (Miovision) are using stop-to-stop data for performance evaluation. These logs and software help to track and improve the performance of TSP and traffic signals alike.

Additional Information on IndyGo's TSP Systems

The BRT Red Line consists of 74 intersections and 31 buses and has already shown success in the last few years since its opening in September 2019. The Purple Line is expected to traverse through 25 intersections, and the Blue Line is expected to traverse through 72 intersections.

Currently IndyGo is undertaking a route prioritization study to determine which routes to develop in the future, as well as what specific changes would be most beneficial (changing the sequences or modifying schedules, etc). They will prioritize the routes with the most benefit sooner, with less beneficial routes being implemented in future years. IndyGo realized that some intersections may function best when running uncoordinated ("free"), while other intersections can have a goal of a bus speed of 30 miles per hour, for example. Overall, from speaking with IndyGo, there is a lot that agencies have already figured out during the process, and there is still much more to learn and optimize as well.

Additional Information on Denver's TSP Systems

Denver staff asked operators where they experienced the most congestion to further their data about the system. Currently, TSP is running unconditionally in Denver, though they are looking at switching it to a conditional program, where sometimes TSP is running and other times it would shut itself off. Denver's system does not allow for phase skipping, as it always will satisfy the minimum green times of each phase. There were complaints by some traffic departments about "ghost calls" where the transit phase is called but there is no transit vehicle present, which caused one agency to shut down TSP due to potential operational traffic impact.

5. Transit Advantages Information

Transit Signal Priority

In a study of four cities, TSP was found to reduce transit travel time on average from eight to ten percent during peak hours[1]. A literature review offered general guidelines for TSP to help cities and agencies implement effective TSP systems[2]. These guidelines covered three general topics:

1. Specific hardware installation
2. Infrastructure layout features
3. Passenger amenities.

Traditional TSP systems require hardware on each bus and at each intersection. Newer TSP systems use wired and wireless communication and center-to-center connectivity to reduce the amount of hardware required. Some cities have multiple bus lines running the same corridor, though only the bus lines with TSP equipment installed will have the ability to request priority at intersections. Bus tracking systems must provide location updates every 10 seconds or less[3]. It is also important to ensure that the hardware systems are compatible with the signal controller. Some older controllers are not compatible with TSP and would need a full replacement, which could be costly, whereas other controllers only need a software upgrade.

Secondly, infrastructure layout is also an important aspect for TSP to operate efficiently[1]. Updates to transit routes and stops and improve the outcomes of TSP. Improvements can include separated right-of-way, dedicated lanes, optimal stop spacing, and far-side stops[1,2]. Separated right-of-way and dedicated lanes help move buses without stopping between traffic lights. Optimal bus stop spacing reduces the number of stops a bus makes. Bus stops on the far side of an intersection work better with TSP by allowing buses to be detected earlier and reducing stop dwell impacts[1,2].

Lastly, other updates to stops and station support TSP goals. This may include level boarding, pavement treatments, a concrete bus stop pad, new lighting fixtures, and a shelter with seating or leaning rails[1,2].

Queue Jumps

Where intersections operate near or at capacity, queue jumps allow buses to move ahead of queued vehicles at a signal before merging into general traffic. Used with a leading transit phase or TSP, this tool can generate significant travel time savings where intersection queues are typically long. Queue jumps may use an exclusive bus lane or a right turn lane, as shown in Figure 1.

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[1] Hu, Jia, Byungkyu Park, and A. Emily Parkany. "Transit signal priority with connected vehicle technology." Transportation research record 2418.1 (2014): 20-29.

[2] Anderson, Paul, Michael J. Walk, and Chris Simek. “Transit Signal Priority: Current State of the Practice (TCRP Synthesis 149). No. Project J-7, Topic SA-47. 2020.

[3] https://azmag.gov/Portals/0/Documents/MagContent/Tech-Memo-1-Opportunities-and-Challenges-Assessment.pdf?ver=ohggT6yXmQjk5eVZVIiAMw%3d%3d

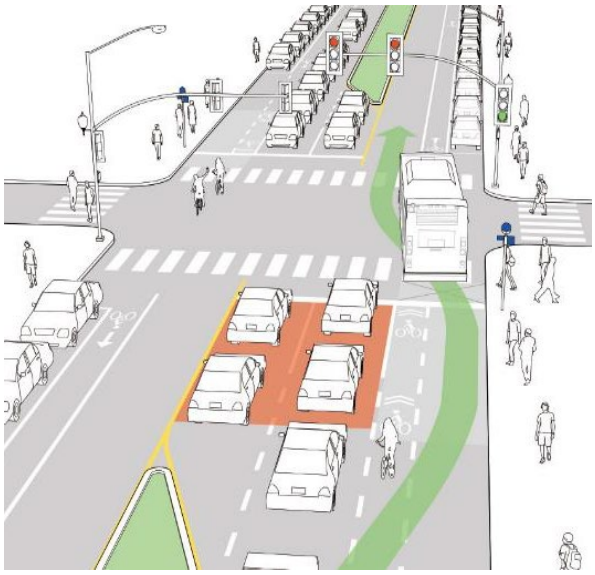


Figure 1: A queue jump allows a bus to pass queued traffic using a designated lane at an intersection. The bus re-enters travel lane after the intersection. Source: NACTO

The queue jump can extend beyond the intersection and may also use bus-only signal phasing to facilitate progression. Intersections may also employ separate traffic signals for buses to allow for safer bus operations. Queue jumps require ample lane length on the approach for the bus to navigate around a stopped queue. Bus stop location should also be considered, as a far-side stop can delay buses attempting to merge into traffic ahead of other vehicles if the stop is out-of-lane. Coordination with local agencies is required to study traffic impacts, and public education may be necessary to ensure road users understand the function of queue jumps.

Pedestrians crossing parallel to the queue jump may also benefit where right turns are restricted, since pedestrians can potentially cross earlier with buses. Higher traffic volumes can pose a barrier to reallocating sufficient cycle time to a queue jump. Queue jumps may also create delays to queued vehicles using the same approach. Right-of-way acquisition may also be necessary to achieve optimal length for the queue jump lane.

Bus Stop Placement

Whether a bus stop is located near-side or far-side of a signalized intersection impacts bus operations. A bus stopping at a near-side stop has less opportunity to progress through the signalized intersection and may stop twice—once for the bus stop and again for the red light. A bus approaching a far side stop can clear the intersection first, stopping only for the bus stop. Stop relocation can provide the opportunity to reduce signal delay and improve operations by generating travel time savings and reducing variability. Stop relocation can also produce other benefits such as providing more space for amenities, waiting riders, and buses.

The intersection environment affects where stop placement is most appropriate. For example, near-side stops may allow better accessibility during the winter due to more frequent snow removal and are generally located closer to crosswalks. Relocating a stop can impact other road users, pedestrians, residents, and businesses around the current and proposed stop location. Additional steps may be required to ensure that relocation occurs effectively with minimal negative impact. This could include working with the roadway authority to relocate on-street parking or communicating potential impacts to business owners.

Level Boarding

Boarding and alighting speeds are impacted by physical characteristics of bus stop infrastructure and the challenges they may present in moving quickly on or off the bus. Level boarding, characterized by bus stop curb heights that align with the vehicle floor, can facilitate faster boarding and alighting as a strategy to reduce overall dwell time.

ADA ramp deployment may also be a source of delay if drivers must undergo time-consuming processes, such as bus leaning and ensuring a smooth and safe path to the curb. Level boarding reduces this need by allowing buses to create one continuous surface for riders with limited mobility to easily traverse the surface. This further improves reliability by establishing more consistent boarding and alighting times for passengers regardless of physical ability.

Level boarding generally has minimal impacts on road users, as it requires only the adjustment of curb heights. However, existing roadway slopes or geometry may limit opportunities for its implementation. Coordination to ensure that designs are feasible can mitigate these challenges.

In-Lane Stops

Typical street design requires buses to leave the travel lane to access a curbside bus stop (a "pull-out" stop). The bus must spend time approaching the stop and merging back into traffic and may experience delays, especially where traffic volumes and queueing in the travel lane impede the bus's ability to pull in and out of the stop. Street redesign that allows buses to serve stops in the travel lane ("in-lane" stops) eliminates merging and promotes faster movement between stops.

Curb Extensions

Extending the curb across the width of the parking lane can create a stop where no merging movements are required to serve the stop. Curb extensions are best deployed at bus stops where there is an adjacent lane for on-street parking. The extension must be sufficiently long to accommodate the length of 1-2 buses, depending on bus volumes at the stop. Further, the extension must accommodate ADA ramp deployment; curb height may also be designed for level or near-level boarding. Coordination with local government is required to plan and construct a curb extension, especially due to potential impacts to the turn radius required at intersections.

Fare Prepayment and Non-Cash Fare Payment

Paying fares with cash and coins takes longer than paying with other methods. In addition to the time required to insert money into the farebox, riders may need extra time to retrieve and count out the correct fare. This may hold up passengers waiting to board, requiring the bus to dwell longer at the stop.

Encouraging more riders to pay before boarding, especially if using cash, reduces dwell time by speeding up payment and boarding, generating travel time savings, particularly on routes with a high proportion of riders paying cash fare.

Expanding Go-To Card (GTC) use among riders and encouraging their adoption as a primary fare payment method is another strategy that can affect all routes throughout the transit network. Additionally, embedded transfers on Go-To Cards provide faster boardings compared to paper transfers that use a magnetic strip, reducing excessive driver interactions with riders. Outcomes may depend on the methods used to encourage GTCs. These may include providing more locations to instantly add stored value or passes to GTCs; implementing GTC vending machines; and promoting enrollment in the Transit Assistance Program (TAP) to encourage more low-income riders to adopt GTCs.

Low-income riders are more likely to be cash-dependent and may not have reliable internet access to allow them to take advantage of GTC online functions (e.g. refilling stored value or adding a pass). GTC expansion should be implemented in a manner that does not impede a rider's ability to pay cash fare.

All-Door Boarding

To reduce bus dwell time at stops where high rider activity causes delay, all-door boarding allows riders to board using both front and rear doors of the bus. This can also mitigate other boarding-related delays (e.g. riders requesting information from operators).

All-door boarding is currently used on the METRO A Line, C Line, and D Line, and the METRO Red and Orange Lines where offboard fare payment does not require that riders pay at the front of the bus upon entry. On local routes, all-door boarding can be implemented on corridors where there are high boarding volumes, especially during busy peak hours. Metro Transit currently applies all-door boarding to pay-on-exit express routes and BRT. Faster boarding using all doors can reduce travel time variability and generate overall time savings.

Implementing new fare payment methods, such as pay-on-exit or new equipment (e.g. fare validators at the rear door, off-board fare collection at high-activity stop locations) should also be considered. Fare enforcement may be necessary where off-board fare collection is implemented, as it has been on BRT routes.

Signal Optimization

To improve the flow of traffic along signalized corridors, agencies typical retime/optimize signal timings every three to five years. This involves analyzing current traffic patterns and volumes and developing updated cycle lengths, split times for movements, and offsets between intersections based on the current traffic conditions. By optimizing signal timings, the traffic flow along corridors is optimized so there is improved flow between intersections, which reduces the delay of various transportation modes. By having improved signal timings, buses experience reduced delays at signalized intersection, ultimately reducing their travel time. Signal optimization commonly has benefit-cost ratios greater than 40:1, which indicates that signal optimization is a cost-effective solution to reducing delay and travel times for transit vehicles.

Bus Lanes

Buses typically share the same travel lanes as general traffic. As a result, bus speeds can slow significantly in areas of high traffic congestion. In addition, queued vehicles may also block a bus from entering a bus stop or clearing an intersection. Providing a dedicated bus lane allows buses to bypass congested travel lanes and operate at faster, more consistent speeds. This can produce significant travel time savings and mitigate travel time variability, especially on streets with both high bus frequency and high general traffic volumes.

Bus lanes may be all day or during peak hours. A continuous dedicated bus lane is more effective than intermittent bus-only lanes, so it may be a challenge to implement a bus lane that is sufficiently long. Further, other road users may compete for the same space, such as cyclists, delivery vehicles, vehicles dropping off or picking up passengers, and vehicles making right turns. This might require enforcement to

ensure that the bus lane is free of other users. On-street parking may also be impacted by bus lane implementation, necessitating engagement with adjacent businesses.

Coordination with local government is required for planning and implementation. Public outreach and engagement can also ensure that community stakeholders understand the potential impacts of a bus-only lane.

Bus Stop Consolidation

Local bus routes typically have 1/8-mile stop spacing, about the length of one long block or two short blocks. The 2040 Transportation Policy Plan guidelines allow for stop spacing of 1/8- to 1/4-mile on urban local routes. Consolidating bus stops that are closely spaced reduces the number of times a bus must stop while still providing reasonable access to stops. Eliminating frequent stopping allows the bus to stay in motion longer between bus stops, reducing delays associated with curbing, dwell time, and clearing the bus stop.

Analysis of stop activity and rider outreach is necessary to identify which stops are candidates for removal. Removing a stop with few boardings and alightings is generally less impactful for riders, but is also less beneficial in reducing travel time. Additionally, some bus stops serve special functions or are important for maintaining accessibility. For example, bus stops near shopping destinations minimize walking for riders, which is especially important when riders are carrying bags or small carts. A bus stop may also be close to senior housing or assisted living facilities; for older adults and disabled riders, removing the stop could impair their access to transit and therefore reduce their ability to get around independently. Retained stops may see increased use, which could lead to additional improvements like transit shelters.

Route Streamlining

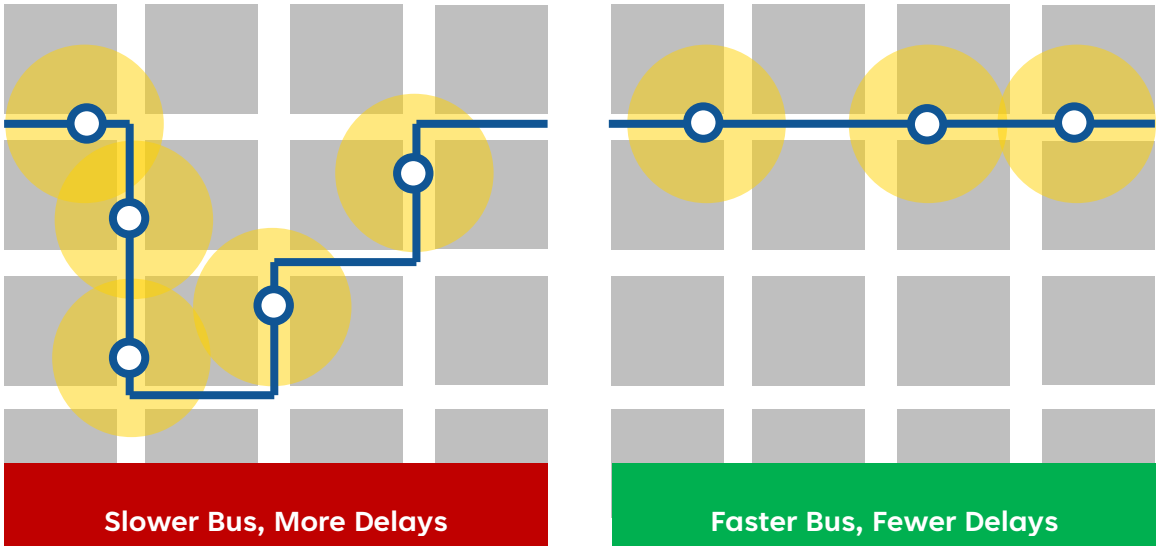
Inefficiencies in both route design and scheduling can result in reduced speed and reliability. Redesigning routes and optimizing scheduling can both promote efficient bus movement and support other transit advantages.

Route Design

Buses may encounter operational challenges based on factors such as street design, turning movements, congestion, or land uses. Changing route design can improve travel times and reduce travel time variability by avoiding these sources of delay and taking advantage of more efficient routes, shown in Figure 2 below. Possible redesign solutions include straightening a route to reduce turns or rerouting along an alternative street to achieve faster speeds. Analysis is required to understand potential impacts to ridership levels, bus stop accessibility, and travel time.

Rerouting may require stop relocation, and in some cases stop relocation may also be advantageous. Route changes may become more complicated where stop removal or relocation is required. This can have negative impacts on riders whose bus stop access is reduced. Receiving public approval may also encounter setbacks if there are concerns over impacts to residents on streets that will receive new bus service.

Figure 2. Route straightening can result in decreased travel times.



Scheduling

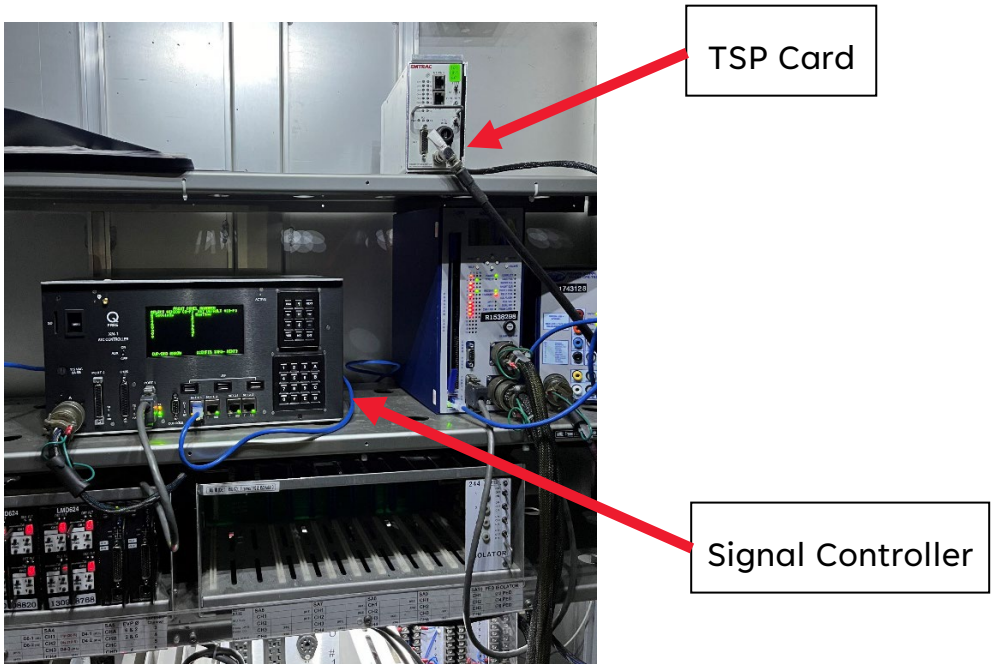
Schedules tell riders when a bus will arrive, but they must also reflect and respond to operating conditions. Insufficient frequency on a route may cause excessive riders to accumulate at stops, which can cause overcrowding and slow down boarding and alighting. In a corridor, multiple bus routes may be scheduled in a manner that causes buses to “bunch” together and block bus stop access. Schedule optimization addresses inefficiencies in day-to-day bus operations and can be especially effective for individual routes with highly-utilized stops or across multiple routes that share a corridor. Analysis is required to understand potential impacts to passenger volumes and vehicle costs. Maintaining or improving adequate transferring connections between bus routes can be an additional challenge.

6. Transit Signal Priority Operation

TSP in the Metro region operates in the following manner:

- As a bus approaches a traffic signal, it enters a predefined GPS bounding box. A computer on the bus decides whether it will request TSP, based on the following factors:
    - TSP requests are only made if a bus is at least one minute behind schedule. This schedule threshold can be modified in Metro Transit's central system, TransitMaster. This is known as Conditional TSP.
    - The bus uses its GPS to determine if it is traveling in the correct direction to request TSP. This allows TSP to operate for multiple intersection approach directions.
    - Inputs wired into the onboard computer such as "Stop Request" or "Door Open" are checked against the parameters of the TSP zone. TSP may not be requested if the inputs are in the incorrect state.
- The bus computer and the TSP card in the traffic signal cabinet communicate and the bus requests that a TSP call be placed. The card processes the TSP request and sends it to the traffic signal controller. The cabinet equipment is shown in Figure 3.

Figure 3: Intersection TSP Equipment



- The controller processes the TSP request and, if possible, signal timing is modified to prioritize the transit vehicle.
    - A traffic signal controller can respond in many different ways to the TSP request.
        - Local bus TSP in the Twin Cities can hold a green light longer ("green extension") or shorten a red light ("red truncation").
        - Light rail TSP has included holding a green light for an extended period of time, skipping traffic or pedestrian phases, and reordering the phase sequence.

The amount of benefit that a transit vehicle can receive from a TSP request varies significantly by intersection. Factors include:

- Geometry of roadway and intersections

    - Intersections with many movements (such as 5-legged intersections) require more traffic phases, reducing the time available to each phase. This also reduces the time available to prioritize transit.
    - Wide roads require longer pedestrian phases to safely clear persons from the roadway. This additional time reduces the amount of time available to reallocate to transit.
- Signal spacing
    - Intersections spaced too closely limit the speed of the transit vehicle and create uncertainty on when the bus will arrive at the intersection. The travel time between signals is also short, limiting the amount of time each signal has to react to a TSP request.
    - Traffic signal grids (such as in downtown St Paul or Lake Street in Minneapolis) are all timed together to create good traffic flows and reduce delays for everyone. It is not possible to prioritize all traffic directions equally, so the disadvantaged transit direction may be more reliant on TSP to reduce travel time variability.
- Route design
    - Intersections with buses approaching from multiple directions can make it challenging to shift green time around because it might benefit one route, while negatively impacting another.
    - Providing TSP where buses turn can also be complex and there maybe limited time available to give to the bus.
- Cycle length and flexibility within the timing plans
    - Long cycle lengths cause a lot of delay for a transit vehicle if it gets stopped. Conversely, longer cycles provide more time to prioritize the transit vehicle.
        - Long cycles are usually used in response to high traffic volumes or on high speed roadways. When traffic volumes are high, the transit vehicle may have trouble getting to the intersection in time to take advantage of TSP. In this situation, a bus only lane or queue jump can provide significant benefits.
    - Short cycle lengths cause smaller delays when a bus has to stop for a light, but they also reduce the available time to reallocate to transit. Short cycles are also more responsive to pedestrians and cyclists. They are likely to be used in dense urban environments, where local buses usually operate.
- Transit stop location
    - TSP works best with far-side stops or no-stop intersections, which allow the bus to be detected earlier and proceed through the intersection more efficiently prior to stopping.
    - Near-side bus stops may require the bus to stop twice, once at the bus stop and once at the traffic light. Dwell times at the stop are variable which leads to uncertainty on when to service a TSP request. An extended dwell can last far beyond the time available for the TSP movement. This creates a situation where TSP was requested and served, but the bus did not use the advantage.
- Other priorities at the intersection, such as pedestrians, bicycles, and emergency vehicle preemption.
    - For each TSP request, the traffic signal controller decides whether TSP can be granted and how much benefit can be provided. Competing priorities at the intersection reduce the

number of TSP requests that can be served and how much advantage is provided. Emergency vehicles are the highest priority movement and are allowed to disrupt normal traffic operations for an extended time. During this time and a period thereafter while the signal “recovers”, TSP may not be granted. Pedestrians and cyclists may require special phases or timings that limit time available for the transit movement.

- Existing signal infrastructure
    - Traffic signal controllers have proprietary algorithms for responding to TSP calls. Over time, controllers and the algorithms have become more advanced, allowing greater levels of priority for the same level of disruption to the intersection. In Minneapolis and St Paul alone, there are over 1000 traffic signals. Many of the controllers are more than 5 years old with some being 10-20 years old. There are also a number of controller brands, each with their own requirements and capabilities. Replacing controllers can be the greatest expense in a large TSP project. Other limitations such as older traffic cabinets may make controller replacement infeasible. Inevitably, in a large urban area, there are a multitude of brands and ages of controllers, making standardization of TSP installations difficult.